Scandinavian Orthopedic Association

Proceedings of the 44th Assembly Århus, Denmark, June 8–11, 1988

Editors: Ivan Hvid and Björn Strömqvist

ACTA ORTHOPAEDICA SCANDINAVICA SUPPLEMENTUM NO. 227, VOL 59. 1988

MUNKSGAARD · COPENHAGEN

ISBN: 87-16-06438-0
ISSN: 0300-8827

Printed in Sweden
Studentlitteratur
Lund 1988

Proceedings of the Scandinavian Orthopedic Association 44th Assembly

Århus, Denmark, June 8–11, 1988

Precongress meeting

Verapamil induces osteopenia in the rat

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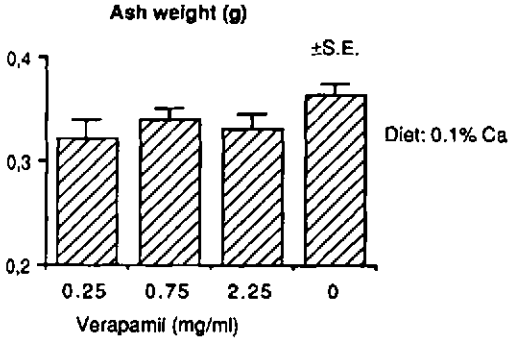
Introduction: Animal studies have shown that verapamil inhibits the intestinal absorption of calcium (1, 2). When the effect of verapamil on human calcium balance was studied (3), no decrease in the intestinal absorption of calcium was evident. However, serum alkaline phosphatase (ALP) was increased after verapamil treatment. This suggests that verapamil increases bone turnover.

Material and methods: Male Sprague-Dawley rats weighing 400 g were given verapamil 0.25, 0.75, or 2.5 mg/ml (Isoptin®, Knoll AG) in the drinking water and a low calcium diet (0.1 percent Ca, 0.5 percent P) or a medium Ca diet (0.3 percent Ca, 0.5 percent P) or a high Ca diet (1.2 percent Ca, 0.5 percent P). There were 7 animals in each treatment group. After 11 weeks the rats were killed. Blood was collected; and the left tibiae were dissected free of soft tissue, weighed, and ashed.

Results: Four out of the 7 rats receiving 2.5 mg/ml of verapamil died within 2 weeks. The remaining rats increased in body weight and seemed to thrive. Rats on a low calcium diet and verapamil had increased levels of ALP; and their tibial bone ash, wet weight, and dry weight were significantly lower than controls. In rats on a medium or high calcium diet, the bone mineral content did not change.

Discussion: The use of calcium channel blockers is common. About 5 percent of persons over 70 years of age receive these drugs in Sweden. It was previously found that verapamil in humans increased ALP. A study on the incidence of fractures in persons receiving calcium channel blockers seems warranted.



Conclusion: Verapamil can induce osteopenia in rats on a low calcium diet.

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The effect of salmon calcitonin on immobilization osteopenia

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Introduction: Calcitonin has the capability in vitro and in vivo of inhibiting osteoclastic bone resorption. This hormone therefore becomes a possible agent in the treatment of disorders of bone in which resorption is increased. This study was conducted to see if this increase in bone resorption due to immobilization could be prevented by calcitonin.

Materials and methods: In each of 12 female rabbits, disuse osteopenia was produced in the right hind limb by immobilization with a plaster of Paris spica cast. The left hind limbs served as controls. Six rabbits received subcutaneous injections of synthetic salmon calcitonin, diluted in physiologic saline (SF) twice daily at 12-hour intervals for 24 days. The dose of calcitonin was 1 MRC μ/kg of body weight per injection. Equivalent amounts of SF without calcitonin were administered to the 6 control animals. Blood samples were collected from each animal after the first and the last injections of calcitonin and SF. The blood was analyzed for calcium, phosphate, and alkaline phosphatase. The animals were killed on the 24th day, and femurs of each animal were used for comparison of the percentage of dry bone weight loss. The tibiae of each animal were used for radiographic measurements, and determination of the ratio of cortical and medullary thickness (c/m ratio) was carried out for histologic sections (Figure 1).

Results and discussion: Studies of the last blood samples showed a significant fall of serum calcium levels and a rise of serum alkaline phosphatase levels in the calcitonin-treated animals as compared with the controls (for calcium $t = 5.31$, $P < 0.01$ and for alkaline phosphatase $t = 4.4$, $P < 0.01$). There was significant weight loss in the immobilized bones of calcitonin-treated and control animals. Percentage of dry weight

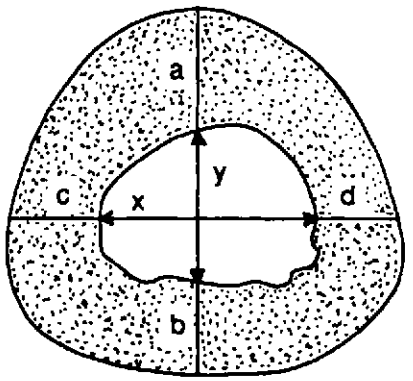

Figure 1. A histologic micrographic section used for calculation of c/m ratios.

$$c = \frac{a+b+c+d}{4}, m = \frac{x+y}{2}$$

loss in the immobilized bones of calcitonin-treated animals was less than that of control animals ($t = 2.64$, $P < 0.05$). There was no difference between radiographic measurements of cortical thickness of tibiae in each animal group. The ratios of cortical and medullary thicknesses measured from micrographic histologic sections (c/m ratio) significantly decreased in the immobilized tibiae of the two groups of rabbits compared with nonimmobilized tibiae. The decrease in c/m ratio in the bones of calcitonin-treated animals was less than in control animals ($t = 2.56$, $P < 0.05$).

Effect of growth hormone on the regeneration of atrophied diaphyseal bone

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Introduction: The present investigation was designed to study the morphologic and mechanical events during regeneration of experimentally atrophied diaphyseal bone in the rabbit after rigid internal fixation, and specifically, to analyze whether growth hormone can influence this process.

Methods: Fifty-six adult rabbits weighing 3,250–4,750 grams were used. Rigid internal fixation plates were attached to the medial aspect of the mid-diaphysis of both tibiae using four screws. The plate on one tibia was removed, and the screws were reinserted into their holes. After 12 weeks, the plates were removed at a second operation, and the screws were reinserted into their holes. On the control tibia the screws were loosened and then retightened. *Human growth hormone (hGH) treatment*: Starting on the day of plate removal (second operation), half of the rabbits were given 0.03 IE/kg BW hGH (Crescormone, KABI Vitrum AB, Stockholm, Sweden) as a daily i.m. injection. The animals were killed at 0, 1.5, 3, and 6 weeks after plate removal.

Results: The maximal torque capacity of the plated tibiae was reduced by 40 percent at the time of plate removal. Three weeks later, the bones had regained their strength. The rate of recovery was not affected by treatment with hGH. The area of periosteally formed new bone was 2–5 times greater in hGH-treated groups, in plated as well as in sham-operated bones, at 3 and 6 weeks. The bone mineral density and mineral content was slightly decreased in plated bones at the time of plate removal; this reduction was normalized 1.5 weeks after plate removal.

Conclusions: hGH did not affect the rate of recovery of torsional strength in the previously atrophied tibiae. However, there was an enlargement of cortical bone area, in plated as well as in sham-operated bones, due to increased bone formation in hGH-treated groups. Because the new bone formation took place subperiosteally at the site of the plate or screws, it was considered to be a result of the surgical procedure. Thus, hGH appears to have an enhancing effect on the periosteal reaction to trauma.

The influence of growth hormone on fracture healing in the rat: A dose-response curve

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Introduction: Biosynthetic human growth hormone (b-hGH) stimulates the proliferation of chondrocytes. Experimental fractures of long bones heal through a stage of cartilaginous callus. The effect of different doses of b-hGH on the mechanical properties of healing fractures was studied.

Materials and methods: In 90-day-old female Wistar rats, a standardized fracture was produced by three-point bending in the tibia. Medullary nailing was performed. The rats were randomized into 6 groups: no injections, 0.9 percent NaCl, b-hGH 0.08, 0.4, 2.0, or 10 mg/kg/day given subcutaneously in two daily doses from 1 week prior to fracture and until mechanical testing, which was performed by a three-point bending procedure in a materials testing machine after 40 days of healing.

Results and conclusion: After 40 days of healing, fractures treated with b-hGH in doses of 2 mg/kg/day and 10 mg/kg/day had increased maximum load and stiffness compared with the saline-treated controls, but there was no significant difference between the two treatment groups.

Treatment	N	Maximum load N	Stiffness N/mm
1) no injections	13	37.2 ± 6.5	171.0 ± 31.0
2) 0.9% NaCl	14	30.2 ± 4.9	138.0 ± 24.2
3) b-hGH 0.08 mg/kg/day	10	35.6 ± 8.2	166.0 ± 39.3
4) b-hGH 0.4 mg/kg/day	15	34.9 ± 5.8	179.7 ± 30.5
5) b-hGH 2.0 mg/kg/day	10	55.3 ± 10.2*	219.9 ± 31.8*
6) b-hGH 10 mg/kg/day	13	69.3 ± 8.4**	323.0 ± 30.0**

Mean values ± SEM. *$2P < 0.05$; **$2P < 0.01$

Diet and the calcium ion

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Introduction: A satisfactory calcium intake is felt to be important in the maintenance of a positive calcium balance. Numerous dietary factors have been associated with impaired calcium absorption and are thought to have a major effect on calcium homeostasis. The effect of the alimentary state on the measurement of serum ionized calcium has not been clearly defined. To further investigate this area, a study was set up to examine the effects of a large meal on serum ionized calcium.

Patients, methods, and result: Twenty-two healthy males were studied in the fasting state and 1 hour after a large meal. Serum was analyzed for ionized calcium, total calcium, and albumin. There was a highly significant fall in serum ionized calcium 1 hour after a large meal. There was a smaller fall in total calcium and no significant change in serum albumin.

Discussion: It is suggested that there is a sufficient combined effect from the postprandial fall inparathyroid hormone and rise in calcitonin to cause the observed fall in serum ionized calcium after food ingestion. This interpretation is discussed in association with the known effects of the different components of a mixed diet and variations in intestinal calcium absorption on calcium balance.

In conclusion, it is clear that an appreciation of the alimentary state is essential when any studies involving ionized calcium are being undertaken.

Bone density, strength, and exercise

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Introduction: Wrist bone density and grip strength are related (1). Does an improvement in grip strength increase bone density?

Method: Female volunteers (mean age 60 years) had a grip-strength test and photon absorption scans of both wrists. Irrespective of age, grip strength and bone mineral density were closely correlated ($P < 0.001$). There was a difference in strength and bone mineral content between dominant and nondominant wrists ($P < 0.005$). One wrist had forced isometric exercise for 20 seconds a day for 6 weeks.

Results: Fifty-seven subjects reattended. They had a relative increase in strength on the exercised side of 7.2 percent ($P < 0.001$), associated with a relative increase of 2.3 percent ($P < 0.05$) in bone mineral content. Sixteen good subjects developed a mean increase in strength of 21.5 percent ($P < 0.0001$) on the exercised side with a relative increase in bone of 4.2 percent ($P < 0.008$) compared with their control unexercised wrist. A recall was arranged 6 months after the experiment ended. The 21 patients who attended had lost strength and bone mineral density from both forearms, but less on the exercised side.

Conclusion: In normal women, grip strength is closely associated with forearm bone mineral density, with differences between dominant and nondominant forearms. Strength and bone mineral density are increased by brief periods of stressful isometric exercise: this control is of importance in osteoporosis.

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BMC measurements in the proximal tibia: Influence of sex and knee flexion in young, normal subjects

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Subjects and methods: BMC (bone mineral content) in the proximal part of the tibia was determined using dual photon absorptiometry. The measurements were performed just below the subchondral plates of the tibial condyles.

The precision of the scanning device was high, with SDs of 0.03–0.05 g/cm on 20 repeated measurements on standards.

The study comprised 10 young male and 10 young female human subjects, and was designed to evaluate the sex differences and the influence of flexion of the knee joint on BMC.

Results: Significantly higher values were found in the males than in the females. No significant influence of flexion from 0°–20° was found.

Conclusion: BMC/BMD investigations in the proximal tibia are precise and important measurements. Flexion between 0° and 20° does not influence measurements significantly.

Serial barriers to mineral transport in cortical bone

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Introduction: The diffusion properties of capillaries in bone have been reported previously (1). However, the importance of capillaries in the overall exchange of molecules between blood and bone has yet to be resolved. The direct measurement of rate constants in bone is very difficult, and in this

Table 1.

	PS_C	V_I	PS_B	V_B
^{14}C-sucrose	0.053 ± 0.006	1.03 ± 0.47	–	–
^{99m}Tc-MDP	0.022 ± 0.012	2.16 ± 0.26	0.011 ± 0.002	14.09 ± 8.39
^{22}Na	0.063 ± 0.002	0.71 ± 0.16	0.041 ± 0.017	5.11 ± 3.37
^{85}Sr	0.056 ± 0.00	2.63 ± 2.04	0.041 ± 0.022	13.80 ± 12.47

paper we have used multiple tracer outflow dilution techniques in an attempt to provide more direct measurements of mineral movement in bone.

Materials and methods: Mature dogs, approximately 25 kg in weight, were used in all the experiments. Under anesthesia the tibial nutrient artery and the ipsilateral femoral vein were cannulated. Fifty milliliters of blood was collected from the animals, and the tibia was infused with blood through the nutrient artery at a rate of 3.8 ml/min. Two groups of animals were studied in which a bolus of three tracers was injected into the nutrient artery; and their concentrations in the femoral vein were measured for 5 minutes. ^{125}I-albumin was used as a reference tracer in both groups. In one group of animals, ^{85}Sr and ^{22}Na were used as capillary permeable tracers; and in the other group ^{99}Tc-MDP and ^{14}C-sucrose were used. To analyze the data, we used a mathematical model for exchange between blood, bone fluid, and bone using finite difference techniques to calculate transport functions for the permeable tracers (2).

Results and discussion: The model gave estimates for four parameters: the permeability-surface area product for capillary (PS_C), and bone (PS_B), and the volumes of distribution in fluid (V_I) and in bone (V_B) (Table 1). It is assumed that ^{14}C-sucrose is not taken up by bone. The values of PS_B for ^{85}Sr and ^{99m}Tc-MDP are considerably greater than PS_C, indicating that capillary permeability is very large for both the bone-seeking tracers. PS_C is greater for ^{85}Sr and ^{22}Na, reflecting their smaller molecular weight and higher diffusion coefficient.

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Intraosseous hydrostatic pressure and pO_2 in early nontraumatic necrosis of the femoral head

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Introduction: The development of severe degenerative changes in hips with nontraumatic necrosis is probably preceded by episodes of localized infarction. In earlier stages the bone is without radiographic changes, but scintimetry or recording of intraosseous hydrostatic pressure has been shown to be more sensitive.

The aim of this study was to measure hydrostatic pressure and pO_2 in patients with pain in the hip and no or only slight radiographic changes and to correlate the measurements with the histologic findings in a core biopsy.

Material and methods: Eighteen hips were examined. Hydrostatic pressure was measured by a pressure transducer. The pO_2 was measured in the subchondral cancellous bone by a mass spectrometer via a catheter inserted through a cannula. Osteonecrosis was graded according to Durroux.

Results and discussion: Eleven of the 18 hips showed histologic signs of necrosis. The hydrostatic pressure in the femoral head was 44 ±6 torr in the hips with histologic necrosis and 29 ±6 torr in the hips with normal histology ($P > 0.05$, Mann-Whitney test). The pO_2 was 35 ±7 torr and 69 ±8 torr in the hips with and without necrosis, respectively ($P < 0.005$).

Our study confirms a correlation between histologic necrosis and decreased intraosseous pO_2 in patients with hip pain. Also the study supports the pathogenetic hypothesis that osteonecrosis is caused by anoxia due to intramedullary stasis.

A comparative study of bone healing of stable and unstable fractures of the rabbit tibia

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Introduction: The controlled study of fracture healing, and of the factors that influence such healing, requires reproducible and standardized experimental conditions, with ease of radiographic and histologic assessment. An animal model is therefore necessary. An ideal experimental model would use a readily available, relatively inexpensive, small animal with bone morphology similar to that in man. The aim of this study was to evaluate healing of an experimental fracture of the tibia in rabbits under conditions of both stable (AO/ASIF dynamic compression plate) and unstable (loose-fitting intramedullary rod) fixation.

Materials and methods: Totally, 23 male New Zealand white rabbits were used. Under general anesthesia, an experimental midshaft fracture of the tibia was produced using the method of Ashhurst et al. (1). Animals were randomly allocated to either stable or unstable fixation. Bone healing was evaluated by serial radiographs, taken at 2-week intervals, and by histologic assessment after killing (at 12 weeks postoperatively).

Results: There were three technical failures, leaving 10 animals in each group for assessment. Animals in the stable group showed radiographic healing without external callus formation, and primary bone union was confirmed on histologic assessment. Rabbits in the unstable group showed typical radiographic and histologic appearances of healing by external callus formation. Contact cortical necrosis was seen where both plates and rods were in contact with bone. It never affected more than 50 percent of the cortical width, and was seen in less than half of the sections cut. No histologic or radiographic signs of infection were seen in any of the animals studied.

Discussion: This study confirms that under conditions of anatomic reduction and stable fixation, primary bone healing of fractures occurred reliably in rabbits. Unstable fixation led to uneventful healing by external callus formation.

Our preliminary studies suggest that this animal model is ideal for comparative studies of fracture healing. A standard fracture that will heal in a reproducible manner can be reliably created. Both primary bone union and external callus formation can be induced by varying the techniques of fixation similar to those used in man.

References

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The occurrence of different bone- and cartilage-specific proteins and proteoglycans in experimental fracture healing

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Introduction: Callus in experimental rat fractures originates from two different sources: viz., the one from committed osteoblastic cells in periosteum (the primary response), the other from mesenchymal cells migrating from the surroundings (the external or inductive callus). A hypothesis that can be put forward is that the pluripotent mesenchymal cells become induced by proteins released from the damaged bone and the primary response. It is also likely that differentiation of cartilage that then undergoes enchondral bone formation occurs during production of different macromolecules. Polyclonal antibodies against different proteins and proteoglycan from bone and cartilage, and against laminin in the vessel walls, have been used in order to localize them on a well-known fracture model (tibia fractures in rats).

Material and methods: The right tibia was manually broken after insertion of a thin steel thread in bone marrow in rats weighing 100 g. Rats were killed after 3, 5, 8, and 11 days. At the 5th day, the periosteal callus was fully developed, and cartilage had begun to be formed on the periost-denuded ends of the fracture. The granulation tissue (PL) with mesenchymal pluripotent cells under differentiation to chondrocytes is easy to study.

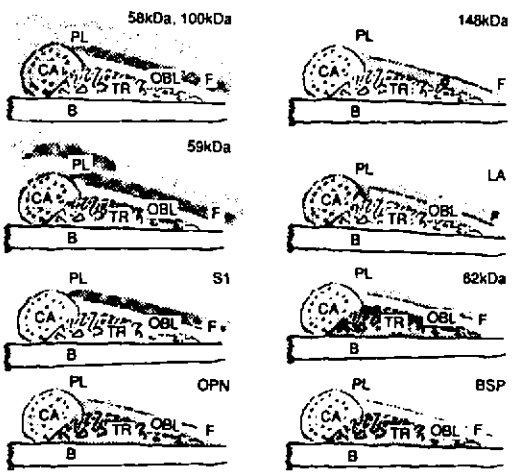
Results and discussion: The bone-specific proteins were osteopontin (OPN), sialoprotein (BSP), and 62 kDa. All of these occurred among the newly formed periosteal trabeculae (TR) and also in the zone immediately outside the osteoblast layer (OBL). BSP is also present as thin extensions from the trabeculae into the osteoblast layer. OPN stains the osteoblast layer completely. All three proteins are diffusely spread in the granulation tissue (PL). On the 11th day, the proteins appeared in the new bone trabeculae formed by enchondral bone formation.

The cartilage proteins and proteoglycans were 58, 59, 100, and 148 kDA, S1 and S 2 (small PG) and LA (large PG). S2 did not stain anything. Bone trabeculae were stained by only 59 kDa. Both 148 kDa and LA stained the osteoblast layer (OBL). Present in the zone immediately outside the osteoblast layer (F) were 58, 59 kDa and 100 kDa and S1. The granulation tissue was stained weakly by 58 kDa; but 59 kDa and 100 kDa stained very strongly, particularly collagen-like structures. They did not stain the fracture exudate between the muscle fibers. The cartilage (CA) was stained by 58, 59, 100 kDa, and LA.

Laminin antibodies and basal membrane antibodies stained vessels in the musculature, in the granulation tissue, and in bone. Even cartilage on Days 5 to 11 had stained structures, residua of vessels or cells.

The experiments have shown different proteins and PGs during direct bone formation in the periost and among the cells differentiating into chondroblasts. The vessel structures left behind in cartilage speak against the belief that cartilage occurs in avascular sites.

The figure shows the distribution of the different proteins and PGs on Day 5. B = bone, TR = periosteal trabeculae, OBL = proliferating osteoblasts, F = fibrous layer of periost, CA = cartilage, PL = pluripotent cells in granulation tissue.



Mechanical effects of intramedullary reaming on the healing of nailed femoral fractures in rats

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Introduction: Implantation of medullary nails without reaming causes minor damage to the blood circulation, whereas reaming is associated with destruction of all the vessels in the medullary canal. The present study was undertaken to investigate the influence of intramedullary reaming on the healing of fractures in rat femora.

Methods: Bilateral transverse fractures were performed at the midshaft of the femora in rats. On the left side, but not on the right side, the medullary canal was successively reamed. The fractures were then stabilized with intramedullary nails of 1.0 mm. At 15, 30, 60, and 90 days postoperatively, the bending moment and rigidity at the fracture site were evaluated.

Results: During the experimental period, there were no significant differences between the left and right sides in bending moment, bending rigidity, and in callus production.

Discussion: We found that intramedullary reaming did not affect the mechanical properties of healing fractures in rat femora. The fractures were nailed, but not rigidly fixated, so they healed by periosteal callus production. This study indicates that the periosteal system has the capacity of compensating for damages to the endosteal system, so that healing of fractures is not delayed by reaming. On the other hand, reaming dust with possible bone induction potential was not found to be of significant importance for fracture healing.

Effect of dynamization by removal of interlocking screws after intramedullary fixation with interlock: An experimental study in cats

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Introduction: Intramedullary fixation rod systems with interlocking were developed in order to make the fixation method available also in cases with multiple fragments or crushing of fracture ends. Removal of interlocking screws, as soon as the bone ends can carry a load, has been recommended as a means of speeding up complete mechanical restitution of the bone. The rationale for this procedure is to enhance bone remodeling in the callus by subjecting the new bone to axial and torsional loads before the device can be removed entirely. We have developed an animal model for investigation of interlocking and dynamization.

Methods: Intramedullary rods with an open slot and holes for insertion of interlocking screws were manufactured from stainless steel tubes (length = 95 mm, O.D. = 5.5 mm). Eighteen adult cats were used. The right femoral diaphysis was cut transversely and reamed before the rod was inserted from the proximal end. A diastasis of 3 mm was created at the osteotomy site, and the fragments were fixed by interlocking screws. All the animals were killed at 12 weeks.

Results: Bony union was achieved in seven out of nine of the bones where dynamization had been performed compared with four out of nine of the bones with static fixation. Although not significant the results may indicate that bony union occurs more readily after dynamization. There was no significant difference in strengths that could favor dynamization as a means to enhance mechanical restitution of bones after fixation with intramedullary rods with interlocking.

Stimulation of bone formation in segmented bone defects

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Introduction: Injectable bone transplants would be useful in a variety of conditions requiring local stimulation of bone formation. The present study compares pulverized bone matrix and autologous bone marrow with conventionally implanted whole-bone matrix and marrow or cancellous bone.

Methods: A segment of the rabbit radius diaphysis was excised, demineralized, and pulverized. The demineralized matrix particles were mixed with autologous bone marrow from the femoral canal and injected into the defect from which it had been excised. On the contralateral side the demineralized bone was reimplanted without pulverization, but with bone marrow. The bone yield was measured after 2 and 4 weeks by radiographic planimetry and Tc-99m-MDP scintimetry. The forearms of the rabbits were sectioned into standardized transverse segments. The ash weight and Ca-45 count were measured.

In another series, cancellous bone from the tuber ischii of the rabbit was transplanted to the radius defect and compared with a mixture of autogenous bone marrow and allogenous or autogenous bone matrix particles.

Results: At 2 weeks the ash weight was greater on the pulverized than on the nonpulverized matrix side. By four weeks, the measurements showed no difference. The other parameters determined showed no significant difference. When comparing the injectable matrix-marrow bone graft with cancellous bone, no side differences were found with Ca-45, whereas the callus ash weight of the matrix-transplanted side was around 60 percent of the cancellous bone side (due to the original mineral content of a cancellous bone transplant). Nontransplanted defects had very low ash weight and Ca-45 values.

Summary: An injectable bone transplant consisting of pul-

verized demineralized bone matrix and bone marrow is quantitatively similar in bone yield both to whole matrix and marrow and to cancellous bone transplants.

Osteotomy counteracts atrophy of diaphyseal bone after rigid internal fixation

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Introduction: Rigid internal fixation of diaphyseal bone causes atrophy and reduced strength due to protection of the bone from loading and deformation. We studied the effect of osteotomy on the strength and metabolism of bone after rigid internal fixation.

Material and methods: Fifty adult rabbits were randomized into six groups. Four experimental groups were used to compare a rigid plate fixation combined with tibial osteotomy to a contralateral plate without osteotomy at 3, 6, 9, and 12 weeks. Two control groups were used to compare tibial osteotomy and plate fixation to a contralateral sham operation, or a rigid plate to a sham operation, at 12 weeks. Two days prior to death, the animals were injected with ^{45}Ca and ^{3}H-proline. Isotope incorporation and maximum torque capacity of the bone underlying the plates was analyzed.

Results: In the experimental groups the strength of the osteotomized bone was increased by 30 percent at 6 weeks compared with the contralateral (plated) side, but this effect gradually decreased at 9 and 12 weeks. In the control groups, both the plated and the osteotomized/plated tibiae showed a 30 percent decrease in strength compared with sham-operated bones. The incorporation rate of both ^{45}Ca and ^{3}H-proline of the osteotomized bones was increased 3–4-fold at 3 and 6 weeks, but was normalized at 9 and 12 weeks.

Conclusion: Osteotomy of diaphyseal bone in adult rabbits caused increased matrix formation and mineral accretion, and increased bone strength, during the healing process, thus counteracting the atrophy caused by the rigid plate. The bone formation levels returned to normal values within 12 weeks, and the bone became subject to atrophy due to stress protection by the fixation plate.

Calcitonin and fracture healing

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An experimental study was made with randomized series of fractures in rats with and without calcitonin (CT) therapy. The healing of the fractures was monitored biochemically and histologically, and by measuring the tensile strength of the callus tissue. The healing of a fracture was followed from 3 days up to 9 weeks postoperatively. Half of the rats in each age group were given daily CT 10 MCR-μ/kg body weight subcutaneously. Mechanical properties of the healing tibial fractures, as well as various connective tissue components of the callus tissue, were analyzed.

No differences in the radiographic or microscopic appearance of the fractures were detectable between the animals receiving CT and the controls. In the biochemical analysis, matrix production as assessed from the concentrations of nitrogen, hexosamines, and hydroxyproline within the callus followed the usual lines of undisturbed fracture union without any differences between the groups with and without CT. No differences could be detected in the mineralization of the callus, and the tensile strength values of the fractures increased almost linearly up to 9 weeks. At 1 week the tensile strength values for fracture union in the animals without CT were about 50 percent higher, but later on no differences could be detected between the groups.

The results indicate that, although in the early phases of long-term CT therapy collagen synthesis may be impaired, there will be no effect on the net content of collagen or calcifying tissue in callus or on the mechanical strength of healing fractures.

Clinical use of phase shift vibrational analysis in tibial fracture healing

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Introduction: In routine practice the healing of fractures is usually assessed by clinical examination and radiographic features. Quantitative methods of measurement are desirable not only for the assessment of the strength of fracture union, but for the prediction of delayed and nonunions. Expense and size and complexity of equipment have limited the use of many techniques in routine clinics, and difficulties have also been encountered in some vibrational techniques with soft-tissue thickness, muscle tension, and volume of callus (1). We report the preliminary results for phase shift vibrational analysis in a portable inexpensive form on 100 patients with fractures of the tibia.

Patients and methods: Patients were evaluated at routine fracture clinics, but independent of clinical management. A 2-point system was used with the vibrational source, and the accelerometer was placed at a set distance either side of the fracture. "In-phase" frequency recordings were repeated three times on fractured and normal tibias. The results were expressed as a percentage ratio of affected to normal sides. The evaluation was repeated at each clinic attendance, the same sites of recording being used on each occasion. If the

limb was encased in plaster,"small windows" were fashioned. Recordings were also taken of limbs stabilized by external fixators.

Results and discussion: Totally, 1,388 readings were recorded on 100 patients with fractures of the tibia. Results in 15 patients with clinically and radiographically united fractures indicated the range of"end points" from 110 percent in an undisplaced fracture to 80 percent in a segmental displaced fracture with a mean of 96 percent. In 70 patients with healing fractures less than 26 weeks old, patterns of fracture healing dependent on fracture configuration and displacement were revealed. In 9 patients with union delayed to beyond 26 weeks, results were lower and increases prolonged. In 6 patients with hypertrophic nonunion, an initial decline in results could be demonstrated following fibular osteotomy and low results were seen at many months after plating or external fixation.

Despite minor variations due to technique, methods of management, and adiposity, the initial results are encouraging. Patterns of fracture healing are emerging, and potential early identification of delayed and nonunion is suggested. If further studies confirm these results, then, this method of analysis will prove to be a useful clinical tool in the assessment of healing in tibial shaft fractures.

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Biodegradation and biocompatibility of polylactic acid in bone

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Introduction: Vihtonen et al. (1) showed in an experimental study of rabbits that fixation of osteotomies of the distal femur with biodegradable polyglycolic acid (PGA) thread resulted in normal healing in 79 percent of the cases. Vainiopää et al. (2) used in their study in rabbits biodegradable PGA rods and threads in fixation of similar osteotomies. In that study all the osteotomies healed in 6 weeks.

On the basis of these studies, we started to investigate the possibility to use polylactic acid (PLA) as the fixation material of osteotomies in bone. Polylactic acid (PLLA and PDLLA) is a synthetic, biodegradable material. In vivo PLA undergoes hydrolytic de-esterification into lactic acid, which becomes incorporated into the tricarboxylic acid cycle (3). The self-reinforced (SR) absorbable materials, SR-PLLA and SR-PDLLA/PLLA rods consist of an absorbable polymetric matrix reinforced with fibers of the same material. The biodegradation, biocompatibility, and fixation properties of SR-PLLA and SR-PDLLA/PLLA rods were investigated in the present study.

Materials and methods: The biodegradation in vitro was investigated in a hydrolysis test. The SR-PLA rods were submerged in distilled water at 37°C for a period of 48 weeks. Changes in the bending strength were measured. The effects of gamma-irradiation in the bending strength was also clarified. The molecular weights were measured. The biodegradation and biocompatibility of SR-PLA rods in vivo were investigated in cancellous bone of 56 rats. Osteotomies of the distal femur were fixed by SR-PLA implants. After operation no external support was used, and the rats were allowed to walk freely. The follow-up times were 1, 3, 6,12, 24, 36, and 48 weeks. Radiographic, histologic, microradiographic, and OTC-fluorescence studies were done.

Results and discussion: The initial bending strength of SR-PLLA was 185 MPa and SR-PDLLA/PLLA 170 MPa. After 48 weeks hydrolysis in vitro, the bending strength of both materials were about 50 percent of the initial value. Gamma-irradiation decreased the bending strength of both materials (Figure 1). The initial molecular weight of both materials were 100,000. The viscosimetric measurements after hydrolysis in vitro and in vivo revealed that the decreasing rate of molecular weights was faster in vivo than in vitro. The macroscopic, radiographic, microradiographic, and OTC-fluorescence examinations showed that 95 percent of the osteotomies were consolidated. In histologic studies, there was no evidence of inflammation or foreign-body reaction in the bone. The biodegradation started peripherally in the area of SR-PLA implants and continued with subsequent replacement of new bone. SR-PLLA/SR-PLLA implants were seen in all the specimens during the 48-week follow-up period.

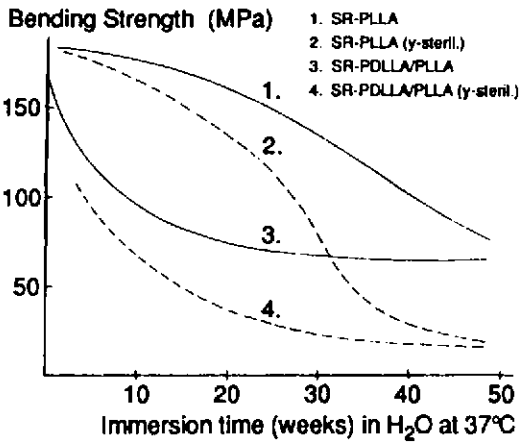

Figure 1.

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Totally biodegradable self-reinforced rods and screws for internal fixation of bone fractures

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Introduction: Ideal osteosynthesis material must have high strength and stiffness and ductile mechanical behavior. Additionally, it must be biocompatible and dissolve after fracture healing to small molecules that are digested by living tissues. This eliminates the need of a removal operation. We have developed self-reinforced (SR), coated polyglycolide (PGA) and polyactide (PLA) composites that fulfill the above demands.

Materials and methods: Medical grade biodegradable PGA, poly-L-lactide (PLLA) and poly-DL-lactide (PDLLA) powders or fibers were used as raw materials. SR-coated rods with diameters of 3.2 mm or 2.0 mm and lengths of 50 mm or 40 mm, respectively, and 4.5 mm SR-screws (AO-profile) with a length of 50 mm were manufactured of PGA, PLLA, and PDLLA by the recently developed sintering method at an elevated temperature and pressure (1–2).

Results and discussion:

Table. Initial mechanical strength properties of biodegradable SR composite rods and screws

Sample	Matrix	Reinforcement	Coating	Bending strength (MPa)	Bending modulus (GPa)	Shear strenght (MPa)
Rod	PGA	PGA	PGA	350 ± 50	14 ± 1	200 ± 40
Rod	PLLA	PLLA	PLLA	260	9	150
Rod	PDLLA	PLLA	PDLLA	220	4	100
Screw	PGA	PGA	PGA	300		150

SR-PGA rods retained their strength 7–8 weeks in vivo (subcutaneous implantation in rabbits). SR-PGA screws retained their strength up to 5 weeks in vivo. It was shown that SR-PGA rods and screws are suitable for internal fixation of cancellous bone fractures in combination with plaster cast (3). More than 500 operations have been performed in Helsinki University Central Hospital during a 3-year period with SR-PGA rods and screws (Biofix®). SR-PLA rods retain their strength at least 15 weeks in vivo. They are potential materials for cortical bone fracture fixation.

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Biodegradable implants in the fixation of physeal fractures in cats

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Introduction: In an experimental study of surgical traumas in the physeal plate, it was shown that the degree of the retardation of growth was roughly proportional to the cell number destroyed, to the firmness of the rigid bridge between the epiphysis and the metaphysis (bone or metal), and to the growth potential left in the physeal plate at the time of the injury (Campbell et al. 1959).

Biodegradable implants made of self-reinforced polyglycolic acid (PGC) were successfully used in the fixation of cancellous bone fractures of cats and dogs (Axelson et al. 1988).

The effect of a penetrating biodegradable implant on the physeal plate was studied by Mäkelä et al. (1987). The pressure of the growth broke the implant of 3.2 mm in diameter at the level of the growth plate as early as 3 weeks after the operation, which allowed the growth cartilage to regenerate (Mäkelä et al. 1987).

Materials and methods: In a preclinical and a clinical study, physeal fractures of 10 cats and 8 dogs were fixated with biodegradable implants made of self-reinforced PGA. Fractures of the distal femoral growth plate were most common (10/18). The surgery was performed according to modern manuals of orthopedics. The patients were allowed to use their operated on limb immediately after the operation without any external support. The final retardation of growth was measured in the physeal fractures of the distal femurs.

Results: All the patients started to used their operated on limb during the first postoperative week and 16/18 patients could walk without lameness in 3 weeks and the other 2 in 6 weeks. No malformation or pathologic reactions of the fragments were seen radiographically in any patient. The physeal fractures of the distal femur of the cats fixated with 2-mm thick implants caused 1.3 percent retardation of the growth, and those fixated with 3.2-mm thick implants caused 6.1 percent. No bone shortening could be found when a similar fracture of a medium large (15 kg) dog was fixated with a 3.2-mm implant.

Discussion: This biodegradable implant was strong enough to keep the fragments in place for the 3 weeks needed. The minimal growth-retarding effect was due to whether the growth potential of the physeal plate was strong enough to break the implant and to the percentage of the cell number destroyed in the physeal plate.

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Changes of articular cartilage and subchondral bone after experimental intraarticular osteotomies of the distal femur

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Standardized areas of the medial and lateral condyles of the right femur in 117 adult rabbits were investigated after osteotomies of the distal femur and of the medial condyle of femur fixed with two different methods. The left femur served as a control. Follow-up times were 1, 3, 6,12, 24, and 48 weeks. The distal part of each femur was removed, fixed in alcohol, embedded in methylmethacrylate, and sectioned 5-µm thick. Quantitative histomorphometric analysis of the articular cartilage and subchondral bone adjacent to it was performed using a semiautomatic computer linked via a television camera to a light microscope. The numerical measurements were analyzed with the Student's *t*-test. The influence of the operation in general, of the quality of osteotomy, of the fixation method, of the success of bone healing, and of the time of examination were evaluated. The comparison of the results of the operated on knees to those of the controls showed significant increase ($P < 0.001$) in the area of the articular cartilage of the medial condyle and less increase ($P < 0.2$) of the lateral condyle. At the same time the number and area of living chondrocytes remained unchanged. In adjacent subchondral bone, a significant decrease ($P < 0.002$) in the volume of matrix was observed in the medial condyle. In the lateral condyle the decrease was less prominent ($P < 0.1$). On the basis of the present study, it is obvious that the diminished use of the operated on limb caused by pain is the reason for the changes noticed in the articular cartilage and subchondral bone. This hypothesis was confirmed with the finding that if the healing of the osteotomies was disturbed, the increase of the area of the cartilage was larger than after normal bone healing.

The treatment of cancellous bone fractures with biodegradable screws

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Introduction: We present early results of a clinical study in the treatment of fractures with biodegradable screws. Bending strength of this screw is 320 MPa, shear strength 200 MPa, and elastic modulus 10–15 GPa. This means that the screw can take 160 kg weight bearing when the diameter of the core is 3.2 mm. The decrease in the bending strength of the screw is gradual, so that the screw loses its strength after 5–7 weeks in vivo.

Material and methods: Since May 1987, we have treated 22 ankle fractures, 2 olecranon fractures, and 1 patella fracture with biodegradable screws. The criteria for entry into the study were age between 16 and 70 years, trustworthy cooperation of the patient, and displacement of the fracture of at least 2 mm. After reduction of the fracture, the self-reinforced screws of synthetic biodegradable polyglycolide were inserted into the drill hole. The ankle fractures were immobilized in a plaster cast for 6 weeks — without weight bearing in the first 3 weeks, then 2 weeks with partial weight bearing, and in the last week full weight bearing. The patella fracture was immobilized in plaster for 8 weeks and the olecranon fractures for 3 weeks.

Results and discussion: The follow-up is more than 3 months in 17 ankle fractures, and in 1 patella and 1 olecranon fracture. In treating ankle fractures the mean duration of the operation was 52 minutes including the plaster application, and the mean disability time was 51 days. Early results were good. There was only one insignificant secondary displacement in the first olecranon fracture. Sinus formation was observed in 3 patients, but it did not have any effect on bone healing. The fluid of the biodegradable material should be removed from the sinus with needle aspiration. There was bacterial growth after opening the sinus in one of these 3 patients, but no osteitis. All the fractures had united clinically in 6 weeks. All the patients followed over 3 months have returned to their work and are asymptomatic.

Three years' audit of biodegradable osteofixation in orthopedic surgery

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Introduction: The utilization of biodegradable implants instead of metals in orthopedic surgery abolishes the need to remove the fixation material. For 15 years, biodegradable synthetic polymers have been in worldwide use as resorbable sutures. However, the development of implants suitable for osteofixation of these polymers has proved laborious.

Materials and methods: For this study, cylinder-shaped biodegradable implants of self-reinforced polyglycolide and lactide-glycolide copolymer were developed and manufactured. The clinical introduction of these implants was preceded by thorough experimental studies. The assortment of the clinically utilized biodegradable rods were 2.0, 3.2, and 4.5 mm in diameter and 20 to 70 mm long. The main principle of the surgical technique was to place the rods in channels of the same diameter drilled into the cancellous bone across the fracture surfaces or osteotomies.

From November 1984 to January 1988, the biodegradable method of osteofixation was used in 534 operations. These included 388 with displaced malleolar fractures (1, 2), 75 with chevron-osteotomy for hallux valgus, 20 with scaphoid non-

Table 1 Patients operated on using biodegradable implants

	No. of patients		No. of patients
Upper extremity		Lower extremity	
Fresh fracture of		Fresh fracture of	
capitellum humeri	6	patella	5
olecranon	18	distal femur or proximal tibia	8
radial head	19	ankle (Weber type A or B)	295
distal radius	3	ankle (Weber type C)	43
carpal bones and hand	13	talus	1
Coracoid osteotomy	13	Osteochondritis dissecans	2
Scaphoidnonunion	20	Hauser's operation	11
Trapezio-metacarpal fusion	2	Chevron osteotomy	75
Total	94		440

union, 19 with displaced fracture of the radial head, 18 with displaced fracture of the olecranon, and 64 patients with other fresh fractures or elective orthopedic conditions requiring surgery (Table).

Results and discussion: The postoperative course was uneventful in 473 patients (89 percent). A reoperation was necessary because of failure of the fixation in 6 patients. A clinically insignificant redisplacement was noticed in 19 patients. In 9 cases there was a superficial wound infection and in 27 a sinus formation without demonstrable bacterial growth. This sinus complication probably has some analogy with the well-known stitch sinuses. It has also been observed in abdominal surgery when using resorbable sutures of the same biodegradable synthetic polymers as the implants of the present study. A sinus formation did not influence the functional or radiographic end result. The costs caused by implant removal procedures associated with use of metallic implants in orthopedic surgery are undoubtedly enormous (3). Besides these economic points of view, the psychologic advantages of biodegradable fixation implants must be emphasized as well. The overall results of this study were considered favorable and have encouraged us to continued experimental and clinical research on the theme.

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The development of chevron osteotomy

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Introduction: Chevron osteotomy is a modification of the Mitchell osteotomy, and can be used in young adults with hallux valgus and metatarsus primus varus. The osteotomy is made in a V-shape to provide greater stability and to make the procedure easier. We describe the development until now, and introduce a new procedure with internal fixation with a biodegradable implant and postoperative treatment.

Methods: Six feet in 6 patients had a chevron osteotomy, stabilized with a biodegradable implant. No plaster cast was used; during the first 2 postoperative weeks, the patients wore a bulky bandage.

Because of the solid osteotomy, combined with the biodegradable fixation, the operation was performed as an outpatient procedure under local anesthesia. Our preliminary experience revealed the patients to be very satisfied with this procedure, which so far has no complications.

Repair of the meniscus

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Introduction: Previous studies (1, 2, 4) in rabbits have shown that the repair tissue in longitudinal substance lesions of the meniscus consisted mainly of fibrous avascular tissue, whereas the repair tissue in wedge-shaped lesions was of a fibrocartilaginous type. In cases where a T-shaped lesion was sutured with the aid of a synovial flap on a pedicle, repair tissue consisted predominantly of fibrous vascularized tissue.

Materials and methods. This study concerns the use of a biodegradable implant for use in reconstructions of artificially made meniscus lesions in dogs. Fourteen T-shaped lesions were repaired with an organic polymer implant containing segmented polyurethanes, poly(L-lactide) and carbon fibers (3). In 34 dogs T-shaped meniscal lesions were repaired with the aid of an implant containing polyurethanes, poly(L-lactide), and poly(L-lactide) fibers (6, 7). A synovial flap on a pedicle was sutured to the implant.

Results: In the first series, complete fibrous tissue repair (5) was observed in 10 cases. In 2 dogs a dislocation of the implant was observed, combined with a synovitis. In the second series, complete fibrocartilaginous repair was found in 25

cases, 7 showed partial repair, and 2 implants had been dislocated. Synovitis was not observed. Preliminary compression experiments showed an elastic modulus of healed fibrocartilaginous sections that resembled original meniscus tissue.

Discussion: From these studies it can be concluded that in animals fibrocartilaginous repair in longitudinal substance lesions will occur only if a connection to the synovial lining has been made.

PU-PLLA implants appear to enhance this process considerably. Our compression tests seem to match those done by Newman [8], who also found that the force compression displacement curves in fibrous tissue repair cases did not resemble the curves of the normal meniscus tissue. Therefore, mere suturing procedures in longitudinal meniscus lesions will probably not yield a histologically and biomechanically optimal result.

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Experimental orthopedics

Bone graft revascularization and mineral accretion in T-cell-deficient rats

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Introduction: Bone allografts are inferior to their autogenic counterparts with regard to bone induction properties and revascularization. Analogous to cell-mediated mechanisms in skin graft rejection, T-lymphocyte immune response might be important for the incorporation of allogenic bone grafts. The influence of the T-lymphocyte system on the acceptance of allogenic bone grafts can be studied in congenitally athymic rats. These animals have no T-lymphocyte function. A difference in the revascularization and bone induction properties of allogenic bone grafts between athymic and normal rats may therefore be ascribed to the T-lymphocyte immune system.

Materials and methods: Recipients were normal or athymic rats of the Lewis strain. Fresh syngenic or allogenic corticocancellous bone from donor os ileum were grafted into intramuscular pouches in the back of the recipient. The animals were killed 2 or 3 weeks postoperatively. ^{85}Sr incorporation was used as a measure of the osteogenic activity. Ingrowth of new vessels in the graft was measured by intraarterial injection of ^{141}Ce-labeled microspheres.

Results and discussion: The ^{85}Sr radioactivity showed that the osteogenetic activity was similar in the syngenic groups and the athymic allogenic recipients. Allogenic grafts in normal recipients had significantly lower mineral accretion rate than the other groups. The ingrowth of new vessels showed the same pattern with relatively similar ^{141}Ce activity in the syngenic grafts and in the athymic recipients, whereas allogenic grafts in normal animals had relatively less graft blood flow. The results confirm that the osteogenetic activity and the revascularization of allogenic bone grafts are less than in syngenic grafts. The results further suggest that the T-lymphocyte system of the recipient is at least partially responsible for this difference. Thymus-dependent graft rejection mechanisms are probably important for the biological function of allogenic bone grafts.

Behavior of normal, avascular, and revascularizing cancellous bone in the femoral head

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Introduction: Idiopathic avascular necrosis of the femoral head (IANF) has become an increasingly frequent problem. There is apparently a real increase in incidence, and treatment is often inadequate. The treatment of IANF must be based on two principles: revascularization and prevention of collapse. This can only be conducted successfully when enough is known about the remodeling process and the development of the bone strength. In particular, little is known about the velocity of remodeling and the relationship between remodeling and bone strength. The present study was conducted to investigate these relations.

Materials and methods: An animal model was created to study vascular and revascularizing cancellous bone in the femoral head in vivo under normal loading conditions. Using a sterile surgical procedure, the anterosuperior segment of the left femoral heads of 52 African pygmy goats was devascularized and isolated in situ using PMMA cement. Fifteen goats were killed 6 (n 5), 12 (n 5), and 24 (n 5) weeks postoperatively, and cylindric test specimens 5 mm in diameter and 4-mm thick were cored from the segments. They were subjected to unconfined compression on a Zwick materials testing machine. Yield strength, elastic modulus, and apparent density were determined. Test samples from the unoperated on right-sided femoral heads served as controls. In a second group of 21 goats, revascularization was introduced by perforating the cement barrier. Histomorphology and mechanical studies were performed 7 (n 8) and 12 (n 13) weeks postoperatively. In the last group of 16 goats, revascularization was introduced by means of an arteriovenous bundle transplantation (AVBT). The segments were loaded in vivo and the goats were killed 12 (n 11) and 24 (n 5) weeks postoperatively. Histomorphologic studies were performed. To evaluate the testing methods, 45 specimens from 3 human femoral heads were tested.

Results: The tests on the controls supplied us with the mechanical properties for normal goat cancellous bone (apparent density: 0.59–1.48 g/cm^3; yield strength: 4.7–54.6 MPa; elastic modulus: 84–1,434 MPa). The mechanical properties of avascular cancellous bone did not change significantly up to the 24th postoperative week (apparent density: 0.88–1.44 g/cm3; yield strength: 22.8–45.2 MPa; elastic modulus: 167–821 MPa). Histomorphology showed that the segment remained avascular up to the 24th postoperative week, and the percentage of bone did not change compared with normal bone (normal = 62 percent, avascular = 64.7 percent). Test specimens taken from the passively revascularized segments showed a significant decrease in strength (20.8 MPa) and stiffness (294 MPa). The apparent density did not change significantly (1.13 g/cm3), but histomorphology showed a highly significant decrease of the percentage bone (bone volume 31.6 percent). In the AVBT group the decrease in the percentage bone was also seen, but this decrease was significantly less than in the previous group (53.0 vs. 31.6 percent) Histology showed a positive influence of the AVBT on the repair process, but osteolysis occurred nevertheless.

Conclusions: The relationships between apparent density and yield strength, and the apparent density and elastic modulus of cancellous bone were quadratic exponential functions. This study supports the usefulness of the exponential model over an expanded apparent density range, from very porous to very dense cancellous bone. Avascular bone, isolated in situ under normal loading conditions, does not change up to the 24th postoperative week. It remains as strong and stiff as normal cancellous bone. Fracture, collapse, and fragmentation are the result of the revascularization process. The AVBT does not always prevent a fracture and collapse of the segment, but the loss of bone is significantly less than in the passively revascularized segments.

Effects of different degrees of rotational stability of intramedullary fixation on experimental bone healing

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Introduction: Experimental studies indicate that rotational instability is detrimental to healing of fractures, whereas clinical experience may indicate that some rotational instability hardly has any negative effect. The aim of the present study was to investigate the effect of different degrees of rotational instability on fracture healing.

Material and methods: Twenty-four adolescent Chinchilla male rabbits were used. An open, transverse, midshaft tibial osteotomy was performed on one leg, while the other served as a control. After reaming the medullary canal, intramedullary nailing was performed. The animals were divided into three groups according to different nail types: A triangular steel nail with a cross-section of 3.3 x 3.3 mm (standard nail), the same nail with proximal and distal interlocking (interlocking nail), and a Kirschner pin with a diameter of 2.8 mm (K-pin). The first group was regarded as slightly rotational unstable, the second involved better rotational stability, and the third was highly unstable. Each group comprised 8 animals. They were killed after 6 weeks, and bone healing was evaluated by radiography, measurement of periosteal callus formation, and mechanical testing in 4-point bending.

Results: All the osteotomies were radiographically healed, except for one in the K-pin group. The periosteal callus formation was abundant in all the osteotomies, except for two in the interlocking group, which showed moderate callus formation. There were, however, no significant differences in the amount of periosteal callus between the groups. Compared with strength of control bones, the median strength of the healing bones was 62 percent in the interlocking group, 94 percent in the standard nail group, and 69 percent in the K-pin group. The differences between the three groups were not significant. The stiffness was significantly greater in the standard nail group than in the two other groups.

Conclusions: 1. There was a trend towards more rapid bone healing when the nail with the medium rotational stability was used. 2. Even with gross rotational instability, the speed of bone healing was normal in most osteotomies.

Torsional stability of interlocking intramedullary nails in experimental femoral shaft fractures

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Introduction: We have measured the torsional strength and stiffness of an interlocking intramedullary nail (Grosse-Kempf) for treatment of femoral shaft fractures.

Material and methods: Ten fresh cadaver femora, obtained at autopsy and stored in plastic bags at –20 °C were used. The testing was performed on an Instron type 1272 with a torsional device added. Intact bone and bone with a standard fracture, fixed with a 12-mm and a 14-mm nail, were tested successively.

Results and conclusions: The torsional strength and stiffness were about 3 percent of that of the intact bone with no difference between the 12-mm and 14-mm nail. Removal of the distal or proximal bolts made the system even weaker, and the deformation was permanent in contrast to the intact system with bolts in place.

The interlocking intramedullary nail is a very weak system, but acts as a springback, returning to the original position upon release of the applied force. Increasing the diameter of the nail did not increase the fixation rigidity, so extensive reaming should be avoided.

The influence of growth hormone on fracture healing in rat: A dose-response study

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Introduction: Biosynthetic human growth hormone (b-HGH) stimulates the proliferation of chondrocytes. Experimental fractures of long bones heal through a stage of cartilaginous callus. The effect of different doses of b-HGH on the mechanical properties of healing fractures was studied.

Materials and methods: In 9-day old female Wistar rats, a standardized fracture was produced by three-point bending in the tibia. Medullary nailing was performed. The rats were randomized into 6 groups: no injections, 0.9 percent NaCl, b-HGH 0.08, 0.4, 2.0, or 10 mg/kg/day given subcutaneously in two daily doses from 1 week prior to fracture and until mechanical testing, which was performed by a three-point bending procedure in a materials testing machine after 40 days of healing.

Results and conclusions: After 40 days of healing, fractures treated with b-HGH in doses of 2 and 10 mg/kg/day had increased maximum load and stiffness compared with the saline-treated controls, but there was not a significant difference between the two treatment groups.

Treatment	N	Maximum load N	Stiffness N/mm
1) no injections	13	37.2 ± 8.5	171.0 ± 31.0
2) 0.9% NaCl	14	30.2 ± 4.9	138.0 ± 24.2
3) b-hGH 0.08 mg/kg/day	10	35.6 ± 8.2	166.0 ± 39.3
4) b-hGH 0.4 mg/kg/day	15	34.9 ± 5.8	179.7 ± 30.5
5) b-hGH 2.0 mg/kg/day	10	55.3 ± 10.2*	219.9 ± 31.8*
6) b-hGH 10 mg/kg/day	13	69.3 ± 8.4**	323.0 ± 30.0**

Mean values ± SEM. *$2P < 0.05$; **$2P < 0.01$.

IGF-1 effects on fracture healing in rat

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Introduction: The somatomedins or insulinlike growth factors (IGF) are peptide growth factors. Many cell types, including osteoblasts, synthesize these peptides. In this study we have analyzed IGF-1 mRNA during fracture healing in rat. Further experiments have been performed in local administration of human IGF-1 (KABIgen AB) in a rat fracture model.

Materials and methods

IGF-1 mRNA analysis. The left tibia of 12 rats was fractured by mechanical force. The rats were killed after 4, 6, 8, and 14 days, and tissues surrounding the fracture – bone callus and muscle – were analyzed for IGF-1 mRNA. The contralateral leg served as a control.

Local IGF-1 administration. Sixty-seven Sprague-Dawley rats were randomized into four groups. A standardized midshaft drill hole was performed on both femurs. The left drill-hole region was perfused with the content of an osmotic minipump. The four different groups were a) a"nondrilled" group, minipumps delivering sterile water; b) controls, minipumps containing sterile water; c) IGF-1 group, minipumps delivering 0.1 μg/h of IGF-1; and d) an IGF-1 group with minipumps delivering 1 μg/h of IGF-1.

The rats were killed after 1 and 2 weeks, respectively, and ultimate torsional strength and other variables were determined in both femurs.

Result and discussion: In the present study an experimental model was developed with regard to growth-factor influence on fracture healing. In our initial experiments, we found that IGF-1 mRNA was greatly increased during the course of fracture healing in this experimental model. In a second series of experiments the effects of exogenously added IGF-1 on fracture healing was tested. No significant increase in fracture healing rate in the IGF-1 treated rats was found when compared with the controls.

Influence of indomethacin on bone remodeling after tibial osteotomy: An experimental study in rabbits

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Introduction: In experimental studies, indomethacin and other nonsteroid anti-inflammatory drugs inhibit bone healing. The influence on the remodeling processes in bone is, however, almost unknown. The aim of the present histomorphometric study was to evaluate the effect of indomethacin on the remodeling processes in cortical bone close to a plated tibial osteotomy in rabbits.

Material and methods: A tibial midshaft osteotomy was performed in the right tibia of 32 rabbits and fixed with a small AO DCP plate®. The animals were divided into two groups, one group served as controls and the rabbits in the other group were treated with indomethacin 10 mg/kg/day. Animals in the two groups were killed 2 and 6 weeks after the operation, and the remodeling processes histomorphometrically were quantitated in both legs.

Results: In the osteotomized leg (control group) compared with the control leg, the number of both resorptive foci and porosity were increased after 2 and 6 weeks, whereas the number of formative foci and bone formation rate were unchanged after 2 weeks, but significantly increased after 6 weeks.

In the osteotomized leg of the indomethacin group compared with the placebo group, the number of dilated haversian canals and formative foci were significantly reduced after both 2 and 6 weeks, indicating a reduced number of resorptive

and formative foci after indomethacin treatment. The porosity did not differ after 2 weeks, but was significantly reduced after 6 weeks of indomethacin treatment. There was no difference in the bone formation rate between the indomethacin and the control group.

Discussion and conclusion: The change in cortical bone following plated osteotomy demonstrates a rapid internal reorganization in bone neighboring a plate osteotomy – the regional acceleratory phenomenon. Increased porosity in the traumatized leg after 2 weeks followed by an increased number of formative foci after 6 weeks confirm that osteoblastic bone resorption precedes osteoblastic bone formation.

The study demonstrates that indomethacin inhibits this regional acceleratory phenomenon by reducing both bone resorption and formation. The homeostasis between osteoclasts and osteoblasts seems unchanged.

Application of lasers in the joining of bone fractures

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Lasers can be used as efficient surgical tools. There are signs of even more rapid progress, and the general acceptance of laser techniques in more fields of surgery are being demonstrated.

We have studied the application of laser beams in orthopedic surgery. In our experiment, CO_2 and Nd YAG lasers were used. We used calcium stones, which have a spongy structure, and lamb bone as the objects for our laser treatment. The calcium stones were selected because of their similarity to spongy bone. The temperature rise in the heated and melted region was predicted theoretically, whereas the actual temperature rise inside the studied objects was measured. Photographs of the laser-damaged sites were taken to examine the effects of the laser beam on the structure of the two studied objects.

Laser-object interactions involve very complicated phenomena, such as transient heating, melting, and evaporation. Laser heating depends on the laser parameters and the properties of the object under treatment. Keeping the laser parameters constant, the thermal properties of the treated object, then, play a significant role on the transient heating mechanism. Materials having a low thermal diffusivity and absorptive depth prevent heat conduction and cause the temperature of the the heated spot to rise, i.e., high temperature gradient in the heated region occurred. On the other hand, the cooling rate also depends on the thermal properties of the material in the cooling cycle of the interaction.

Vaporization only occurs if the power intensity becomes sufficiently high, i.e., of the order of 10^{12} W/m^2. The mechanism governing laser-study object interaction becomes very complicated, and there is mass transfer accompanying the heat transfer. In this case, resolidification occurred, as well as cavity formation.

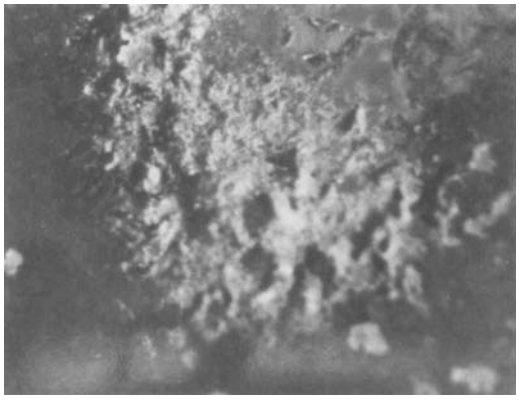

Figure 1. Laser-treated lamb bones. X 20.

In Figure 1, a photograph of a laser-melted bone is shown. Melting occurred on the surface and the debris appeared on the surface. There is also a small cavity that appeared inside the bone. This indicated that the mass removal occurred during the interaction. However, no burning occurred inside the cavity, i.e., there was no carbonization. This was due to the shielding gas used in the experiment. The depth of the heat-affected zone is on the order of 15 μm.

Bone formation induced by PGE_2 in humans

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Introduction: Prostaglandins interfere with bone metabolism and may lead to imbalance between resorption and formation. This is demonstrated in several studies where bone repair was inhibited by using NSAIDs (1, 2). The influence of PGE_2 is believed to be mediated by the inflammatory reaction, but there are few reports on the direct influence on bone remodeling in animals (3), and none are known to the authors in humans. To illustrate the influence of PGE_2 in human bone modeling, we present the following case.

Case history: A 2-day-old girl with cyanotic heart disease was treated with PGE_2, given continuously through a central intravenous catheter, to keep the ductus arteriosus open. The treatment resulted in stable circulation, disappearance of the cyanosis, and a rise in pO_2. On day 50, tenderness and circumferential increase of the lower limbs were observed, and cortical hyperostosis was demonstrated. The girl was followed by serial radiography. On day 75, an aortopulmonary shunt operation was successfully performed; and on day 82, PGE_2 treatment was tapered off. On day 144, the girl was readmitted because of sepsis and died. Radiography of the whole skeleton and histologic examination of the bones were performed. The histologic findings showed a fibrous thickening

of the periosteal membrane under which large amounts of hyperosteotic woven bone were present. Radiography showed regression of the periosteal hyperostosis observed earlier.

Discussion: The histologic findings were most striking, showing a fibrous thickening of periosteal membrane under which large amounts of primitive woven bone were present. The structure of the bone was not indicative of an accelerated normal appositional growth, but rather of rapid formation of reactive bone. The latter feature is supported by a high rate of bone formation according to serial radiography. If the hyperostosis, then, was in progression, the outer surface should be bone-forming. But on the contrary, this surface was undergoing pronounced resorption, and the inner surface almost only formation. This observation indicated that the previously enhanced new bone formation was reversible and that the hyperostosis was being remodeled towards normality.

Summarizing, prostaglandin treatment with PGE_2 seems to initiate bone formation on the outer surface of cortex leading to hyperostosis. The formed bone exhibits an abnormal woven structure similar to that observed after local application of prostaglandin in rats (4)

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Bone mass distribution in the femur: A cadaver study on the relations of femoral density, mass, and strength

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Introduction: Given the specific shape of a bone, its mineral content is correlated with its strength (1). In a previous study (2), we found a correlation between the density of cancellous bone in the femoral condylar area and the strength of the bone in axial loading, where the fracture usually occurred in the femoral neck. In a further quantitative computed tomographic (QCT) analysis, we found such correlations in various femoral cortical and cancellous regions (3). In the present study, we analyzed the distribution of cancellous and cortical bone masses in the femur by QCT and compared the density and mass with the maximal forces at fracture in axial loading.

Material and methods: We collected femora from 16 male and 10 female cadavers, median age 76 (56–88) years. The left femora were used for the study. The QCT was made on a GE 8800 equipment (General Electric, Milwaukee, WI) using standard scanning parameters, 120 kV and 100 mAs. Ten millimeter-thick slices were made from the center of the femoral head, cervicotrochanteric region, mid-diaphysis, and condyles. The densities of cancellous bone varied from 50 to 500 Hounsfield units (HU); those of cortex were above 500 HU. The relative bone masses were calculated as the product mean density x total volume of the slice. After the QCT the bones were mounted on an Instron machine (Instron Ltd, High Wycombe, Bucks, England). An axial load, 5 mm/min, was applied by placing the condyles on the platform and the cross head on the femoral head. The maximal force at fracture was used as the strength parameter in the correlation analyses. In all, 25 fractures occurred in the femoral neck and only one in the femoral shaft.

Results and discussion: The bone masses, calculated as the product bone density times volume, increased steadily from the femoral neck down to the condyles, totally by 26 percent. No significant differences were found between the bone densities of male and female, whereas the bone volumes differed significantly. Several correlations were found between the shearing strength of the cervical trabecular/cortical bone and cortical and cancellous bone densities in different locations of the femur. The correlations between the cervical bone strength and bone mass were significant in all the locations.

We conclude that the strength and effective mass of an idealized long bone is equally divided along its long axis as demonstrated by the fact that highly significant correlations were found between the bone mass values in all the femoral locations as determined by QCT and the strength of the femur at fracture. The geometry of the femur may determine that a fracture in "supramaximal normal loading" as represented by low-energy fractures in the elderly occurs in the femoral neck.

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The consequences of compression strain level on energy absorption in trabecular bone specimens

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Introduction: A nondestructive test procedure is mandatory

when determining energy absorptions. The energy absorptions (hysteresis energy and unloading energy) are, like stiffness, dependent on strain. However, the relation between strain and mechanical parameters is, on the whole, unknown.

The purpose of this study was to analyze the influence of strain level on the mechanical properties of trabecular bone specimens and to compare those results with the properties derived from destructive testing.

Material and methods: Forty-four cylindric trabecular bone specimens were used. The specimens were taken from the condylar areas of the proximal tibia with their axis parallel to the long axis of the tibia. Compression testing was performed with an Instron® universal test machine. The strain rate was 0.002% sec^{-1}. All the specimens were after initial conditioning tested by nondestructive cyclic compressions to 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7 and 0.8 percent strain. The specimens were retested at 0.1, 0.2 and 0.8 percent strain. Afterwards, a destructive test was performed. Finally, the bone specimens were defatted for determination of apparent density.

Results and discussion: The value of the unloading and the hysteresis energy is dependent on strain level at any rate between 0.1 and 0.8 percent, whereas the stiffness is strain dependent only up to about 0.7 percent, where strain approximates Σmax (0.82 percent). It is interesting that the loss tangent is increasing at the strain level 0.7–0.8 percent compared with the other levels, where it is nearly constant. An increasing loss tangent signifies a relative increase in energy dissipation, and perhaps this is the first sign of trabecular damage. The strong correlation between the results from the destructive test and from the nondestructive test with high strain level, compared with the risk of trabecular damage at high strain levels, makes it appealing to use a strain level between 0.6 and 0.7 percent.

Strain distributions in trabecular bone specimens

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Introduction: Little attention has been paid to strain distributions in mechanical testing of trabecular bone. In this study, compressive strain distributions were examined in trabecular bone specimens from the proximal tibia.

Methods: Compressions of the test cylinders was performed on an Instron® materials testing machine. During compressions, images of the specimens were grabbed with two video cameras. Load-deformation curves were recorded simultaneously using an extensometer attached close to the specimen. When examining the images, failures were classified as transverse or oblique. Landmarks on the surface of the test specimens were followed through compression, and local strains were calculated in the transversely failing specimens.

Results: Transversely failing specimens never failed in the intermediate third. At 1 and 2 percent specimen strain, the local strain in the failing third and the nonfailing distal third was significantly higher than the strain in the intermediate third. Above 2 percent specimen strain, the local strain in the intermediate third and the nonfailing distal third was significantly lower than in the failing third. All the local strains were significantly different from overall specimen strain, except for the failing third at 1 percent specimen strain and the nonfailing distal third at 1, 2, and 3 percent specimen strain.

Conclusions: The strain distribution in the direction of compression was very uneven in both the prefailure and the postfailure phase. An isotropic material is expected to be strained maximally in the central part of the specimen owing to end forces deviating from pure axial compression. The opposite distribution was found in this study. Values of Young's modulus for trabecular bone reported in the literature seem underestimated.

Effect of life-to-death transition and storage mode on mechanical properties of trabecular bone

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Introduction: Alterations of mechanical properties of trabecular bone have been demonstrated to occur within 5 hours postmortem. Storage by freezing has demonstrated either a small increase of strength and stiffness or no changes. The purpose of the present study was to analyze the effect of life-to-death transition and different storage modes on mechanical properties of human trabecular bone.

Material and methods: Trabecular bone specimens were obtained from the upper tibial epiphysis of two amputees operated on because of osteosarcoma localized to the distal third of the femur. Cylindric specimens were machined and tested within 2.5 hours after removal from the body and retested after 24 hours. Specimens were stored in physiologic saline at room temperature. After 24 hours, they were randomly allocated into four groups: One group (n 64) stored in 70 percent ethanol at 10 °C and tested after 1, 10, and 100 days. Three groups (n 112) stored frozen at -20 °C and tested after 1 day, 10, and 100 days, respectively. Specimens stored frozen were after testing refrozen for 1 day and retested. This procedure was repeated five times with 1 day interval. Testing was performed by unconfined nondestructive compression testing to 0.45 percent strain, and stiffness, recoverable energy, and energy dissipation was computed.

Results: There was a 10 percent decrease in stiffness and recoverable energy from 2.5 to 24 hours postmortem. Neither freezing nor preservation in ethanol caused alteration of the stiffness or recoverable energy, but both caused a 25 percent

increase ($P < 0.001$) in energy dissipation at 100 days of storage. Thawing, testing, and refreezing five times did not affect mechanical properties.

Bone: A flexible sponge? — physiology, anatomy, and pathology

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Physiology: Intraosseous pressure (IOP) was studied experimentally and in man, with and without proximal vascular occlusion and weight bearing. IOP was raised by increased systemic blood pressure, venous occlusion, dependent lowering of the limb, and weight bearing: IOP was reduced by the opposite effects and fluctuated during walking. Intraosseous saline injection raised IOP throughout a bone, but this pressure was not transmitted across adjacent synovial joints or epiphyses. Bone behaved as a compressible perfused sponge within a relatively tight outer membrane, IOP reflecting a simple hydrodynamic relationship between bone perfusion, drainage, and physical load.

Anatomy: A previously undescribed subchondral vascular plexus was demonstrated. The existence of a subchondral cancellous bone blood pump was proposed and supported by a reassessment of some macroscopic and microscopic features of bone.

Pathology: Further evidence from caisson disease patterns in divers and tunnellers was advanced, together with the results of barometric microbubble induction experiments.

Increased levels of proteoglycan fragments in joint fluid after knee injury

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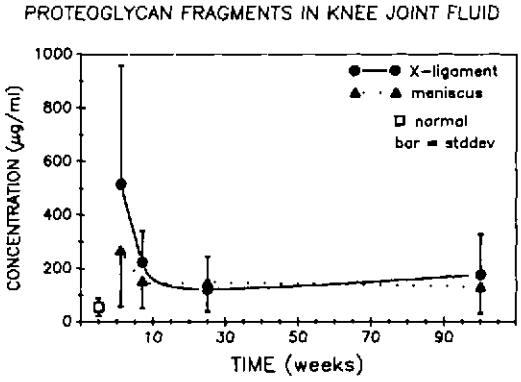
Introduction: During normal and pathologic turnover of joint cartilage matrix, degradation products are released in the synovial fluid. Newly developed assays of cartilage proteoglycan fragments allow the sensitive and specific detection of these fragments in joint fluid (1). Recent data suggest that such assays may have diagnostic and predictive value in inflammatory joint disease (2–4). We present the results of a case-control study on the levels of proteoglycan fragments in knee joint fluid at different times after cruciate ligament or meniscus injury.

Patients and methods: Joint fluid was aspirated at routine arthroscopy. Samples were analyzed by immunoassay (1) for cartilage proteoglycan fragments. Patients were aged 16 to 50 years. Samples were collected consecutively and included in the study if either of the three following diagnoses was made by arthroscopy: A) Cruciate ligament tear isolated or in combination with injuries to menisci (100 patients); B) Meniscus tear without other injuries (98 patients); C) Completely normal arthroscopy in the absence of hemarthrosis (14 patients).



Results and discussion: The control group with normal arthroscopic findings contained patients with persistent knee joint pain for variable lengths of time leading to arthroscopy. The average proteoglycan fragment concentration in this group was 55 µg/ml joint fluid, which is in the same range as in healthy knee joints. Cruciate ligament tear, alone or combined with other injuries, led to a dramatic increase (about tenfold) in the levels of joint fluid proteoglycan fragments in the immediate period after injury. With increasing time after trauma, the levels gradually decreased, but remained high even after more than 1 year, about three times that of the control group. Meniscus tear gave a fivefold increase in proteoglycan concentration in the acute phase with a decrease with time. The data suggest that in the acute phase the levels of joint fluid cartilage proteoglycan fragments are related to the severity of the trauma. At later times, the levels may reflect the degree of chronic joint instability. It is notable that more than 1 year after cruciate ligament or meniscus injury, proteoglycan levels were significantly elevated, perhaps even rising. Further, the essentially normal concentrations in the control group show that knee joint pain in the absence of pathologic arthroscopic finding is not associated with increased proteoglycan levels in joint fluid. Longitudinal studies may with time demonstrate whether or not the patients with persistently elevated levels after trauma are more prone to develop early arthrosis in the knee joint.

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99mTc-DPD three-phase scintimetry of the immature knee during simulated joint effusion

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Experimental studies on growth disturbances in juvenile chronic arthritis of the knee have revealed depressed growth plate metabolism as judged by uptake of ^{99m}Tc-DPD. The impact of joint effusion on metaphyseal hemodynamics still is unsettled. We studied the juxtaarticular uptake of ^{99m}Tc-DPD in the immature knee during simulated joint effusion.

In 7 mongrel dogs, ^{99m}Tc-DPD three-phase scintimetry was performed initially and during unilateral joint tamponade of 10.0 KPa. Uptake in the distal femoral growth plate (FGP), the distal femoral epiphysis (FE), and the proximal tibial growth plate (TGP) was quantitated in an angiographic phase (I: 0–20 s), a "blood pool" phase (II: 20–256 s), and a bone uptake phase (III: 2 h). A static study was done after joint evacuation. Count ratios (CR) between right and left were similar in all phases. CR was reduced by 20 percent in FE (significant in phases II and III), and by 8 percent in TGP (significant in phase III). A minor fraction of changes in FE and FGP could be ascribed to attenuation of gamma emission by the presence of joint fluid.

The findings suggest that increased joint pressure may lead to hypoperfusion of growth plates and juxtaarticular epiphyses and contribute to the growth disturbances associated with chronic synovial inflammation.

Hip arthroplasty

The Anaform femoral endoprosthesis: A multicenter study in the Netherlands

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Introduction: The Anaform femoral endoprosthesis is a straight stem prosthesis coated with a soft porous layer of Proplast®, a composite of polytetrafluoroethylene polymer and aluminum oxide. Proplast® was developed by Homsy from Houston in the late 1960s and is approved by the U.S. Food and Drug Administration.

Material and patients: In September 1984, six hospitals and 15 orthopedic surgeons started a prospective study. The clinical results were evaluated according to the Harris Hip rating system, and the radiographic results according to a rating system that was especially made for this prosthesis.

Results: Until September 1987, 438 patients were operated on. One year postoperatively, 87 percent of the patients rated more than 80 points (maximum 100) on the Harris Hip Score (HHS). This percentage 2 years postoperatively was 92 percent.

Totally, 38/50 patients with intraoperative complications rated more than 80 points 12 months postoperatively; and 10/14 patients with postoperative complications rated more than 80 points 12 months postoperatively. In 34 patients the prosthesis was too small. The HHS in 30 of these patients 12 months postoperatively was more than 80 points. In 38 patients the abduction angle of the cup was more than 50°. The HHS in 34 of these patients 12 months postoperatively exceeded 80°.

The prosthesis was used in revisions of cemented prostheses in 30 patients. The HHS in 28 of these patients 12 months postoperatively exceeded 80.

During this period, seven prostheses were revised because of pain and a loose prosthesis and were replaced by a cemented prosthesis. Calcar atrophy was seen in 5 percent of the patients 12 months postoperatively and in none of the patients 36 months postoperatively.

Conclusions: The fixation by ingrowth of fibrous tissue in a 2-mm thick coating around the femoral stem can provide painless, clinical stabilization and normal gait also in revisions of cemented prostheses.

Bulk homologous bone grafting in total hip replacement

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Introduction: Loosening of total hip arthroplasties is often connected with bone loss, which has been replaced by cement, metal, or autologous bone grafts. Because the latter is difficult to obtain in adequate amounts, we have introduced deep-frozen, bulk homologous bone grafting for reconstruction of acetabular defects, as well as proximal femoral defects.

Material and methods: During the period March 1984 to August 1987, we have operated on 43 patients, aged 52 (19–84) years, with bulk grafting in 45 hips, including 32 acetabular, 8 combined acetabular and femoral, and 5 femoral grafts. All the patients were followed radiographically for 16 (1–39) months. In 34 cases the grafts were used in aseptic loosening, 6 for defects in septic loosening, 3 in arthrosis, 1 in a

congenitally dislocated hip, and 1 following femoral fracture around a prosthesis.

Results: Postoperative complications included three peroneal palsies, two hematomata, and 11 dislocations. Deep infection occurred in one previously noninfected hip and recurrent infection in three hips. In 1 case the graft loosened in connection with a dislocation, and a further three grafts were removed at reoperation for deep infection. Two of these four grafts were replaced with new bulk grafts.

The radiographic follow-up revealed slight graft absorption in 3 cases, medium in 1, and severe in 1 without affecting the mechanical support of the graft. None of the remaining 40 grafts showed signs of loosening of grafts or screws used for acetabular reconstruction or subsidence of femoral components.

Blood-type matching was not performed, but this did not affect the destiny of the graft.

Corrosion of multicomponent total hip prostheses

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The use of multicomponent prosthetic designs diminishes the necessary inventory and cost for hip prostheses. They also give a freedom of choice at the operation— and a damaged femoral head can easily be replaced. No specific disadvantage with this type of design has previously been reported.

Material and methods: We have revised 10 Lord prostheses (of 110 inserted from December 1979 through December 1983). Eight of these cast Co-Cr prostheses were of the universal type, i.e., four had separate 32-mm heads and four were bipolar prostheses with a separate 28-mm head. The two remaining prostheses had welded heads. The latter two and the four biarticular devices were macroscopically unchanged at revision, whereas three of the four 32-mm heads showed macroscopic signs of corrosion at the head/neck junction, seen as a black deposit.

A metallographic investigation was performed on the eight separate heads and for comparison on one new 32-mm head from the same manufacturer. The heads were cut in half and the interior wall of the channel was examined using scanning electron microscopy (SEM). The cut surface was polished and etched to reveal cast structures and eventual defects in the metal. In addition, microprobe analysis (SEMQ) was used to determine the composition and distribution of alloying elements.

Results: Microprobe analysis of the black deposit revealed a composition of Cr, Co, Mo, Ca, and P.

The structure of the material was one of coarse dendrites with interdendritic regions of carbides and shrinkage pores in all the examined prostheses. In the four 32-mm heads, we also found larger voids and a more marked porosity than in the smaller heads.

A composition of 2–3 percent Ni, 7 percent Mo, 29 percent Cr, the remainder being Co, was established with the microprobe analysis also showing an uneven distribution of the alloying elements with high concentration of Mo in the interdendritic areas.

Scanning electron microscopy (SEM) of the inner surface of the heads proved the interior surface of four 28-mm heads to be without pores and corrosion. Three of the four 32-mm heads demonstrated the interdendritic phase to be dissolved producing deep holes in the metal. The corrosive attack had penetrated to a depth ranging from 100 µm to 4 mm.

Discussion: The crevice introduced between head and neck with multicomponent systems puts them at increased risk of corrosion. Chemical inhomogeneity and structural imperfections in the metal might also be of etiologic importance for crevice corrosion.

This points out the necessity for superior material properties. Co, Cr, and Mo can be toxic and carcinogenic. Serious side effects from the use of metal-to-metal components were considered important for some of them. It is possible that we again are facing similar problems with some of our currently used multicomponent hip prostheses.

Uncemented total hip replacements in young adults — A Scandinavian multicenter PCA study

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Introduction: Cementless hip replacement is now used widely and thought to be a significant advance in orthopedics. The proper indications are not clear, and a cementless implant should probably not replace the cemented prosthesis. In 1984, we started a prospective multicenter study of a porous coated implant (PCA) in young patients. The purpose of the study is to assess patient function, implant fixation, and bone modeling by careful clinical and radiographic evaluation.

Material and methods: A total of 420 arthroplasties in 387 patients were followed. There were 45 percent men and 55 percent women. The age at surgery was 49 (20–70) years. One hip was replaced in 354 patients and both hips in 33. The preoperative diagnosis was arthrosis (A) 55 percent, secondary A to pediatric disease in 16 percent, arthritis 11 percent, and secondary A to trauma in 8 percent. All the patients have been followed prospectively, longitudinally with yearly clinical and radiographic examinations. Clinical results have been evaluated according to the Harris hip score system, as well as the Charnley-d'Aubigné system. The radiographic examination revealed a high percentage of bone-ingrowth fixated acetabular components, and only 2 percent of the patients showed radiolucent lines. On the femoral side, we estimated 48 percent bone ingrowth fixation of which 3.4 percent showed subsidence between 2 and 5 mm.

Complications: Very few peroperative complications were noted. At 1 year of follow-up, 14 percent of the patients

were complaining of thigh pain; and at 2 years, 3 percent. Two acetabular components and two femoral stems were revised owing to aseptic loosening. No deep infection was recorded in the series.

Conclusions: Cementless porous-coated prostheses are not as effective in relieving pain during the first 1–2 years as cemented devices are. We found a high patient satisfaction and good clinical outcome with this short follow-up. This type of surgery in young patients must still be regarded as experimental and is technically demanding. The multicenter approach has been proven a success and will enable us to answer further questions within a period of 2–3 years.

Parhofer uncemented total hip replacement — A 2–4-year follow-up

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Introduction: The purpose of the study was to evaluate the medium term results of Parhofer uncemented hip replacements, and the value of Tc-scintimetry in detecting loosening of the two components.

Material and methods: Sixty hips (50 patients) were operated on between August 1983 and January 1986. Four patients with six involved hips could not participate in the study. Nine patients had been reoperated on because of symptomatic loosening (nine femoral and two acetabular components were replaced) after a mean of 24 (11–34) months. These patients were included in the radiographic part of the study. The remaining 45 hips (37 patients) were evaluated by clinical examination, radiographs, and scintimetry at follow-up after a mean of 39 (25–51) months. In evaluating the radiographs, the bone-to-metal interface in the AP and lateral projections of the femur were each divided into six equal lengths, and the width of any radiolucent zone in the center of each of these areas was measured by aid of a magnifying glass. In the peroperative radiographs, we noted an absence of medial proximal cortical bone contact and measured the percentage of the contact between the prosthesis and cortical bone. At scintimetry the uptake ratio around the acetabulum, proximal femoral and distal femoral components were compared with the distal femoral diaphysis.

Results and discussion: Ten acetabular components had radiolucent lines of 0.5–1 mm width in one or two zones. Three hips had acetabular protrusion measuring 1.2 mm. With the exception of the acetabular components, which had been revised, none of the patients had symptoms indicating acetabular loosening. The nine revisions of the femoral components were performed in patients with severe thigh pain. Progressive radiolucency was seen in these patients; the mean value for the width of the radiolucency of the 12 zones was 1.0 (0.8–1.5) mm. Six unrevised hips with clinical signs of loosening had a mean radiolucency width of 0.7 (0.3–1.0) mm; the differences were significant ($P < 0.0005$ and $P < 0.05$, respectively). Absence of primary proximal medial cortical contact in the AP view was definitely more pronounced in the revised hips than in the symptomless hips. In the unrevised clinically loose hips, intermediate values were seen. By scintimetry, we found an increased uptake around the distal part of the femoral component in nearly all the hips. There was no correlation of uptake between the width of the radiolucent zones, the initial cortical bone contact or between the absence of primary proximal medial cortical contact. However, a correlation was seen with the presence of thigh pain (13 hips). Scintimetry seems so far to have no value in the evaluation of the loosening in this type of cementless hip replacement. The finding of increased uptake around the distal part of the femoral component 2–4 year after the operation probably indicates remodeling of the bone due to concentrated stress transfer in this region.

Uncemented hemispherical threaded acetabular cup (MEC-ring)

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Since 1984, we have used the uncemented hemispherical threaded acetabular cup (MEC-ring) primarily and when possible in revision arthroplasties.

Totally, 109 arthroplasties in 98 patients were included in the study— 92 primary arthroplasties and 17 revision operations. There were 60 women and 38 men. Central spongious plasty was done in 9 patients and a primary plasty on the roof in 1 patient. The follow-up period ranged from 18 to 40 months. Four complications required reoperation: one Girdlestone procedure because of deep infection and three revisions because of subluxation (1) and luxation (2) due to malposition of the ring. In the last 2 cases, repositioning of the ring was performed.

The Harris hip score increased from an average of 50 preoperatively to 90, 18 months postoperatively

Primary stability of a threaded cementless acetabular prosthesis

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Introduction: To ensure osseointegration of a cementless prosthesis, stable primary fixation is essential (1) We investigated micromovements of a threaded cementless acetabular cup during the postoperative period using roentgen stereophotogrammetric analysis.

Patients and methods: Twenty-four hips were operated on using the Link V-type cementless cup. Peroperatively, 0.8-mm tantalum balls were implanted into the polyethylene component and into the pelvis. Roentgen stereophotogrammetric investigations were performed 1 week, 6 months, and

12 months postoperatively. Fifteen acetabular components were made of chrome-cobalt alloy and nine prostheses of Tilastan®.

Results: Two acetabular components (both made of Tilastan®) showed no significant migration. Twenty-two cups migrated mainly in the cranial and medial directions. The mean proximal displacement was 0.7 (0.3–2.3) mm.

Conclusions: The primary stability of the threaded Link V-type acetabular component is inferior to cemented acetabular prostheses (2). Osseointegration is probably not to be expected in the majority of the cases. Progressive migration over a long time period may indicate increased risk of clinical symptoms and loosening.

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The Endler cementless acetabular prosthesis in hip revision arthroplasty

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Introduction: The Endler cementless acetabular prosthesis is a screw cup with continuous threads and conical shape. It is all made of high-density polyethylene, and has been in clinical use since 1978. We have used the prosthesis since January 1985 and found it suitable, especially in revision. Cementless acetabular revision has several advantages compared with cementing, where adequate interlock is difficult in a smooth bony cavity. The concept polyethylene against bone is controversial. Morscher, in his latest follow-up, reported insufficient stability of his spherical polyethylene socket without threads.

Materials and methods: At the end of 1987, 51 hips had been revised using the Endler cup in 33 women and 18 men, aged 65 (32–87) years. Time from primary operation to revision was 10 years for Müller's prosthesis, 6 years for Christiansen's prosthesis, and 4–5 years for different double cups.

At the revision, 30 patients received a cemented Landos stem prosthesis, 15 received a cementless Zweymüller stem, and in 6 patients only the acetabular prosthesis had to be exchanged. Bone grafting was necessary in 41 hips. In only 26 hips; it was possible to make threads in the bone. In 25 hips the prosthesis was screwed home on the bone grafts. All the patients used crutches for 3 months before full weight bearing was permitted. All the patients have been seen at follow-up at 4 months, 1 year, and yearly since the revision.

Results and discussion: Merle d'Aubigné-Postel's index for pain improved from 2.4 preoperatively to 5.5 at 4 months (46 hips), 5.6 at 1 year (31 hips), and 5.8 at 2 years (11 hips). Gait improved from 2.9 preoperatively to, 4.0 at 4 months, 4.9 at 1 year, and 5.5 at 2 years. The mobility improved from 3.9 preoperatively to 4.3 at 4 months and 4.5 at 1 and 2 years. Radiography confirmed unchanged position of the acetabular prosthesis throughout the period of observation. The bone had condensed around the prosthesis, and new bone formation was noted in 44 of 46 hips at 4 months, and in all (11 hips) at 2 years' follow-up. All the patients felt their hip function improved by the revision. However, 3 patients were not satisfied with the result at 4 months. At 1 year, 2 patients were not satisfied, but at 2 years, all the patients were satisfied with the result of the revision.

Conclusion: Hip revision using the Endler cementless acetabular prosthesis provides good stability, new bone formation around the prosthesis, and a good functional result at follow-up.

Influence of acetabular component position in noncemented total hip arthroplasty: A radiographic and clinical study

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Introduction: It has been frequently observed that noncemented threaded acetabular components appear radiographically to be partially uncovered by acetabular bone. The question has arisen whether this correlates with the clinical outcome. A new radiographic grading for the position of threaded noncemented acetabular components has allowed us to evaluate the relationship between a lack of superolateral cover of the acetabular component and clinical outcome.

Patients and methods: Sixty-three patients operated on with noncemented HP Garches total hip arthroplasties with a follow-up time of 3–5 years were available for radiographic and clinical follow-up. Standard AP and lateral views of postoperative radiographs of each patient were examined and the number of threads of the acetabular component that were not covered with bone was recorded. The patients were categorized in five grades according to the number of uncovered threads. For the clinical assessment, we used Harris' hip score.

Results and discussion: The clinical outcome according to Harris' hip score was excellent in 50 patients, good in 7 patients, and fair in 6 patients. Twenty-eight hips were Grade 0, i.e., all the threads were covered with bone. Thirty-five hips were of Grade 1–4, i.e., one or several threads were not covered with bone. One hip that was Grade 0 required revision owing to mechanical loosening of the acetabular component. There were no significant differences in the hip scores of Grades 3 and 4 in comparison with those of Grades 0, 1, and 2. In no patient, not even in the patient with a loose cup, did we find radiolucent zones exceeding 1 mm in width.

Out of 63 hips, 62 had no evidence of migration or loosening in spite of the fact that several components lacked complete bony coverage.

Conclusion: Although the follow-up time in the present study is short, we conclude that the clinical outcome is not affected if noncemented threaded acetabular components are not completely covered by acetabular bone.

Results of a prospective comparison between a cemented and an uncemented hip prosthesis

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Introduction: Mechanical loosening of cemented hip prostheses has led to the development of different concepts of cementless implantations. However, any new type of hip prosthesis has to stand the comparison with the conventional hip replacement, and the present study was initiated to answer this question.

Material and methods: Patients in the age-group 60–72 years with coxarthrosis treated with the cementless Zweymüller/Endler prosthesis (n 60) and the cemented Landos Titan prosthesis (n 60) entered into this prospective comparative study in the period January 1985 to April 1986. The sex ratio, mean age, and body weight of the two groups were statistically similar. All the prostheses were inserted via the direct lateral approach by the same 9 surgeons.

Results and discussion: The mean operative blood loss was 0.61 and 0.69 liters, respectively (NS). No deep infection occurred. One cemented hip dislocated. All the hips were graded according to the Merle d'Aubigné/Postel numerical rating system. Preoperatively, no difference in the ratings for pain, walking ability, and hip motion was seen. Four months after surgery, the ratings in the uncemented groups were 5.7, 4.6, and 4.2, respectively. The corresponding figures in the cemented group were 5.8, 4.9, and 4.6 ($P < 0.05$). The significantly better functional results in the cemented group became more evident after 1 year and the difference was the same after 2 years. The typical thigh pain reported in patients with uncemented hips was seen in 13 percent of the uncemented cases and in none of the cemented ones 1 year postoperatively. Two years postoperatively, 10 patients in the uncemented group reported thigh pain, while still none in the cemented group reported thigh pain. One uncemented hip had to be revised a few days after the operation because a too small femoral prosthesis had been inserted. No other revision operations were carried out. Radiographically, no signs of prosthetic loosening were seen in either group 2 years after surgery.

We conclude that the clinical results of an uncemented hip prosthesis are inferior to the results of a cemented prosthesis 2 years after implantation.

Total hip replacement (THR) in congenitally dislocated hips

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Introduction: The treatment of persisting dislocation of the hip in adults represents a challenge to orthopedic surgeons. The surgical treatment was formerly restricted to different kinds of osteotomies, cup arthroplasties, or arthrodesis. These procedures may still be of interest. Arthrodesis is, however, frequently refused as an alternative by the patient. Total hip replacement of the dislocated hip is technically difficult due to considerable anatomic alterations. The acetabulum is shallow, and there are varying degrees of shortening and femoral anteversion. The reconstruction of the joint level with the anatomic acetabulum may place stress on nerves and blood vessels. Often it is necessary to perform a shortening osteotomy of the femur and an acetabular plasty with autogenous bone grafting. Extensive tenotomies are required.

Materials and method: From 1974, 49 hips in 39 patients were operated on: 3 males and 36 females. Ten patients had a THR of both hips, 12 of the right hip, and 17 of the left hip. The mean age at surgery was 52 (20–73) years. The mean observation period was 60 (7–140) months. Information was collected by studying clinical and radiographic data, and all the patients recently answered a questionnaire. Indication for surgery was severe pain from the dislocated hip, and the criterion for inclusion in the study was a lack of contact between the anatomic acetabulum and the femoral head. All the patients were operated on in a sterile environment. Prophylactic antibiotics were used in all the noncemented and revision arthroplasties. Antithrombotic prophylactics were administered to all the patients. The anterolateral approach was used in 39 hips, and the posterolateral approach in 10. Acetabular plasty and femoral shortening osteotomy were performed in 23 hips; femoral shortening in 7, and acetabular plasty in 7.

Results: Twenty-nine patients had no hip pain. Eight patients still had slight pain on weight bearing. One patient had severe pain from the hip due to loosening of the prosthesis and is pending revision arthroplasty. Revision arthroplasties have been performed in 11 hips; once in 7, twice in 3, and five times in 1. The last patient had a deep infection. Two revisions were necessitated by luxations due to malposition of the implant. The other revisions were due to loosening. Two patients were revised for ectopic bone formation. Nerve lesions occurred in 5 cases; 3 persisted for more than 21 year after surgery (one femoral and two sciatic nerve lesions). Peroperative femoral fracture occurred in 11 hips; all of them were immediately stabilized with cerclage or the Partridge device. No deep venous thrombosis was recorded.

Conclusion: Twenty-nine out of 39 patients with persisting hip dislocation were relieved from pain after THR. Eight patients still had slight pain on weight bearing. Even if the surgery is technically difficult and the rate of complications is considerable, THR may be indicated in selected cases.

Total hip arthroplasty in congenital dislocation of the hip: A minimum follow-up of 5 years

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Introduction: Reconstruction with total hip arthroplasty in

adults with a congenital and complete dislocation of the hip offers special considerations due to leg shortening, dysplasia of the acetabulum, and a narrow femoral shaft, as well as muscle weakness or pelvic imbalance. Acetabular bone grafting and special prostheses are often required. Long-term results are sparsely reported.

Patients: Twenty-one hips in 17 patients, all women, were subjected to THA due to sequelae after complete hip dislocation of ≥100 percent, according to Crowe. –The patients were examined after 7.5 (5–11) years at an age of 54 (29–83) years, by one of the authors not involved in the primary operations.

Results: At follow-up the classification of function according to Charnley-Merle d'Aubigné-Postel was pain 6, walking capacity 4, movement 5, and according to Harris 82. Totally, 10/17 patients younger than 65 were employed in professions. 7 had a positive Trendelenburg, and all but 2 had a leg difference of less than 3 cm. Revisions had been carried out in 7 patients with loosening of five sockets and three stems, of whom all but 1 with a Christiansen prosthesis had their primary operation in the 1970s. Fourteen patients had acetabular bone grafts. Nineteen patients declared themselves prepared to undergo the operation and the postoperative time period once more in order to achieve their present status of function. The median value of the patients' subjective classification (visual analogue scale) was 93 out of a maximum of 100 (range 0–100).

Summary: Late results of total hip arthroplasties in complete CDH are inferior to those in arthrosis in older patients. However, so far the majority of the patients are satisfied with the functional results. Some of the revisions reflect deficiencies of the early cementing technique and hopefully future results will improve.

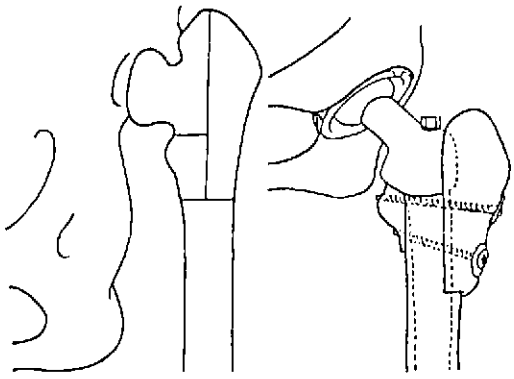
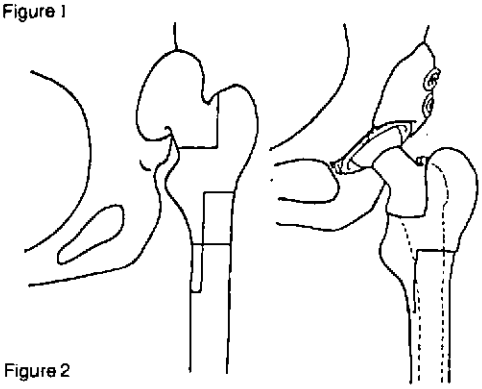


Figure 1



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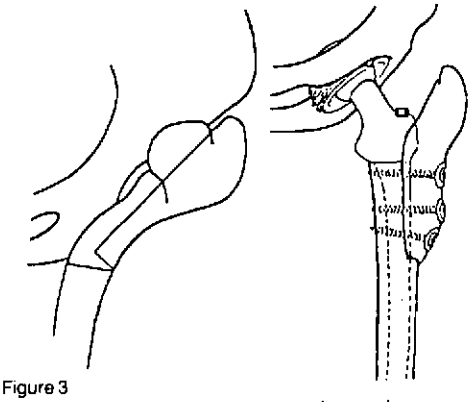

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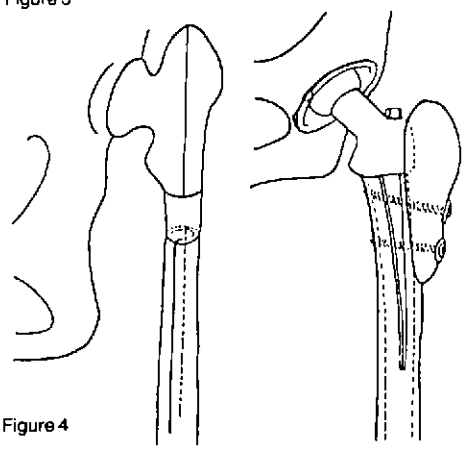

Figure 4

Total hip replacement of severely dysplastic or dislocated hips

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In the total hip replacement of 100 hips (85 patients) with secondary arthrosis, cementless endoprosthesis (Lord) was used. Osteotomy of the femur was necessary in 46 hips (40 patients, mean age 50 (22–78) years. Thirty-six out of these 46 hips were totally dislocated, and the others were severely deformed. Because of the hypoplastic cotyloid part of the pelvic bone, the acetabular ring was placed lower than the normal acetabulum in 20 hips (Figure 3). In 15 hips the deficient roof was reinforced with a bone graft (Figure 2). Corrective osteotomies of the femur were performed according to Figures 1–3 (Figure 1, 26 hips; Figure 2, 15 hips; Figure 3, 5 hips). In addition, because of a small diameter of the proximal femur, the diaphysis was split longitudinally in 7 cases (Figure 4). Leg length inequality was corrected 1–4 cm, and in

cases with adduction contracture even more. One traumatic fracture-dislocation of the acetabular rim, two aseptic loosenings of the acetabular component, one nonunion of the osteotomy line, and one dislocation because of malalignment of the components required reoperation. The osteotomy consolidated in all but 1 case. The ability to walk and to perform daily activities was improved. The preoperative disabling pain was abolished or essentially relieved. The Trendelenburg sign was preoperatively negative in 6 cases, whereas postoperatively it was positive in only 5 cases. All the patients without the above-mentioned complications were satisfied with the result. In all but 3 cases, active foot care was possible. Prosthetic reconstruction of dysplastic and dislocated hips can be performed provided that the quality of bone is satisfactory. Due to technical advantages, certain new prosthetic models have replaced Lord prosthesis in our hospital.

Total hip replacement following intertrochanteric osteotomy

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Introduction: The aim of this study was to assess the significance of intertrochanteric displacement osteotomy on the outcome of subsequent total hip replacement.

Material and methods: Totally, 108 consecutive total hip replacements performed for the failures of previous intertrochanteric osteotomy were clinically and radiographically evaluated on an average 5 years after surgery. The mean time between osteotomy and THR was 6 years. The hip prostheses used were Müller (n 55) and Lubinus (n 53). The patients were categorized into two groups according to the amount of displacement at osteotomy. Each group included 54 patients. The mean displacement index (the amount of displacement divided by the diameter of the diaphysis) was 6 (0–9) percent in Group I and 21 (10–53) percent in Group II.

Results: Postoperative hip mobility and pain ratings were significantly more favorable in Group I than in Group II. A positive correlation between the displacement index and radiographic loosening was found. Five out of six THRs complicated by peroperative fractures belonged to Group II. One revision arthroplasty was performed, but no infection was encountered.

Conclusions: Our results indicate that the amount of osteotomy displacement is correlated with peroperative complications, radiographic loosening, and unsatisfactory outcome of subsequent total hip replacement. Consequently, simple intertrochanteric osteotomy without displacement should be preferred.

Revision hip arthroplasty with Mathy's cementless total endoprosthesis

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In revision arthroplasty the main problem is the lack of bone in both the femur and the acetabulum. Our revision arthroplasty material consists of 72 rearthroplasties with Mathy's prosthesis. The longest follow-up time was 4 years.

With the femoral stem, further problems after revision arthroplasty have been rare, even in cases where the femur has been broken. Peroperative fractures occurred incidentally; they were easily repaired with cerclages and transplantations of bone. In fractures at the level of the tip of an ordinary prosthesis, the long revision prosthesis serves as a medullary fixation device. Also, because the prosthesis is soft, fixation with a plate and screws is possible. Only rarely have we performed a two-stage operation with a medullary nail and a later prosthesis insertion. On the acetabular side, we have used a titanium or steel ring or an original Mathy's polyethylene cup. Autologous bone transplantation has been performed regularly.

Mathy's revision prosthesis is one option in this demanding field of THR surgery. Technically, it is proper in cases where the architecture of the femur is preserved and the acetabular ring is intact. Its benefits are gentleness to the bone, versatility in different situations, and regenerating effect on the bone due to its elasticity.

Total hip replacement of fused hips

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Introduction: Arthrodesis was formerly a common treatment for arthrosis of the hip. In most cases the result was good with reference to pain and function. Some patients, however, may develop serious low back pain, a few also complain of persisting hip and knee pain, and some have problems in daily life activities due to the fused hip. For these reasons, total hip replacement (THR) of the fused hip in some cases may be indicated.

Patients and methods: Forty-one patients, 8 males and 33 females, have been operated on. The mean age at arthrodesis was 44 years, and the mean time span from arthrodesis to rearticulation was 16 (7-46) years.

The primary diagnosis was congenital dislocation of the hip in 27 of the cases, primary arthrosis in 9, and fracture of the femoral neck in 3. Three patients were dead, and 2 were excluded from the study because of cerebrovascular disease. Thirty-seven patients were reviewed retrospectively by studying clinical and radiographic data. These patients have re-

cently answered a questionnaire. Low back pan was the sole indication for rearticulation in 17 cases, and hip pain was an additional indication in 8. Five were operated on because of hip pain only, 5 due to intolerable problems in daily life activities and 2 because of fractures of the fused hip. In 35 hips the fusion was sound, and in 2 there was pseudarthrosis. All were operated on in a sterile environment. Prophylactic antibiotics were not used in the primary THR. Antithrombotic agents were used in all the operations.

Results: In 30 patients the results were excellent or good with reference to the preoperative complaints, in 8 patients fair, while 3 patients still had severe, persisting symptoms, either from the lower back or the hip. Two patients underwent revision arthroplasty because of loosening of the implant and 1 is pending revision arthroplasty. One patient has been operated on for a femoral fracture below the prosthesis. Three have been revised for ectopic bone formation. Luxation of the prosthesis occurred in 4 cases, 1 was reduced by surgery, and in 1 the luxation necessitated a revision arthroplasty due to malposition of the implant. One patient has paresis due to peroperative damage to the sciatic nerve. There has been one deep venous thrombosis. No deep infections were recorded.

Conclusions: Thirty out of 37 patients with fused hips converted to THR had an excellent or good result with reference to low back pain, hip pain, and disability in daily life activities. Conversion of fused hips may be indicated in selected cases.

Total hip replacement with Müller acetabular support rings

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Bone deficiency in the acetabulum often implies difficulties at revision total hip arthroplasty. Considerable acetabular protrusion or dysplasia can also render primary hip arthroplasty more difficult. Wire meshes, Eichler rings, and screw-fixated bone grafts have been used to reinforce the acetabulum. These techniques, however, have sometimes been insufficient for optimal position and fixation of the acetabular component. Müller rings, which are screw-fixated, give a reinforcement of the roof of the acetabulum, as well as of the medial wall.

Fifty-five Müller rings have been used in 52 patients — 23 males and 29 females. Their mean age was 54 (22–88) years. Seventeen of the arthroplasties were primary operations and 38 were revisions. The main indications for a Müller ring were protrusion of the acetabulum at primary operations and a very large acetabular cavity or defect in the medial wall at revisions. At 33 operations the Müller ring was combined with a bone graft.

There were no complications related to the support rings. The mean time for follow-up was 30 (24–60) months. No loosening of acetabular components has been noted. Most patients have become totally or almost free of pain and their walking ability has improved considerably. Thus, the results are equivalent to what nowadays can be achieved after conventional total hip replacements.

The Müller support rings facilitate an optimal position of the acetabular components in cases of protrusion and dysplasia of the acetabulum. The rings also yield an excellent reinforcement in cases of bone defects in the acetabulum. The rings seem to provide firm anchorage for cement and to be a form of metal backing, and may reduce the risks of late loosening.

Aseptic failure in revision hip replacement

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The incidence of aseptic failure in revision total hip replacement was studied. Because operative technique is considered very important, we reviewed only the operations performed by senior orthopedic surgeons, all of whom were using the same technique. A minimum follow-up of 5 years was chosen.

Operation: Infection was ruled out by preoperative aspiration and deep cultures taken at operation. The operation was performed by the anterolateral approach and a trochanteric osteotomy. The bone stock was judged; and any deficiency was grafted, both on the acetabular and the femoral sides, making use of autogenous iliac crest grafts. On the acetabular side the sclerotic bone, if present, was left intact. Cancellous bone impacted with a punch in 8–10-mm drill holes, and acetabular roof plasty whenever acetabular coverage is insufficient are two important technical points. If necessary, an acetabular reinforcement ring was used. Cementing techniques were standardized; for the acetabulum this technique has been the same for the last 12 years; on the femoral side, pressurization was improved in 1980 by the use of a polyethylene femoral plug. Refixation of the trochanter was obtained by one or two lag screws with or without cerclage wires.

Results

Clinical follow-up: Ninety-three patients with 103 operated on hips fulfilled the above-mentioned criteria; 15 had died and 5 were lost to follow-up. A complete clinical and radiographic follow-up was possible in 73 patients with 80 hips. Follow-up averaged 9 years. At follow-up there had been three infections (one early, two late) and six hips had been re-revised. The Harris Hip Score averaged 78 points in the total material, and 80 when the infected and re-revised hips were excluded.

Complications: There was only one dislocation, which occurred in the first postoperative week, and it was treated by closed reduction. There were four trochanteric nonunions, two of which were reoperated on. There were no stem fractures.

Radiographic follow-up: On the femoral side 11 percent radiolucent lines of 50–99 percent of the prosthetic circum-

ference were seen: 10 percent had 100 percent radiolucent lines and 12 percent had subsided or tilted. Progressive radiolucent lines were seen in 7 percent only. The acetabular side was divided into three zones as described by DeLee and Charnley. Twenty-six percent had radiolucent lines in zone I, 22 percent in zone III, and 16 percent in zone II. There were complete radiolucencies (all three zones) in 10 percent, whereas migration of the cup was seen in only one hip. None of the acetabular radiolucencies was progressive. Brooker grade 3 or 4 ectopic bone formation was seen in only two hips.

The following items were shown to be correlated with the clinical and/or radiographic results: weight of the patient, length/weight ratio, number of previous operations, use of a femoral plug, ceramic versus metal head, the surgeon. No relationship was found as regards sex or age.

We concluded that revision arthroplasty can lead to results comparable to primary total hip replacement when performed by experienced surgeons using standardized techniques.

Revision arthroplasty of the hip: A follow-up of 100 consecutive cases

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Inferior prosthetic design and cementing technique during the 1970s caused a number of prosthetic failures necessitating revision arthroplasty. This is a report on 100 consecutive total hip revision arthroplasties.

Material and methods: A total of 100 consecutive hip revision arthroplasties in 98 patients were followed for 59 ±28 (SD) months. Age at the primary hip replacement ranged between 19 and 80 years, mean 62 ±11 years, the diagnoses were mainly degenerative arthrosis (71 percent) and fracture of the femoral neck (19 percent). The most common prostheses revised were Charnley-Müller (53 percent) and Wagner surface replacement (15 percent). The mean survival time of the first prosthesis was 56 ±35 months. The prostheses used in the revision procedure were Harris calcar replacement (33 percent) and HD2 (31 percent). Gentamicin cement and i.v. antibiotics were used. Cultures were obtained before antibiotics were given. Thirteen patients died of causes unrelated to the hip surgery 12–94 months after the revision.

Radiographically, loosening of the primary femoral component was mainly between bone and cement in 38 percent, scalloping was seen in 7 percent, and cement fracture was the most important factor in 28 percent. Four cases had fractured stems. The primary acetabular component had a significant radiolucent zone in 45 percent, in 15 percent it had migrated, and in 5 percent the component had tilted.

Results

Bacteriologic findings: Two or more separate cultures obtained at revision surgery grew identical organisms in 27 percent of the operations. *Staphylococcus epidermidis* was cultured in 13, *Propionibacterium acnes* in 9, *Staphylococcus aureus* in 4, and α- *Streptococcus* in 1 case. One *S. aureus* and the α- *Streptococcus* case persisted and ended in a Girdlestone procedure 6 and 35 months after the revision. One case with *Staphylococcus epidermidis* growth was revised a second time after 80 months.

Clinical findings: At follow-up 74 percent of the hips reported no or only slight pain (Charnley-d'Aubigné score 6 and 5); 93 percent had a total ROM exceeding 100 (Charnley-d'Aubigné score 4–6); two thirds of the patients depended on a cane or crutch when walking.

Radiographic findings: Totally, 5 cases were revised a second time. Two were treated with a Girdlestone procedure, both because of infection. Loosening of one femoral and one acetabular component resulted in a second revision in each case (80 and 76 months postoperatively). One case of revision where a Wagner prosthesis had been used was converted to an uncemented PCA prosthesis 60 months after revision.

Conclusions: Although the results are not as good as with current primary hip replacement, revision total hip surgery is a safe and generally satisfactory alternative. Infection with *Staphylococcus epidermidis* and *Propionibacterium acnes* does not seem to alter the outcome.

Revision total hip arthroplasty in patients between the ages of 55 and 70 years: A minimum 5-year follow-up

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Introduction: The incidence of both primary and revision hip arthroplasty has increased dramatically. Mechanical failure has emerged as the most significant long-term problem. The results of revision hip surgery in young patients have been poor, with high failure rates, because of aseptic loosening. The purpose of this study was to analyze the results of first-time revision arthroplasties in patients between the ages of 55 and 70 years.

Materials and methods: Since 1979, all reoperations performed in Sweden after total hip arthroplasty have been registered in a prospective multicenter study. All the 73 orthopedic and surgical departments performing total hip arthroplasties have joined the study. Between 1979 and 1981, 254 nonrheumatoid patients between the ages of 55 and 70 years (average 64 years) required revision arthroplasty because of aseptic loosening. At the time of follow-up, 42 patients had died and 2 patients were excluded for other reasons. Thus, 210 patients with 212 revised hips were available for analysis of the results a minimum of 5 years after revision. Clinical follow-up data were obtained from a questionnaire sent to the patients. The radiographic results of the revisions were evaluated by comparing the postoperative radiographs with those taken at 1 year and at the time of the follow-up evaluation.

Results: Fourteen percent (30 hips) of the hips included in the study (n 212) had required a second revision or more. To date, 144 hips have been analyzed radiographically. Nineteen hips had required at least a second revision. Twenty-one fe-

moral and four acetabular components in 25 patients had signs of gross loosening. Thirty hips were characterized to be "at risk," with radiographic signs indicating a risk of loosening in the future. Failure, defined as gross loosening or a second revision, was identified in 31 percent (44/144).

Conclusions: In this preliminary report, only about three fourths of the material has been reviewed. However, there are good reasons for us to expect the trend, with a high failure rate, to be the same in the remaining hips to be analyzed. With the increased use of modern cementing techniques and alternative methods, such as cementless and hybrid techniques, the results of revision hip surgery may show improvement. In the future the effect of new solutions for this problem has to be evaluated further.

Survivorship analysis of revision total hip replacement

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The failure pattern of 306 first-time, cemented revision total hip replacements (Re-THR), performed from January 1977 to January 1987, was analyzed and described using survivorship analysis. Failure was defined as removal/exchange of one or both components. By January 1987, the fate of all the prostheses were known. In all, 55 had failed. Discrete failure-time model (logistic type) was used in the analysis of failure. Backward variable selection strategies combined with exact evaluation of P-values were applied for determining factors of importance for failure. Additional survival curves were constructed using standard Kaplan-Meier techniques and tests illustrating the effect of risk factors determined by the procedures described above.

Overall survivorship (i.e., any cause of failure) was compared to existing survivorship analyses of primary total hip replacement (Pr-THR). Survival of the revised acetabular component and femoral component with regard to aseptic loosening was analyzed separately. Overall survival of different types of revision prostheses used were compared. In the overall series, sex, age, time from primary operation to revision, type of primary prosthesis, type of revision and complications were tested as risk factors. Intraoperative fracture of the femoral shaft was tested separately as a risk factor for aseptic loosening of the femoral component.

Results

1. Overall survival of prostheses after Re-THR is inferior to overall survival after Pr-THR.
2. Survival curves, with regard to aseptic loosening, constructed separately for the acetabular and the femoral component both showed late and almost simultaneous decline; however, with a tendency towards a higher rate of failure for the femoral component.
3. There was no difference in overall survival between Stanmore, Lubinus Standard (short stem), and Lubinus Special (long stem) prostheses, but there was a significantly higher rate of failure in the remaining group, where miscellaneous types of revision prostheses were used.
4. In the overall series, only intraoperative and postoperative complications could be identified as risk factors.
5. Intraoperative fracture of the femoral shaft could not be identified as a risk factor for aseptic loosening of the femoral stem.

Results of Girdlestone arthroplasty after failed total hip replacement

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Introduction: The Girdlestone situation is nowadays created when the insertion of a new hip prosthesis, after deep infection or aseptic loosening, is not possible. Because revision surgery is becoming more demanding and the results in the literature are extremely variable, we did a clinical follow-up study of our own patients.

Patients and methods: Forty patients with a unilateral Girdlestone situation after excision of a total hip replacement were evaluated. There were 12 males and 28 females, with an age of 61 (26–80) years; the follow-up was at least 1 year.

The indication for removal of the prosthesis was infection in 23 and aseptic loosening in 17 cases. The patients had their hip operated on 3–15 (mean 5) times.

Results and discussion: The results were judged on the two criteria used by Hamblen (1984): the elimination of infection and the quality of the residual function in the hip. The pain, mobility, and walking support scored good in 15 patients, moderate in 18, and poor in 7 patients. The reason for not implanting a new prosthesis was in 7 cases poor general condition, in 20 cases severe loss of bone stock or other technical reasons, and in 13 cases the risk of recurrent infection. All the patients had a Trendelenburg gait and needed their shoe raised 4.5 (1.5–9) cm. Although most of the patients felt disabled, 25/40 were satisfied with the Girdlestone arthroplasty.

The radiographic results of revision of total hip replacement for aseptic loosening

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Aseptic loosening of total hip arthroplasty (THA) may result from biomechanical failure or formation of foreign body granulomas. Although the majority of patients that have undergone a revision arthroplasty do well, the high incidence of radiographic loosening is of serious concern. The purpose of this study was to examine the radiographic condition after revision arthroplasty of the hip joint.

Of 653 initial total hip arthroplasties performed at our hos-

pital between 1972 and 1986, 22 had been revised since 1975 for aseptic loosening. The mean interval between the initial operation and the revision arthroplasty was 5.7 years, and the follow-up after revision operation was 2.3 (0.8–5.3) years. The primary THA was performed for arthrosis in 14 hips, rheumatoid arthritis in 4, congenital dislocation in 2, and fracture in 2.

The radiographic assessment was accomplished by the Mayo hip score. The mean radiographic score was 8.3 points before revision and 14.7 points after revision. Seventeen hips received more than 14 points.

Although other investigators have reported disappointing results after revision arthroplasty, we found only two hips that were assessed as poor. We conclude that revision arthroplasty usually gives good results.

Quality of revision total hip replacement versus primary total hip replacement

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Recent follow-up studies after revision total hip replacement (Re-THR) concluded that the initial results are potentially as good as those after primary total hip replacement (Pr-THR), but a higher incidence of complications and of late mechanical loosening reduce the final results. This suggests the hypothesis that the quality of results after *uncomplicated, non-loosened* Re-THR is equal to that after Pr-THR. To validate this hypothesis, we compared, in a prospective study, the results regarding pain and function of a series of Re-THRs with results of a comparable series of Pr-THRs at a time postoperatively when maximum clinical improvement is supposed to be achieved, but where a significant difference in incidence of mechanical loosening has not developed yet.

In the Pr-THR series there were 100 patients, 74 females and 26 males, aged 64 (26–87) years; and in the Re-THR series,there were 50 patients, 37 females and 13 males, aged 64 (20–86) years. The two series were evaluated and compared regarding pain (actual pain and pain relief) and function (walking ability, personal function, and social function) preoperatively and 1 year after the operation. Relations between variables were analyzed.

Results: A higher incidence of intraoperative and postoperative complications and of coexisting disabling conditions were found in the Re-THR series, but because the statistical analysis showed that neither pain nor functional outcome were influenced by these factors, the two series were considered comparable. Analyses of relations between variables were used to determine which items alone would describe the clinical outcome most precisely. Pain was found to be only slightly related to function, and walking distance was found to be the central function variable. Based on these analyses, pain and walking distance were chosen for comparing the clinical results in the two series.

For both variables the results were significantly better for Pr-THR than for Re-THR (pain, $P = 0.015$; walking distance, $P = 0.005$)

Conclusions: Substantial improvement can be achieved after revision arthroplasty of the hip, but even if the major problems of intraoperative and postoperative complications and the higher rate of mechanical failure are eliminated, results equal to those after primary total hip replacement cannot be expected after revision total hip replacement.

Clinical results after revision total hip replacement and primary total hip replacement

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In this follow-up study, we compared clinical results after revision total hip replacement (Re-THR) with those after primary total hip replacement (Pr-THR).

Pr-THR series: Totally,184 operations were performed. At follow-up 22 patients had died, 11 had been reoperated on, and 6 were lost to follow-up, leaving 145 patients for evaluation. The mean age was 67 (25–86) years, and there were 101 females and 44 males. The follow-up time was 4 (3–5) years.

Re-THR series: Totally, 233 operations were performed. At follow-up 38 patients had died and 54 had been reoperated on, leaving 141 patients for evaluation. The mean age was 67 (22–86) years, and were 97 females and 44 males. The follow-up time was 4 (2–10) years.

Pain was measured on a semiqualitative graded scale, and for evaluation of function a Functional Outcome Scale was constructed. Relations between variables were analyzed in both series, and risk factors influencing clinical outcome were identified. This procedure makes it possible to eliminate the potential bias caused by differences between the two series in variables influencing outcome when comparing results. Validity testing of the Functional Outcome Scale was done through analysis based on the so-called Rasch Model.

Results

Complications: The incidence of intraoperative and postoperative complications (fracture of the femoral shaft and postoperative dislocation) was higher in the Re-THR series, but did not influence the clinical outcome.

Pain: There was no difference between the two series.

Function: The Functional Outcome Scale was found to be a useful and valid scoring system. For patients *without* coexisting disabling conditions, there was no difference in functional outcome between the two series; but for patients *with* such conditions, functional outcome was significantly inferior in the Re-THR series (chi square, $P = 0.002$; gamma test, $P < 0.0005$).

Conclusion: Except for functional outcome for patients with coexisting disabling conditions, the quality of Re-THR is potentially as good as that of Pr-THR, but overall results are worse due to a high incidence of complications and a high rate of failure (i.e., reoperation).

Banking bone in reconstructive surgery of the hip

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Introduction: Severe bone deficiency associated with failed total hip arthroplasty is an increasing clinical problem. The deficiencies created by loose implants and wear particles provide a surgical challenge, since neglecting deficient bone stock in hip revision surgery may further compromise the remaining bone. Additionally, resection arthroplasty in conjunction with severe bone loss may produce excessive instability and poor functional results. Banking bone provides a valuable tool in this context (1), although long-term results remain to be settled. The aim of this study was to assess the clinical and radiographic results of prospectively registered allografts used as an adjunct in total hip arthroplasty.

Materials and methods: From 1981 through 1987, 29 patients, mean age 62 years, required total hip arthroplasty supplemented by 33 allografts for severe acetabular and femoral deficiencies. The most frequent primary diagnoses were A (15 patients) and RA (6 patients). Average follow-up from primary arthroplasty in revision (25 patients) was 7 years. Mechanical loosening was the main cause for revision (21 of 25 patients). In 5 patients, bone grafting was used in the second total hip revision. Donor selection conformed to the guidelines recommended by the American Association of Tissue Banks (2). Femoral heads or pieces of cancellous bone from patients having primary total hip or knee replacements were stored in glass jars with screw-on tops and frozen at –20 °C. Prior to use, the specimens were thawed in penicillin–saline solution. The allografts were used for central acetabular defects (17 patients), acetabular shelves (2 patients), calcar deficiency (3 patients), trochanteric osteotomies (8 patients), and in the subtrochanteric region (4 patients) with cemented Thackray revision components. The recipient bone bed was freed from fibrous tissue and fenestrated at multiple sites to promote vascular ingrowth in the graft. Only partial weight bearing was allowed 3 months postoperatively.

Results: At follow-up, average 1.7 years posttransplantation, the pain score according to Merle D'Aubigné averaged 4.8. Two acetabular components had migrated necessitating reoperation in 1 case after 1 year. Graft incorporation was then noticed beneath the cement. In another case, resorption of the bone graft at a trochanteric osteotomy was found. In the remaining 26 cases, no radiolucency or signs of graft resorption were seen. No septic complications were noted.

Conclusion: On the basis of this short-term follow-up, the results have demonstrated adequate initial mechanical stability by cancellous bone allografts in cemented reconstructions. The vitality of grafted areas is yet to be determined by 3-D bone scintimetry.

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Total hip replacement combined with bone grafting for acetabular protrusion

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Introduction: A variety of surgical techniques have been described to restore the lack of bone support in acetabular protrusion secondary to disease or a failed arthroplasty. The acetabuloplasty encompassed reinforcement of the medial wall with bone grafts, vitallium mesh, bone cement, and a polyethylene cup.

Material and methods: From 1979 through 1985, 155 hips (145 patients) had a total hip replacement and bone grafting for acetabular protrusion secondary to arthrosis (108 hips), rheumatoid arthritis (38 hips), and trauma (9 hips). Seventy-four of these arthroplasties were primary procedures and 81 were secondary to failure of previous arthroplasties (64 total hip replacements, 14 surface replacements, and 3 hemiarthroplasties). There were 34 males and 111 females. Ten patients had bilateral operations. The age range was 22–89 years. The indications for surgery were pain, progressive functional disability, and radiographic evidence of progressive destruction of bone stock. The presence of infection was excluded. All the patients were followed up by routine examination and with serial radiographs in three views in order to evaluate the incorporation of the graft and the fixation of the acetabular component. Additionally, 14 patients were examined scintigraphically to establish the viability of the graft.

Result and discussion: Three years' follow-up study of 145 patients with a cemented total hip replacement combined with a bone graft showed radiographically 2 patients with symptoms of progressive Grade 3 demarcation. Nonprogressive radiolucent lines were assessed in 11 patients. Clinical evaluation showed no signs of loosening. In all but 2 patients, the graft seemed to be incorporated securely scintigraphically; the scans showed a uniformly elevated uptake of the isotopes.

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Homologous bone grafting in revision hip arthroplasty for acetabular protrusion

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Introduction: In primary hip arthroplasties the autologous femoral head can be used for reconstruction procedures; however, in revision arthroplasties the femoral head is not available for bone grafting. To get autologous bone grafts in these cases, the operation has to be extended by taking grafts from the iliac bones. However, this has many disadvantages, such as longer operation time, more bleeding, and longer postoperative rehabilitation time. But the greatest disadvantage of the iliac bone grafts in these elderly patients is their poor quality. Therefore, in our hospital, we have chosen deep–frozen homologous bone from our bone bank.

Patients and methods: In 23 revision hip arthroplasties, in which acetabular protrusion was encountered, homologous bone grafting was used to reconstruct or reinforce the medial wall of the acetabulum. Loosening of the acetabular component was the cause of the protrusion in all the cases. In some patients, also the lateral wall of the acetabulum was resorbed, and the same deep–frozen homologous bone was used to rebuild the lateral ridge of the acetabulum. In 19 patients a metal ring was placed not only to keep the bone grafts in place, but also to improve local stress conditions (1).

Results: Postoperative follow–up at a mean of 4.5 (3–6) years showed a solid bone socket around the acetabular cup in all the cases and no signs of clinical loosening. No infections or immunoreactions were seen. The Harris hip score at follow–up was significantly better than preoperatively.

Conclusion: Deeply frozen homologous bone grafting offers great opportunities in the reconstruction of the acetabulum wall in revision arthroplasty.

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Indomethacin as a prophylactic and a therapeutic agent against heterotopic ossifications following total hip replacement

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Introduction: The formation of heterotopic ossification (HO) following total hip replacement may compromise the result of even the most well–performed surgical procedures by causing increased pain, decreased mobility, and in severe cases eventually complete ankylosis (1)

To date, several prophylactic and therapeutic agents and methods have been described: EHDP, radiotherapy, fat–tissue transplantation, and Indomethacin are the most important.

Material and methods: A group of 24 patients with resection of HO following 25 total hip replacements were treated with Indomethacin. HO on preoperative and postoperative serial radiographs was classified according to Brooker et al. (1). Subsequently, a group of 100 patients were studied with high risk features following 110 total hip replacements and Indomethacin prophylaxis.

Results and discussion: In the group of 24 patients, 17 hips did not show any recurrence of resected bone at 1 year postoperatively. In eight hips a moderate, incomplete recurrence could be observed.

In the second group of 100 patients, only one HO, which was class I radiographically at 1 year postoperatively, was observed. Subsequently, the effect of Indomethacin and EHDP was studies on trauma–induced HO using the experimental model according to Michelsson et al. (2), presumably simulating clinical conditions to a greater extent than the bone-induction model according to Urist.

Control animals showed occurrence of HO consistently, whereas Indomethacin completely inhibited HO at radiographic analysis. EHDP inhibited formation of HO, but after discontinuation a delayed occurrence of HO was noted. The effect of Indomethacin may be explained by its anti-inflammatory properties, interfering with the reaction to trauma and sequential stages of bone differentiation as outlined by Reddi (3).

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Heterotopic bone formation following noncemented porous-coated total hip replacement

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The aim of the present investigation was to study the incidence of HBF following noncemented, porous-coated THR in patients with and without postoperative treatment with anti-inflammatory drugs.

Patients and methods: Totally, 64 noncemented porous-coated THRs in 58 patients aged 50 (18–76) years were evaluated 1 year after surgery. HBF and radiolucency were evaluated on AP radiographs of the hips.

Results and discussion: Thirty-one hips in patients without anti-inflammatory treatment developed ossifications. In four hips a severe ossification was recorded. Patients treated with anti-inflammatory drugs during the first postoperative weeks developed significantly fewer ossifications (two thirds), and only one hip had a severe ossification. Eleven hips, three in patients treated with anti-inflammatory drugs, had a radiolucency at the implant-bone interface of 1 mm or more in width in one or more of the acetabular and/or femoral zones. Two patients had a clinicallly and radiographically loose femoral component. None of them were treated with anti-inflammatory drugs.

HBF is as frequent after noncemented porous-coated THR as after cemented THR. Bone cement does not play any role as an inductive substance of HBF after THR. Anti-inflammatory treatment during the first postoperative weeks significantly reduced the incidence of HBF after noncemented, porous-coated THR, but was without influence on the development of early radiolucencies and early loosening.

The incidence of heterotopic bone formation after total hip replacement in patients without postoperative treatment with a nonsteroidal anti-inflammatory drug

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Introduction: The incidence of heterotopic bone formation (HBF) after total hip replacement (THR) varies considerably. The methods used to evaluate hip radiographs may account for part of this. However, because nonsteroidal anti-inflammatory drugs (NSAIDs) are known as potent inhibitors of HBF, postoperative treatment with these drugs may be a major reason for the large variation in the incidence.

Patients and methods. In 99 patients undergoing cemented Lubinus THR, no anti-inflammatory treatment was given during the first 6 postoperative weeks. A control group of 102 cemented Lubinus THRs had 25-mg indomethacin three times daily for the first 6 postoperative weeks. One year after the replacement, radiographs of the hips were evaluated to determine the degree of HBF.

Results and discussion. The distribution of the different degrees of HBF in patients with and without NSAID treatment is shown in Table I. Indomethacin significantly inhibited the postoperative development of HBF after THR ($P <$ 0.0005). The present observation may explain why reports of HBF following THR demonstrate a large variation in the incidence of HBF. Presentations of HBF following THR should include information on the extent of treatment with NSAIDs in the immediate postoperative period.

Table 1. Degree of HBF in patients with and without NSAID prophylaxis

	Degree of HBF					
NSAID	0	I	II	III	I–III	Total
With	89	13	0	0	13	102
Without	27	24	30	18	72	99

Muscle strength and mobility of the hip: Effects of heterotopic bone formation after joint replacement

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Introduction: Heterotopic bone (HB) after total hip replacement (THR) appears to be preventable by measures, such as administration of NSAIDs or low-dose radiation. To justify general prophylaxis, it is important to identify the effects of HB on hip function after THR and especially on hip mobility and muscle strength.

Materials and patients: Totally, 145 consecutive cases of THRs were studied prospectively. Hip range of motion and degree of pain were recorded preoperatively, 6 and 12 months postoperatively. Muscle strength was determined 1.8–2.9 years after joint replacement using a Cybex II dynamometer. Flexion and extension torque was recorded at 45°/s, and abduction strength was tested isometrically at 15° of abduction. The amount of HB seen on radiographs at 2 and 12 months was estimated according to Brooker et al. (1) and in addition measured by planimetry.

Results: Seventy-five percent of the operations led to HB and in 21 percent significant amounts developed (Brooker classes III–IV). Large amounts of HB decreased hip mobility significantly in comparison with the preoperative state (Table 1), whereas hips with smaller amounts (Brooker classes I–II) gained mobility, although not as much as hips with no HB (NS). In men, flexion strength was greater in patients with heterotopic bone, while the strength in abduction 15° seemed to be smaller (Table 2). Similar, but less pronounced, differences were found in women. In men with unilateral hip dis-

Table 1. Pre- and postoperative range of hip motion (mean ± SEM) in relation to HB.

	Flexion-extension	Abduction-adduction	Rotation
Preop No HB	67 ± 4	20 ± 3	12 ± 2
1 year postop	95 ± 2	45 ± 3	39 ± 3
Preop Brooker I–II	72 ± 3	23 ± 2	10 ± 1
1 year postop	90 ± 2	40 ± 1	33 ± 1
Preop Brooker III	76 ± 7	17 ± 3	6 ± 2
1 year postop	79 ± 4**	34 ± 3**	21 ± 1**

** Significantly ($P < 0.01$) smaller than the postopeative findings in the other groups. One-way analysis of variance.

Table 2. Muscle strength (mean ± SEM, Nm) of the operated hip in men with and without HB

	Flexion	Extension	Abduction 15°
No HB	59.3 ± 7.3	105.7 ± 14.9	27.5 ± 3.2
HB	74.9 ± 3.5*	119.4 ± 5.0	21.8 ± 1.5

$P < 0.05$ Student's t-test.

Table 3. Muscle strength (mean ± SEM, Nm) of the non-operated hip in relation to HB after THR among men with unilateral hip disease

	Flexion	Extension	Abduction 15°
No HB	59.5 ± 13.0	99.6 ± 24.1	29.7 ± 7.0
HB	84.4 ± 5.1*	142.3 ± 9.8*	24.9 ± 3.3

ease, we found the nonoperated on hip to be stronger among patients who developed HB compared with the rest (Table 3). Joint pain at 6 and 12 months postoperatively did not correlate with HB. Instead, patients with no or little pain over the lateral aspect of the hip (trochanteric pain) had more heterotopic bone than patients with pain or discomfort in this region.

Conclusions: A large amount of heterotopic bone seems to be associated with decreased hip mobility. We also noted a correlation between small amounts of HB and a lesser gain in mobility compared with hips without HB. The greater muscle strength in flexion-extension among patients with HB apparently related to the patient's constitution and is not a consequence of HB. Heterotopic bone formation does not seem to give increased pain postoperatively.

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Relevancy of radiologic criteria in loosening of total hip arthroplasty (THA)

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Introduction: A retrospective study was carried out to investigate the diagnositic value of radiologic loosening in total hip arthroplasty (THA). Radiologic criteria were based on standard radiographs; scoring the radiolucency by using the Charnley scoring system for cups and stem. Scintigraphy and subtraction arthrography were used as well. The studied group of patients served as its own control group in relation to loosening of either cup or stem, which could be checked during operation. Twelve verified infections were excluded from the study.

Materials and methods: Revisions were carried out on combined clinical and radiologic criteria. The following were regarded as signs of clinical loosening: the combination of pain on weight bearing and traction and rotation of the hip. If there was in addition Grade 3 or 4 loosening of the cup and signs of loosening of the stem on standard radiography, the patient was operated on. Scintigraphy was done in 80 percent and subtraction arthrography in 25 percent of the cases.

Results and discussion: Preoperatively, 12 cases of isolated cup loosening and 28 of isolated stem loosening were found. In 20 cases, both cup and stem were found to be loose using the Charnley scoring system. In 13 cases, revisions were carried out for other reasons (infections, etc.). During operation, we found 10 cup loosenings, 29 loose stems, and in 21 cases both the cup and stem were loose. Perfusion technetium scintigraphy was found to be false positive in 20 percent, false negative in 40 percent, and correctly positive in 40 percent. Subtraction arthrography was correctly positive in 80 percent for cups and in 45 percent for stems. The Charnley criteria proved to be the most conclusive, with a correct positive rate of 95 percent for cups and 90 percent for stems.

Signs of loosening in standard radiographs proved useful in deciding on revision arthroplasty. Scintigraphy had little or no value in our opinion except in diagnosing infections. Subtraction arthrography was useful in cup loosening, but gave no extra information. We therefore conclude that an indication for total hip revision is present when there are signs of clinical loosening and loosening on standard radiographs.

Results of treatment of infected hip replacement with gentamicin-PMMA beads

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In a retrospective study the results of local antibiotic therapy with gentamicin-polymethylmethacrylate beads (PMMA beads) in infected hip replacements were analyzed with special reference to eradication of the infection. Between 1981 and 1986, 57 patients (58 hips) with a total hip arthroplasty, hemiarthroplasty, or cup arthroplasty were operated on for suspected septic loosening of the implant. In 42 cases the diagnosis was confirmed by positive culture of peroperative biopsies, eight of which yielded anaerobic bacteria. In the remaining 14 cases, the diagnosis infection was based on the following data: pain, unexplained elevated ESR, progressive osteolysis in combination with purulent aspect of tissues by macroscopic and frozen section observation intraoperatively.

The treatment comprised two or three operations:
1. Removal of prosthesis, cement, and all necrotic tissues; implantation of PMMA beads: 150–360 for 14 (9–24) days.
2. Exchange of beads (19 hips).
3. Removal of the beads and either revision arthroplasty when technically feasible, including bone grafting and gentamicin-Palacos®(28 hips, 18 of which had been in the group with confirmed infection) or a Girdlestone procedure (30 hips). Following each operation, systemic prophylaxis was given for 48 hours with either cefalotin or methicillin and flucloxacillin.

The follow-up averaged 30 (5–74) months and was focussed on signs of infection (pain, elevated ESR, progressive osteolysis). There had been no side effects from the PMMA beads. Four patients were lost to follow-up.

Results: 43 patients (44 hips) were satisfied and showed no signs of infection. Three patients had mild pain and no signs of infection. Four patients had pain related to the Girdlestone situation or para-articular ossifications, but no infection. Infection was diagnosed in 2 patients, one clinical recurrence in the group "probable infection" and one definite recurrence in the group "confirmed infection."

Conclusions: Out of 42 cases operated on for definitely infected hip arthroplasty, only one recurrence was found after a mean follow-up of 30 months. Gentamicin PMMA beads are very effective in treating septic loosening of hip arthroplasty.

Postoperative fracture of the ipsilateral femur in patients with hip arthroplasty

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Thirty-two femoral fractures following hip arthroplasty excluding peroperative fractures were studied. This type of injury seemed to occur with either high-velocity trauma (7 cases) or weakening of bone stock (25 cases; loosening, osteopenia, previous technical errors). Our guidelines for treatment were the physiologic age of the patient, fracture location, prosthetic loosening or marked cortical thinning, and the preoperative function of the hip (pain, stiffness). Since 1976, 32 fractures were treated in one orthopedic center on 28 patients, 11 males and 17 females (2 bilateral cases, 2 refractures). The age of the patients was 68 (23–89) years. The average delay from hip arthroplasty to fracture was 6 years. Twenty prostheses were cemented, 12 were uncemented; in 18 cases there was a stem loosening. The location of the fracture was in 14 cases at the stem tip, in 15 around the stem, and in 3 below the stem. The treatment was internal fixations with plate (14), plates with supplementary cementing (2), revision of the prosthesis without plate (5), revision of the prosthesis with plate (4), Girdlestone procedures (3), orthotic treatment (3), osteosynthesis by screw and cast (11). All the patients were followed until healing occurred.

Deep vein thrombosis after total hip replacement

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Introduction: The present study was undertaken to investigate 1) the time-related development of deep vein thrombosis (DVT) and 2) the incidence and location of DVT after total hip replacement (THR).

Methods: A lateral approach to the hip was used with the patient in the lateral position. The patients received 500 ml of dextran during the operation and on Days 1 and 3 postoperatively; they were mobilized on Day 2. Prior to the study, it was decided that DVT distal to the popliteal veins should not be treated (approved by the ethical committee).

Series I: Patients were examined by bilateral venography performed on Days 2 and 9 after THR. Series II: the incidence and location of DVT after THR were investigated by bilateral venography performed on Day 2 (based on the results in series I) in 37 patients.

Results: Series I: The formation of thrombi occurred mainly within 2 days after THR. The resolution of thrombi between Days 2 and 9 was greater than the development of thrombi during this period. Series II: DVT was seen in 13/37 cases, bilaterally in 5 patients, on the operated on side in 3 patients, and on the nonoperated on side in 5 patients. The thrombi were always found distal to the popliteal vein.

Discussion: The thrombi were found to be equally distributed between the operated and nonoperated on sides. This indicated that the surgical trauma to the femoral vessels is of minor importance, and that the occurrence of DVT is caused by a general tendency to increased thrombus formation after THR. None of the patients had clinical signs of DVT, and the postoperative course was uneventful in all the patients up to 3 months after the operation.

Oral anticoagulation in total hip replacement

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Introduction: The purpose of the present study was to investigate whether the well-known high incidence of thromboembolic complications after elective total hip replacement (TRH) could be reduced by preoperative anticoagulation.

Patients and methods: Consecutive patients admitted for an elective, primary THR were divided into two prophylactic groups. In Group A, oral anticoagulation was started on the eve of the operation. In Group B, oral anticoagulation was started 4 days before the operation, aiming at a Thrombotest of INR 1.5-1.6 on the day of operation. In both groups the postoperative Thrombotest level was set at INR 2.1. The presence or absence of deep venous thrombosis was checked by radionuclide venography on the 10th day.

Results: A total of 101 patients completed the study. There was no significant difference between both groups in the incidence of proximal – popliteal and/or femoral and/or iliacal – deep venous thrombosis. In Group B, there was a tendency towards further reduction of the incidence of proximal thrombosis (14 percent vs. 24 percent in Group A ; however, only when a peroperative Thrombotest of INR 1.5 or more was

combined with a satisfactory level of postoperative anticoagulation. There were no hemorrhagic complications. No fatal pulmonary embolism occurred during the study. After discontinuation of the oral anticoagulants because of a negative venogram, nonfatal pulmonary embolism occurred in 3 out of 55 patients.

Conclusions: Prophylactic anticoagulation aiming at an INR of 1.5-1.6 during operation and an INR of 2.1 after operation does not result in complete prevention of deep venous thrombosis. In THR the absence of deep venous thrombosis on objective diagnosis on the 10th postoperative day does not exclude later thrombogenesis and pulmonary embolism. Therefore, oral anticoagulation during a 3-month postoperative period is advised during which the Thrombotest level has to be maintained at INR 2.1.

Thromboplastin activity and complement activation following total hip replacement surgery

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Introduction: We have examined thromboplastin activity in nonstimulated and endotoxin-stimulated monocytes and complement activation in patients undergoing total hip replacement (THR) surgery.

Methods: In 8 patients that underwent uncomplicated THR, blood was collected and mononuclear cells were isolated or endotoxin-stimulated. Measurements of thromboplastin activity were then performed. In another 6 patients, plasma concentrations of C3-activated products were measured.

Results: We found that thromboplastin activity was increased in nonstimulated monocytes 2 days after surgery. In the endotoxin-stimulated monocytes, the thromboplastin activity was increased after 1 day. Complement activation was not found to occur during total hip replacement surgery.

Discussion: The present study shows that THR surgery is associated with elevated levels of thromboplastin activity in circulating monocytes. The stimulation of human monocytes to produce thromboplastin was not found to be complement-dependent. An explanation for our results could be that newly mobilized cells from the bone marrow during THR surgery are more readily stimulated to thromboplastin synthesis than the older monocytes. The increased thromboplastin activity in monocytes following THR surgery may play a role in the induction of postoperative thrombosis.

Hip fractures

Rotational stability of femoral neck fractures

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Introduction: Earlier studies (1) have shown that two 5-mm screws give as strong fixation as sliding screw devices in femoral neck fractures when tested for vertical bending. The aim of the present study was to evaluate rotational stability of different implants in femoral neck fractures.

Material and methods: Fifty pairs of cadaveric femora were used. One femur from each pair had a vertical neck osteotomy fixed with the following implants: two von Bahr screws (one cranially/one caudally), three von Bahr screws (one cranially/two caudally), two von Bahr screws (one cranially/one perforating calcar medially), and Richards Hip Compression Screw with or without a lag screw cranially. The contralateral femora were used as controls. All the femoral heads were cemented to fit into the testing device (Instron). With the shaft fixed, the femoral heads were rotated, and the load–deformation data recorded on an X–Y writer. ANOVA was used in the statistical analyses.

Results: At 3° of rotation the torsional moment indices test/control indicated that three von Bahr screws were significantly stronger than all the other devices ($P < 0.05$). The torsional moment indices at maximal load demonstrated that three von Bahr screws were stronger than all the other osteosyntheses ($P < 0.05$), and that either configuration of two von Bahr screws were stronger than sliding screw with or without an additional lag screw. Torsional stiffness indices did not vary significantly. All the control femora fractured vertically in the collum at the ultimate load of 75 ±28 Nm.

Conclusions: Sliding hip screw provides less torsional stability in femoral neck fractures than simple 5–mm screws. Three instead of two screws improves the torsional stability in femoral neck fractures significantly.

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Revascularization of the femoral head after femoral neck fracture in rat

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Introduction: A major question in femoral neck fractures is whether the circulation to the femoral head is irreversibly in-

jured at the moment of fracture or if it is possible to influence it by surgical fixation of the fracture. Clinically, it has been shown by Strömqvist that certain fixation devices may increase the vascular damage to the femoral head (1). In order to study factors of importance for revascularization of the femoral head after fracture, the following rat study was performed.

Material and methods: Rats of both sexes, weighing 300 grams at the beginning of the experiment were used. The right hip was operated on under anesthesia and the left was used as the control. The femoral neck was cut in situ. In one group (A) of animals (n 33), the femoral head was left without fixation. In the other group (B, n 49), the femoral head was reattached to the femur by means of a single wire pin. Studies of the femoral heads were done after 4 (n 38) and 8 weeks (n 44). At this time, 20 MBq ^{99m}Tc methylene diphosphonate (^{99m}Tc MDP) was given intravenously. The radionuclide uptake was recorded for the control and the experimental head. A ratio was created between the operated on head and the intact femoral head.

Results: At 8 weeks, there was a significantly higher uptake in group B than in group A ($P = 0.01$). At 8 weeks this difference remained ($P = 0.001$). In group B (fixation) the uptake increased significantly with time ($P = 0.001$) and became normal in 8 weeks. No change was observed in group A. At 4 week, there was one necrosis of the head in group A. At 8 weeks, there were eight necroses in both groups (NS)

Conclusions: Revascularization of the femoral head after fracture occurs in rat and is improved by fixation of the fracture.

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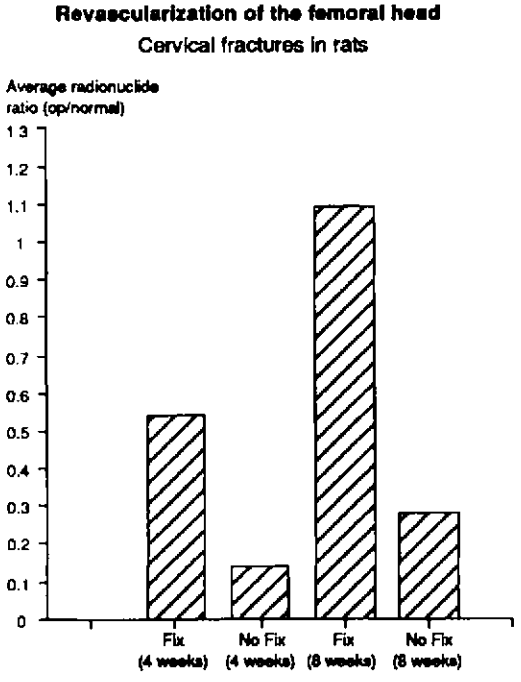

Hip joint pressure in undisplaced cervical fractures

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Introduction: Woodhouse (1) has demonstrated that an intracapsular hip joint pressure of 50 mmHg in puppies for 12 hours results in avascular femoral head necrosis. This mechanism could contribute to avascular necrosis in cervical hip fractures in man by means of compromised venous or arterial circulation.

Patients: Fifty patients aged 34–95 years with undisplaced cervical hip fractures (Garden I and II).

Method: The fractures were diagnosed by routine radiographic examination. In 25 cases, 99-m Tc-MDP scintimetry was performed preoperatively. Prior to surgery the capsule was punctured under fluoroscopy with an epidural needle connected to a piezoelectric crystal via a saline-filled closed system. The intracapsular pressure was recorded in extension and neutral rotation, as well as inward and outward rotation, and in some cases in flexion. The hip joint was then evacuated and the volume recorded. The day after surgery a repeat scintimetry was performed when possible.

Results: The intracapsular pressure ranged from 0 to 320 mmHg with the hip in extension and neutral rotation. Twenty-one patients had a pressure of 50 mmHg or more. The pressure increased in internal rotation and decreased in external rotation and flexion. Totally, 0–36 ml of blood was aspirated, usually with free fat droplets. There was no correlation between volume and pressure. Of 13 patients with a reduced scintimetric uptake over the femoral head preoperatively, 9 were normalized on the day after surgery, 2 were unchanged, and 2 had a lower ratio. The 13 patients with reduced uptake had an intracapsular pressure of 144 (20–320) mmHg as compared with 39 (0–160) mmHg for the 12 patients with increased uptake.

Conclusion: Intracapsular hematoma in connection with undisplaced cervical hip fractures may cause increased intracapsular pressure, which in turn may affect the viability of the femoral head.

Reference

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Factors responsible for failure after femoral neck fracture fixation: A stepwise logistical regression analysis

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Introduction, Material and methods: A prospective series of

101 patients with femoral neck fractures were treated by closed reduction and internal fixation at Södersjukhuset, Stockholm. Patients were reviewed radiographically at 2 years. Different factors thought to influence the complication rate were analyzed with respect to their relative prognostic importance using computerized stepwise logistical regression.

Results: The single most important factor was fracture reduction (Garden alignment index) followed by the type of fracture (Garden Grade I–IV) and the position of the fixation devices (either three Nyström nails or three Scand screws). The predicted probability of a complication arising was calculated for different combinations of these three important factors. The probability ranged from 0.05 (i.e., satisfactory reduction with a Garden alignment index between 155°and 185°, fracture type Garden Grade I–II, and satisfactory position of the fixation devices) to 0.99 (i.e., unacceptable reduction, fracture type Garden Grade IV, and unacceptable position of the fixation devices).

Conclusions: The results show that greatest possible effort must be made in achieving an acceptable reduction of the fracture before fracture fixation; otherwise, a primary prosthetic replacement should be considered. Access to a high resolution image intensifier is a prerequisite in making this decision.

The stability of cervical hip fractures and its influence on healing

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Introduction: Disturbances of healing of displaced cervical hip fractures can be correlated with several factors. The stability of the fracture is one. The stability can be influenced by reduction and by method and technique of the internal fixation. Impaction of the fracture peroperatively can, according to Deyerle, reduce the rate of healing disturbances by improving the stability. The aim of this study was to measure peroperative stability and to investigate whether the stability could be increased by impaction, and to correlate the peroperative stability with the clinical results.

Materials: The material consisted of 41 consecutive patients with cervical hip fractures. Thirty-two fractures were dislocated. The mean age for the whole material was 78 ±8 years. All the 41 fractures were operated on according to the von Bahr method by the same surgeon. For measurement of stability an instrument consisting of a 150-mm long metal rod of 3.5 mm diameter, fitted with strain gauges, was used. When the fracture had been reduced and fixed, the rod was inserted into a channel between and parallel to the von Bahr screws. The rod had its tip anchored in the subchondral bone of the femoral head and the lateral end in the lateral femoral cortex. A compression force was applied to the foot of the operated on leg. The shearing force resulted in deformation on the measuring rod, which could be registered on a recorder. The compression force from the dynamometer at the foot was registered on the same recorder.

Thirty fractures healed. In this group the stability before impaction was on an average 0.28 mm/100 N. After impaction the mean stability was 0.19 mm/100 N. In the group with early redislocation or pseudarthrosis the mean stability changed from 1.36 mm/100 N before impaction to 1.21 mm/100 N after impaction.

Conclusions: This study shows an unequivocal connection between poor peroperative stability and early redislocation or pseudarthrosis. The fractures showing early redislocation or pseudarthrosis all had significantly poorer stability than those that healed. The fractures with late segmental collapse showed a similar stability to those that healed.

Dynamic or rigid fixation in unstable trochanteric fractures: An experimental study comparing three different devices

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Introduction: In vitro testing of implant and bone-implant preparations is usually performed as an assessment of the ultimate static loading causing failure. We have compared the stability in experimentally produced four-fragmentary trochanteric fractures when stabilized by either a Jewett 135°nail plate, a NoLok™ 135° sliding screw/plate without key, or a Hansson 140° sliding pin/plate with additional trochanteric plate, and subjected to a repetitive physiological loading.

Material and methods: Twelve pairs of femora (donors' mean age 73 years) were fractured and stabilized, i.e., eight femora for each type of implant. Each specimen was subjected to 20,000 cycles of a simulated physiological loading. The elastic and permanent fracture displacement was continuously measured along (linear) and around (angular) three orthogonal axes, by an accuracy of ±0.05 mm linear and ±0.05°angular. Out of these six components of fracture displacement, the four fracture movements impaction, shear, rotation, and tilt were calculated.

Results: Five failures occurred, three Jewett and one each from the NoLok™ and Hansson groups. For the Jewett group a continuous increase in elastic and permanent displacement was seen throughout the test. For the NoLok™ group a marked increase in elastic displacement occurred after 1-2000 cycles as the compression screw lost its effect. The lag screw of the failed specimen was bent 4°at the end of the barrel. The Hansson group had a marked elastic and permanent displacement during the first 500-1000 cycles. The pin of the failed device was bent 16° at the end of the barrel. Another two pins were also bent after completing the entire test.

Discussion: A rigid device depends on the fracture being totally immobilized. Once fracture displacement occurs, the implant is unable to adjust to a new fracture position and thus fatigue of the bone-implant interface will cause failure. Dy-

namic devices allow permanent secondary impaction, which will improve fracture stability and the resistance to fatigue, important when dealing with unstable trochanteric fractures.

Stiffness of proximal femora under static and dynamic loading

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Introduction: We have compared the effects of static and dynamic loads when applied to cadaver femora, unfractured or with a trochanteric fracture stabilized by either a rigid Jewett 135°nail-plate, a 135°NoLok™ sliding screw-plate without key, or a 140°Hansson pin-plate.

Materials and methods: Twelve pairs of femora from elderly donors were subjected to an increased static and uniaxial dynamic loading applied to the femoral head by a simulator, while measuring the elastic deformation in the trochanteric region. The load causing an elastic deformation of 1 mm in the trochanteric region was assessed. The different mode of loadings were first applied on the unfractured femora, after which a standardized trochanteric fracture was produced and randomly stabilized by one of the three fixation devices, and then the test was repeated.

Results: For unfractured femora as for each bone-implant preparation, the stiffness under dynamic loading was significantly greater than under static loading ($P < 0.001$). The Jewett nail-plate produced a more rigid fixation than the NoLok™ ($P < 0.01$), and the Hansson ($P < 0.001$) system when subjected to dynamic loadings, whereas under static loading these differences were less pronounced. Still, the Jewett nail-plate as being the most rigid of the three devices showed only 21 and 35 percent of the rigidity seen in the unfractured femora when subjected to static and dynamic loading, respectively.

Discussion: According to Frankel et al. (1) as much as 75 percent of the load applied to an experimental hip fracture, and possibly also to a fracture in vivo, might be absorbed by the bone itself. It is for this reason important that the load applied is dynamic. Otherwise, the important viscoelastic properties of the bone are not considered and the ability to withstand a load in vivo might be underestimated.

Conclusion: Because of the viscoelastic properties of bone, the load applied in a hip simulator should be dynamic; otherwise, the ability of the device to withstand in vivo loading might be underestimated.

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A prospective randomized trial of unstable trochanteric hip fractures

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Introduction: One fourth of all hip fractures are unstable trochanteric hip fractures. There are few prospective randomized studies that compare Ender pins with compression hip screws (CHS).

Patients and methods: All unstable trochanteric hip fractures were randomized between two different types of osteosynthesis: Ender pins and the compression hip screw type Richard, with 100 patients in each group. No significant differences were noted in the patients' background factors. Totally, 172 patients were evaluated with radiographic and clinical examination.

Results and discussion: In all, 24 men and 80 women were treated with Ender pins, and 24 men and 78 women were treated with the CHS. The mean time of operation and the mean peroperative bleeding were significantly less in the Ender group as compared with the CHS group, but the time of fluoroscopy was shorter in the CHS group. Clinical and social rehabilitation was similar in the two groups, but the external malrotation was higher in the Ender group, as well as the leg-length shortening. In the CHS group, only three minor secondary operations were performed, all extractions due to local pain. This is significantly less than the 30 minor secondary operations and four major reoperations that were performed in the Ender group. The indications for secondary operations in the Ender group was in 22 cases pain and discomfort around the knee and in 8 cases changed position of the pins in the head of the femur. Varisation of the fracture of at least 11° occurred in 13 cases in the Ender group, significantly fewer in the CHS group (4 cases). There were no patients with nonunion, and only 2 patients with superficial infection in the CHS group — no patients with deep infection. The outcome of a stepwise logistic regression analysis in the Ender group was that too long Ender pins and previous fracture were significant predictors of reoperation.

From this study, we can conclude that in our hands patients with unstable trochanteric hip fractures should be treated with CHS. The advantages of Ender pins — i.e., shorter operation time and less bleeding — do not compensate for the disadvantages of the longer time of fluoroscopy, the higher risk of varisation and leg shortening, external malrotation, and above all, an unacceptably high risk of a secondary operation.

Ipsilateral fracture of the femoral neck and shaft treated with intramedullary locked nailing and multiple cannulated screws

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Introduction: Ipsilateral fractures of the femoral neck and shaft are a problematic combination. The femoral neck fracture is often missed initially; and when both fractures are diagnosed correctly, the surgeon is faced with complex and difficult treatment choices.

Case reports

Case 1 A 50-year-old woman sustained a fracture of the femoral neck (Garden type II) and a very comminuted fracture of the ipsilateral distal femoral shaft. The femoral neck and the shaft fracture were treated with respectively intramedullary closed reaming and locked nailing and four cannulated screws. One year after the operation, both fractures were united without deformity or radiographic signs of avascular necrosis. Hip and knee motion were acceptable.

Case 2. A 48-year-old man sustained a fracture of the femoral neck (Garden type III) and a spiral fracture of the ipsilateral femoral midshaft. The treatment was the same as in Case 1. Two years after the operation, both fractures were united without deformity or radiographic signs of avascular necrosis. Hip and knee motion were acceptable.

Conclusions: In two cases of ipsilateral fracture of the femoral neck and shaft, a combination of intramedullary locked nailing and multiple cannulated screws allowed early mobilization and gave good end results.

Decentralized follow-up of hip fractures

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Introduction: Hip fractures constitute an increasing challenge to the health care system due to their increasing incidence and their high consumption of bed resources. Of all the orthopedic patients, this group consumes most resources. Improvements in the overall treatment will be necessary to cope with the large number of hip fractures expected by year 2000. At the orthopedic department in Lund, a long tradition exists with interest focused on follow-up and control of technologic, economic, and organizational changes for hip fractures in the elderly. These elderly patients are usually well known and cared for through the primary care system owing to other diseases existing before their fracture. Thus, to optimize the overall treatment and to reduce routine check-ups, the postoperative follow-up of the hip fracture patients were transferred to the primary health care organization.

Methods: All the hip fractures occurring from November 1, 1985, in the Lund University Hospital catchment area are followed prospectively concerning their functional parameters. This report concerns all the fractures from November 1, 1985 through October 31, 1986, and followed for a minimum of 1 year. All the patients were operated on with hook-pins (cervical fractures) or compression hip screw-plate (trochanteric fractures), and immediate weight bearing was encouraged. Radiographs were obtained directly postoperatively on the operating table and then after some days of weight bearing, usually within 1 week. Further radiographic controls were omitted unless symptoms with pain from the hip appeared. A follow-up scheme for each patient was sent from the orthopedic department to the primary health care center. The primary care personnel (mainly the district physiotherapists) contacted the patient at 1, 2, and 4 months postoperatively for all the hip fractures and additionally at 1 and 2 years only for the cervical fractures. The patient's walking ability, quality of life, and resource consumption were determined.

Results: The study included 266 patients. The ratio of women to men was 3:1 and the ratio cervical/trochanteric fractures was 1:1. The mean hospitalization was 16 days (14 for cervical and 18 days for trochanteric fractures). Prior to the fracture, 63 percent lived in their own homes, 20 percent in old peoples' homes, and 14 percent in long-term care hospitals. The rest were staying in temporary living facilities, such as convalescence homes or acute hospital clinics. At 4 months after the fracture, 52 percent were living at home, 13 percent in old peoples' homes, and 24 percent in long-term care hospitals. Home aid was needed by 17 percent of the patients before their fracture and by 18 percent 4 months after their fracture. Compared with our previous rehabilitation schemes with regular follow-up, including radiographic examination at the orthopedic department at 4 months after the fracture, the walking ability and consumption of home help did not differ.

Discussion: There are few studies relating resource consumption to health quality. In the present shrinking economic situation, it is important to look over the routines for follow-up. The present study has shown that decentralized follow-up without radiography or orthopedic expertise gives good functional results provided that cases with pain and walking problems from the hip are guaranteed rapid specialist treatment. This is possible due to released resources in the outpatient ward by this system. Unnecessary check-ups are omitted. This system has been the basis for evolution of a patient follow-up system that is has now been introduced as a multicenter investigation including all of Sweden.

Aluminum-induced hip fractures: A hypothesis on bone fragility

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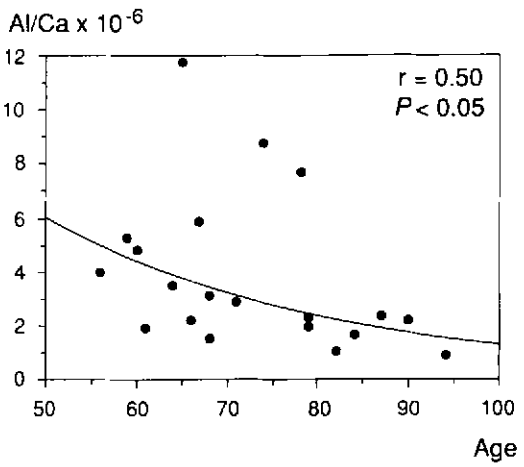
Introduction: The age-specific incidence of hip fractures has increased epidemically during the last four decades. The fragility of bone in the elderly has been associated with decreased bone mineral content, the cause of which has not been clarified despite comprehensive investigations. Fatigue fractures due to aluminum intoxication osteomalacia are well known in patients on chronic dialysis therapy.

The aluminum content in trochanteric bone biopsies was measured in patients with hip fracture.



Patients and methods: At operation in 20 patients, 7 men and 13 women, with hip fractures, 14 cervical and six trochanteric biopsies were taken from the trabecular bone in the trochanter major. The aluminum and the calcium content in the bone ash were measured by atomic absorption spectrophotometry.

Results: All the specimens contained aluminum: the Al/Ca ratio varied between 0.9 and 12 x 10^{-6}. There were no correlations between the aluminum content and sex or type of fracture, but there was a tendency ($P < 0.05$) for a higher aluminum content in the younger patients.

Discussion: The accelerated pollution acidification in the industrialized world since World War II has led to one of the greatest ecologic changes during historical times. The most obvious expression is the extensive forest decline in Central Europe. In the acid environment, aluminum dissolves and becomes poisonous: Pied flycatchers breeding close to acidified lakes, and thus feeding on aluminum-containing insects, produced, for example, defective mineralization of eggshell because of reduced calcium stores (Nyholm 1981).

The toxic effect of aluminum to man became obvious during the 1970s when some patients on chronic dialysis therapy were either dialyzed with city tap water purified with aluminum sulfate or consumed large quantities of aluminium hydroxide to control hyperphosphaturia. Some of these patients developed fatigue fractures owing to renal osteodystrophy (aluminum intoxication osteomalacia), for aluminum was incorporated in the mineralization front and caused inhibition of the bone mineralization.

The increased incidence of fragility fractures in patients with previous gastric surgery, in alcoholics, and in smokers may thus be explained by an above average consumption of antacids. Other possible sources are pots and pans made of aluminum.

It is possible that the increased age-specific incidence of hip fractures, as well as other fragility fractures, may be caused by a chronic low-grade aluminum intoxication. The larger the aluminum exposure, the larger is the risk of an early fracture.

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Nutritional intake and nutritional status of patients with a fracture of the femoral neck: Value of oral supplements

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Introduction: Patients with a fractured femoral neck are often malnourished on admission, and have a low nutritional intake during their stay in the hospital. In a recent study, supplemental tube feeding was shown to increase nutritional intake, improve nutritional status and postoperative mobilization in a group of patients with this fracture. The aims of the present study was 1) to determine the spontaneous nutritional intake, 2) to determine the nutritional status, and 3) to evaluate the effect of oral supplements of patients with a fractured femoral neck.

Patients and methods: Twenty-five patients were included (all women > aged 60 years). On admission, they were randomized to two groups. Anthropometric measurements, including weight, triceps skinfold (TSF), biceps skinfold (BSF), subscapular skinfold (SSF), and upper arm circumference (AC), were made as soon as possible postoperatively and at the end of the study period. Both groups received the normal hospital diet, and in addition patients in group 2 were offered a newly developed liquid supplement containing 5 g protein/100 ml and 420 kJ/100 ml. This supplement was offered thrice daily between meals. The nutritional intake was recorded daily.

Results and discussion: Six of the patients had a low TSF on admission and 3 had a low arm muscle circumference (AC). The two groups were comparable according to nutritional status on admission, and no detectable difference was observed during the study period. The energy intake was significantly higher in the supplemental group than in the control group (5,500 vs. 4,595 kJ/day). Further, the protein intake was significantly higher in the supplemental group (52 vs. 37 g/day). The supplements were well tolerated.

This study shows that using a simple, inexpensive, and uncomplicated method the nutritional intake can be increased significantly in a selected group of patients with a femoral neck fracture. The spontaneous intake was low in the control group, but the two groups were similar in their altered anthropometric measurements. However, these measurements were connected with considerable difficulties, and thus a possible effect on nutritional status may not have been detected.

Colles' fracture as an indicator of later hip fracture: Hvidovre osteoporosis study

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Introduction: One of the main topics in osteoporosis is to pinpoint women at high risk for hip fracture. Alffram (1964) found that 16 percent of a hip fracture population had had an earlier Colles' fracture; hence, an increased risk of a later hip fracture in women with a Colles' fracture was suspected. Other studies have been presented both with and without this correlation. We did a prospective study in women with a Colles'-fracture to study the incidence of later hip fracture.

Subjects and methods: In the 10-year period from 1976 through 1985, all women older than 19 years with a Colles' fracture admitted to Hvidovre Hospital were registered. A total of 1,199 women were followed from 0 to 10 years with a mean follow-up of 3.8 years. The observation time was 4,596 years. According to incidence data on cervical and trochanteric hip fractures in women (Hvidovre Osteoporosis Study 1987), we calculated the relative risk of hip fracture. Confidence limits (CL) of 95 percent were calculated (Table 1)

Results

Table 1 Colles' fracture and later risk of hip fracture

Age	N	Relative risk	95% CL
40–49	86	40.2	5.2–141.6
50–59	223	8.0	1.8–23.1
60–69	351	4.2	1.9–8.2
70–79	309	4.4	2.5–7.0

Conclusions: Women with a Colles' fracture do have a higher risk of later hip fracture than expected from epidemiologic background data. The relative increase is greatest in women near and after the menopausal period before senescence. Therefore, preventive measures against osteoporosis should be considered in women aged 40–70 years sustaining a Colles' fracture.

Reference

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Rising incidence of hip fracture in Århus 1970–1986

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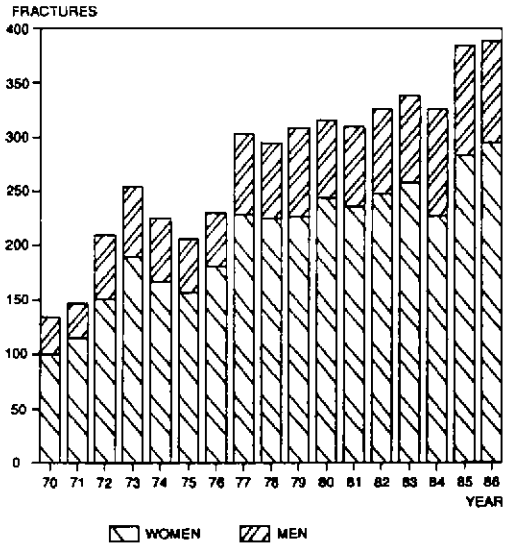
Introduction: Based on the periods 1971–77 (1) and 1973–79 (2), respectively, a twofold increase over 17 years and a threefold increase over 20 years in the number of hip fractures has been predicted in Denmark.

Patients and methods: During 1970–86, a total of 4,697 hip fractures in persons aged 50 years and older occurred in the municipality of Århus. Age- and sex-specific incidence rates were calculated, and a forecast for the future number was computed.

Results: Female:male ratio was 3.1, and the number increased almost threefold (Figure). The overall incidence rose from 2.1 per 1,000 ($F = 2.9$, $M = 1.2$) in 1970 to 5.8 ($F = 7.6$, $M = 3.2$) in 1986. In both sexes the incidence increased exponentially with age, and 63 percent of the fractures occurred in patients aged 80 years and above. As regards the increase in age-specific incidence rates during the survey period, and applying these to an official population forecast for the year 2002, a threefold increase in the number of hip fractures can be expected within the next 22 years according to regression analysis.



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Fractures of the proximal femur in Finland in 1985 and a forecast for the year 2000

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The number of hip fractures is increasing in all the Nordic countries. I have studied the incidence of hip fractures in Finland in 1985 and have made a prognosis for the year 2000. All the patients admitted to Finnish acute hospitals for primary treatment of a hip fracture were selected from the National Board of Health statistics. The material was analyzed according to age, sex, type of fracture, and duration of the treatment in the hospital. The increase in fractures since 1970 and the number of hip fractures in 1970 were counted from an earlier study. In the forecast the age-specific incidence per 100,000 inhabitants was projected on the population forecast for the year 2000.

During the year 1985, 3,212 patients with cervical hip fractures and 1,278 with trochanteric fractures were treated. The total number of hospitalization days was 153,348. The mean hospitalization time was 34 days for both fracture types. The cervical hip fracture was three times as common and the trochanteric fracture twice as common in women as in men. The age-specific incidence for cervical hip fractures rose for women and men over aged 45 years of age. For trochanteric fractures the age-specific incidence rose for men over 45 years and women over 55 years of age. From 1970 to 1985, cervical hip fractures in both sexes increased by 102 percent. For women the increase was 100 percent for trochanteric fractures and only 19 for men. The increase of both fracture types for both sexes was 89 percent. The total number of hip fractures in the year 2000 will be about 5,800 if the expected incidence is the same as in 1985. The total number will be about 7,000 if the expected increase/decrease of the age-specific incidences remain constant in the period 1970 to 2000. The forecast means that the increase of hip fractures in Finland from 1985 to 2000 will be slower (29 percent or 56 percent) than 15 years earlier.

Autopsy-verified major pulmonary embolism in 1954 hip fracture patients not prophylactically anticoagulated

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Introduction: Fatal pulmonary embolism (PE) is a feared complication in elderly patients with a hip fracture, and the frequency of PE in patients not prophylactically anticoagulated is usually considered to be 4-10 percent.

Patients and methods: In our department no prophylactic anticoagulation was used until the end of 1983. In the period 1969-83, 1,954 hip fractures in patients aged 40 years and above were registered. Ninety-two percent were operated on. In all, 274 patients died within 90 days after the fracture. Based on autopsy reports, the frequency of major PE, defined as occlusion of at least one lobar or several segmental arteries, was studied.

Table

Days	No of patients	No of deaths	Autopsy No	Autopsy %	Major PE % estimated No	Major PE % estimated at 100% autopsy
0–30	1954	182	132	73	18	1.3
31–60	1771	55	31	56	6	0.6
61–90	1717	37	18	49	3	0.4
0–90	1954	274	181	66	27	2.1

Results: The most important points are given in the Table. The 27 patients dying of/with major PE included 7 males and 20 females with a median age of 81 (66–95) years. Two patients not operated on died 3 and 6 days after the fracture. The others (11 alloplasties, 14 osteosyntheses) died a median of 13 (0–81) days after surgery.

Knee

CT scan study of intercondylar notch in acute tears of the anterior cruciate ligament

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Narrowed intercondylar notches have frequently been observed during arthrotomy for acute ACL tears in previously uninjured knees. The most important fact is that conflict points do not concern the total area of the intercondylar notch, but particularly the edge of the lateral condyle.

Notch view radiographs, which are mostly used in those cases, are not adequate for such an evaluation.

In this study we describe an original technique using CT scanning. We studied the obliquity of the external condyle with the AOCE, which is a very simple angle calculated with CT scanning. First, 150 cadavers were studied and then 25 patients with acute ACL tears.

Two different populations can be described from this study: in the largest one, the obliquity of the external condyle is important, but a particular population has a very small AOCE. This result suggests that this anatomic point is very important for the predisposition of knees to undergo ACL tears. The cases of isolated ACL tears are usually found in this population.

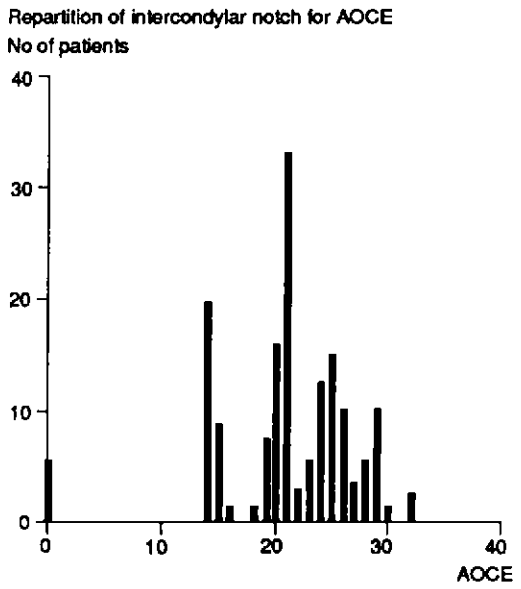

Figure 1. Repartition of intercondylar notch for AOCE.

This study is based on a frontal analysis of ACL conflicts. IRM slides have been correlated with a CT scan study.

IRM shows that the most frequent conflict points to the ACL are against the external condyle. But this parasaggital study also suggests that a narrow and sharp posterior arch of the intercondylar notch may predispose to ACL tears. The incidence of such an anomaly was very low, and this has been confirmed by a retrospective analysis of IRM slides from 50 knees.

Five-year follow-up after extraarticular lateral stabilization of the knee

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See Abstract in Proceedings of the Norwegian Orthopedic Society, *Acta Orthop Scand* 1988;59:110.

Ultrasonographic detection and postoperative control of the mediopatellar and lateropatellar plica in the knee

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In a population of 163 patients complaining of "ill-defined" retropatellar and infrapatellar problems, an ultrasonographic investigation of the patellofemoral space was performed to detect a medial or lateral plica synovialis in the knee. All the patients were controlled by arthroscopy. We found a sensitivity for the ultrasonographic method of 83 percent and a specificity of 79 percent. The ultrasonographic examination of the knee to detect the presence of a plica synovialis was performed with a mechanical sector scanner with a 7.5 MHz transducer (Technicare Autosector III). During the ultrasonographic investigation, a measurement of the ultrasonographic length of the plica in millimeters was performed.

At arthroscopy, we classified the plicas into four types according to Iino and Sakakibara. The types A and B, as found by arthroscopy, correlated significantly with the length of the plica as measured by ultrasonography. A logistic regression analysis of all plica types A and B, i.e., 95 cases, with the measured length at ultrasonography, gave the probability of a plica type B at 6 mm or more.

An arthrotomy was performed to completely remove 27 type-A medial plicas, 3 type-A lateral plicas, 35 type-B medial plicas, and 7 type-C medial plicas. In 31 cases the plica was not removed: viz., in 23 medial plica type A, 7 medial plica type B, and 1 medial plica type C.

Ultrasonographic control of the operated on knees showed a positive image in 27 cases of the original 72. Eighteen of these still classified the operative result as good to excellent. Thirteen patients in the nonoperative group classified the result after only an arthroscopy as good to excellent.

Sagittal instability of the standing knee joint after injury to the anterior cruciate ligament

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Introduction: Clinically and radiographically, a number of methods for measurements of sagittal instability of the knee joint are available. These methods are performed with the knee immobilized, and little attention has been paid to assessing sagittal instability during weight bearing.

Patients and methods: Two series of patients with lesions of the anterior cruciate ligament (ACL) were examined with lateral radiographs in the standing position. The number of patients were 29 and 21, respectively, and the time of follow-up was 10 and 8 years. Additional examinations were scintigraphy and MRI.

Results: 1) All the knees had a normal femorotibial alignment in the nonweight-bearing position. 2) During weight bearing and < 10° of flexion, displacements between 3 and 7 mm were measured in more than half of the knees. 3) During weight bearing and 25–30° of flexion, displacements of 5–24 mm were recorded, and only two were found to be normal. 4) In some patients there was a discrepancy between the clinical and radiographic assessments of instability. 5) Almost half of the patients with a sagittal instability exceeding 10 mm had degenerative abnormalities according to MRI and/or scintigraphy. 6) All the subchondral abnormalities (scintigraphy and MRI) were confined to the femoral condyles.

Conclusion: The sagittal displacement in the standing position represents mechanical instability, provoked by weight bearing. Arthrosis may appear in knees with large sagittal displacements. In view of the results, postoperative and posttraumatic mobilization routines should be reviewed.

Density changes at the proximal tibia after medial meniscectomy

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Introduction: Meniscectomy changes the biomechanical conditions in the knee joint and increases the incidence of gonarthrosis. The aim of this study was to examine the CT densities in the proximal tibial epiphysis as a function of the medial meniscal condition.

Patients and methods: Seventeen partially and 20 totally meniscectomized male patients (5- and 10-year follow-up) and 10 controls were examined. The subchondral 12 mm of the proximal tibia was scanned with 2-mm-thick slices. A paired design was used.

Results: The point of maximal density in the medial tibial condyle in meniscectomized knees is located approximately 4 mm posteromedial to the location of the point in the contralateral nonoperated on knees. In both partially and totally meniscectomized knees, the density in the region of tibiofemoral contact in the medial tibial condyle was higher compared with the contralateral intact knees. The density difference between the meniscectomized and the normal knee in the region of tibiofemoral contact in the medial condyle was higher in totally than in partially meniscectomized patients. No difference was found in the lateral tibial condyle, and no difference was found between patients operated on 5 and 10 years before the examination.

Conclusion: The higher density in the medial tibial condyle is in accordance with the altered biomechanical conditions after meniscectomy. In consequence of the theory of primary changes in the subchondral bone in arthrosis, the utmost conservatism should be employed in surgery on the meniscus.

Treatment of acute ruptures of the anterior cruciate ligament: A prospective, randomized study of three surgical techniques

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Introduction: Treatment of acute ruptures of the anterior cruciate ligament (ACL) is controversial. Recent reports on conservative treatment have shown poor results in long-term follow-ups. Results after primary suture with the Palmer technique, although good primarily, seem to deteriorate with time. This has led to augmentation methods, which seem to have improved the results. There have, however, been no prospective, randomized studies in this field. We are presenting the first report on a prospective, randomized study from Norway.

Method: Totally, 150 patients aged 16–50 years with acute ruptures of the ACL without injuries to the posterior cruciate ligament have been randomized to one of three surgical methods. Fifty patients have been treated with the Palmer reinsertion technique alone, 50 patients with a bone-patellar-bone augmentation as proposed by Clancy, and 50 patients with the Kennedy Ligamentum Augmentation Device (LAD) as augmentation for the torn ACL. All the patients were operated on within 7 days. The postoperative regimen has been identical. The patients are followed prospectively with the Lysholm functional score and the Tegner activity score. Stability is evaluated clinically and instrumentally with the KT-1000 arthrometer. We are now reporting on the first 31 patients followed for 1 year. In this group, 10 patients were operated on with the reinsertion technique, 10 with the Clancy method, and 11 with the LAD method.

Results: There was no age difference within the groups. Sports were responsible for 80 percent of the injuries, with European handball being responsible for more than one third of the injuries. There were no complications. The Tegner score showed a minor decrease in each group, but generally a high level of activity was kept at the 1-year control. The Lysholm score showed an excellent result (95 points) in the Clancy group, whereas the LAD group (91 points) and the Palmer group (90 points) both had a good functional result. In the Clancy and LAD groups, half the patients had an extension deficit of 10°, while only 1 patient in each group had a flexion deficit of > 30°. Three patients in the Palmer group had a 2+ Lachman, 4 in the Clancy group, and 1 in the LAD group. Five Palmer patients had a 1+ pivot shift. In the KT-1000 arthrometer, 4 patients in each group had a side difference of 3 mm or more at the 20-pound anterior drawer test.

Conclusion: After the first year follow-up in this prospective, randomized study, there is a small difference in the functional level between the groups. There is a slight decrease in stability in the Palmer group.

The biomechanics of anterior cruciate ligament rehabilitation

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Introduction: The objectives of this study were to measure the relationship between anterior-posterior tibial displacement, axial tibial rotation, and knee flexion in anterior cru-

ciate ligament (ACL) -deficient knees during activities common to rehabilitation programs used after anterior cruciate ligament surgery.

Patients and methods: Seventeen patients with chronic, unilateral, total ACL tears were studied. Using a computerized goniometer-type instrument (Acufex KSS), knee flexion, tibial rotation, and anterior-posterior tibial displacement were recorded simultaneously while the patients were performing various rehabilitation activities.

Results: Anterior tibial displacement was increased in the ACL-deficient knees when compared with the uninjured knees during quadriceps activity — whether isometric or eccentric — and increased further with loading. Peak values were found between 20 and 30°of knee flexion. At knee flexion beyond 60°, no difference was found between the injured and uninjured knees. Force versus displacement responses for anterior and posterior movement of the tibia, at full extension and 20°of knee flexion, were recorded with partial or full weight bearing. Increases in joint load were followed by increases in stability in both normal and ACL-deficient knees. However, the ACL-deficient knees were stabilized in a position where the tibia was already displaced anteriorly.

Conclusion: During the initial stages of rehabilitation after suturing ACL tears, and following partial ACL ruptures, muscle-strengthening exercises should be performed at knee flexion exceeding 45°.

A modified technique using the middle one third of the patellar tendon in the ACL repair

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In our clinic, we have made an attempt to simplify the classical methods of surgical treatment of injuries to the ACL using part of the patellar tendon as a graft.

The aim was to standardize a simple procedure with a safe positioning and fixation of the graft followed by active postoperative treatment.

The indication for operation was chronic instability causing discomfort to the patient. The middle one third of the patellar tendon was used as a free graft maintaining the bony attachments from the tibial tubercle and patella.

The bone piece from the tibial tubercle is pyramid shaped. The tunnel through the lateral femoral condyle is wider laterally and narrows towards the fossa intercondyloidea. The graft is passed distally through the tunnel with the patellar bone first. The shape of the tunnel causes the pyramid-formed bone from the tibial tubercle to lock within the femoral condyle without sutures and additional devices. The distal end is passed through the fossa and a preformed tunnel in the tibia, and is tightened and fixed with one or two staples. A postoperative cast is applied for 2 weeks followed by using a brace allowing a ROM from 20 to 40°. Weight bearing is allowed after 6 weeks. A maximum observation time of 30 months in 20 patients permits no conclusions regarding long-term results.

However, the present experience allows the following conclusions:

1. The surgical procedure is easy to standardize and requires no investment in special equipment.

2. The fixation of the bony attachments of the free graft is secure, and the tension is easy to control.

3. The length of the graft permits a positioning that does not result in bony pegs forming within the joint.

4. So far, no complications are seen, and the clinical results are good.

Three-dimensional knee movements abnormal after tear of the anterior cruciate ligament

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Introduction: We used a modification of roentgen stereophotogrammetric analysis to register tibial movements at an active flexion of the knee in patients with a chronic injury of the anterior cruciate ligament.

Patients and methods: Ten patients (9 men, 1 woman), with a mean age of 27 years, were examined. All of them had, on an average, 2 years and 3 months previously suffered an injury to the knee and had remaining symptoms of instability.

Two film exchangers designed for 30 x 24-cm films were used. Before the examinations of the patients, a calibration cage was radiographed, together with two reference plates. At the examination of the tibiofemoral movements, the patients were instructed to flex their knees at a constant speed. The frame rate was set to 2 or 4/s. An average of 10 stereopairs were obtained for each series including the reference position (extended relaxed knee). The radiographic setup was designed to register motions between the femur and tibia up to 65° of knee flexion. Observations from all 20 knees were available between 15 and 40°of flexion.

Results and conclusions: In all the patients, flexion of the knee was associated with simultaneous rotations about the longitudinal and sagittal axes. The anterior cruciate-insufficient knees displayed decreased internal rotation and adduction ($P < 0.05$) compared with the normal knees.

Insufficiency of the ACL implied a more lateral ($P<0.01$) and posterior ($P < 0.05$) position of the tibial intercondylar eminence at flexion of the knee. The abnormal movements of the anterior cruciate-insufficient knee joint indicate a more mutiplanar instability than was previously known.

Alteration of tibiofemoral motions during movements of the knee implies that the joint area more or less constantly will be exposed to increased or abnormal compression and shear forces that may be of etiologic importance for the development of secondary arthrosis.

Meniscus repair — a 6–10 year follow-up

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Introduction: Open meniscus repair is a successful method in terms of healing and short-time results. This study presents a 6–10 year follow-up

Patients and methods: In 50 patients (mean age 26 ±9 years at surgery), 50 peripheral longitudinal meniscus tears were repaired. The material was subdivided into group I (32 patients) who all had an anterior cruciate ligament (ACL) tear and group II (18 patients) who had an intact ACL.

All the patients were reexamined after 1 year (33 underwent repeat arthroscopy) and 49 patients could be interviewed (7) or reexamined (42) after an average of 7 years. Instability was measured with the Stryker laxity tester (Stryker Corp., Kalamazoo, USA). The Lysholm knee function score and Tegner activity scale were used. The patients rated the result themselves. Standing radiographs were taken as well.

Results: Twenty-eight of the menisci had healed in group I and 15 in group II. Four of the healed menisci had reruptured (all in group I) until the late follow-up, which makes a total nonhealing and rerupture rate of 22 percent. More failures and reruptures occurred in unstable knees. Knees in group I were more unstable than in group II ($P \leq 0.005$), with a total laxity of 10 ±4 mm. A range of motion impairment was found in two fifth of all the knees. The Lysholm score was similarly high in both groups, with 88 ±11 in group I and 94 ±10 in group II. The patients in both groups changed from a preinjury activity level 8 to 6 at follow-up. The subjective evaluation was equally high in both groups. Radiographs showed in more than half of the knees of group I signs of arthrosis, but in no case in group II.

Conclusion: Meniscal repair of acute and chronic ruptures is very successful in the long run, but whether it improves knee function and helps to prevent gonarthrosis remains to be proven.

Fibrin adhesive – an adequate method for meniscal repair?

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Introduction and technique: Fibrin adhesive was tried for meniscus repair. It can be used in an arthroscopic or open procedure. Nondisplaced peripheral meniscus ruptures (≤3 cm) were selected. The adhesive (Tisseel Kit, Immuno AG, Vienna) was injected into the rupture, which was then compressed for 3 minutes with a special forceps. The arthroscopic procedure was performed in CO_2 gas.

Materials and methods: Five medial and two lateral (one bilateral) menisci in 6 patients with an anterior cruciate ligament (ACL) deficiency (mean age 19 ±4 years) were treated. The ACL was reconstructed in four knees. All 6 patients had a control arthroscopy approximately after 1 year, and 5/7 menisci were healed. A repeat knee examination took place 6 years after surgery, including an evaluation of the sagittal laxity with the Stryker laxity tester (Stryker Corp., Kalamazoo, USA) and of the valgus/varus instability with the Genucom knee analysis system (Faro, Montreal, Canada). The Lysholm knee function score and the Tegner activity scale before injury and at follow-up were used. Standing radiographs were taken as well.

Results: At follow-up, 4/7 menisci were still intact. Increased sagittal instability was apparent in five knees (+5 ±2 mm in comparison with the healthy knee). Valgus/varus instability was increased by +2 mm in five knees. The Lysholm score was 84 ±10, the patients had reduced activities from active team sports (8) to recreational sports of the same category (6). No complications were reported. The radiographs showed slight signs of arthrosis in only one knee with a successful meniscus repair.

Conclusion: Meniscal repair with fibrin adhesive seems promising.

Experimental repair of old lesions in the avascular part of the medial meniscus

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Introduction: Treatment of meniscal lesions displays an increasing meniscus-preserving attitude (1), with repair when possible. Repair of lesions in the central nonvascularized part of the meniscus has in experimental models been shown to be possible when performed instantly (2, 3). The present study deals with late repair of nonspontaneously healing meniscus lesions in accordance with the time of treatment of most of these lesions in humans.

Materials and methods: In 12 full-grown rabbits a longitudinal lesion in the central part of the right medial meniscus was induced through a medial arthrotomy under anesthesia. At the left knee, only a medial arthrotomy of similar extension was performed. Three months later, the lesions were repaired, incising the meniscus from the lesion to the periphery in seven of the animals through a second arthrotomy. Again, a left-sided sham operation was performed. After another 3 months, all the animals were killed. From all the right-sided and three of the left-sided knee joints, the medial menisci and pieces of synovia from identical locations were excised and prepared for histologic examination.

Results and discussion: Six of the seven repaired menisci showed complete macroscopic healing. Histologically, the defect was filled with fibrocartilaginous tissue with fibrous areas. In one meniscus the repair was incomplete. Neither gross examination nor microscopy revealed any sign of repair in the five unrepaired menisci. Synovial alterations were

found in all but the sham-operated knees. The results suggest that repair of old meniscal lesions in a nonvascularized area is obtained by invasion of cells from the periphery. Repair was made in knees with preceding synovitis due to a meniscal lesion, obtaining healing of the lesion without the use of transposition of a synovial flap (4).

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Three-year follow-up of cementless total knee arthroplasties (AGC 2000)

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Introduction: In the period April 1984 to February 1985, 40 cementless, total knee arthroplasties were performed as primary intervention for arthrosis in 36 patients. At clinical and radiographic follow-up 3 years after the operation, 5 patients had died, leaving 34 knees in 31 patients with a median age of 77 (61–83) years. Patient assessment was graded according to Aichroth et al., and for knee evaluation the knee rating scale from Hospital for Special Surgery was used. The overall alignment (tibiofemoral angle) was measured from weight-bearing radiographs.

Results: All the patients except 1 (one knee) were enthusiastic or satisfied. Respectively, 31 and 30 knees were without significant pain (painfree or mild pain) at rest or during walking. In 25 knees the walking distance was unlimited. The median knee flexion was 110°(70–135°). All but one knee was rated "excellent" (26) or "good" (7). One was rated "poor" because of increasing pain and decreasing range of motion without radiographic signs of prosthetic loosening. Surgical excision of hypertrophic fibrous tissue relieved symptoms and increased knee range of motion.

Radiographic examination did not reveal radiolucent zones around the prosthetic components. The overall alignment was within 7 ±5°of valgus in 80 percent.

Conclusions: In this 3-year follow-up study of cementless total knee arthroplasties with AGC-2000 components, good or excellent clinical results were found in 33 of 34 knees, and no radiographic signs of prosthetic loosening were revealed. The cumulative survival rate was 97 percent.

The Oxford Knee in early arthrosis: 7-year results

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Introduction: The Oxford Knee is an unconstrained device in which spherical metal components on the femur are separated from flat metal components on the tibia by polyethylene meniscal bearings. The bearings are fully congruous on their upper and lower surfaces with the metal components throughout the range of movement, minimizing wear and creep. The components can be used either unicompartmentally or bicompartmentally, with retention of all the ligaments. Choice of bearing thickness to an accuracy of 1 mm allows restoration of ligament tension, and therefore ligamentous control of movement laxity and muscle leverage. Because the components offer no resistance to sliding and distraction movements of the bones on each other, they transmit only compressive forces so that long intramedullary spikes are not needed for fixation. The small components minimize bone resection; there is virtually no blood loss so that simultaneous bilateral arthroplasty is simplified. When varus/valgus deformities are passively correctable, limb alignment can be restored to normal without soft-tissue release. Absence of a patellar flange avoids stress shielding of the anterior distal femur and the many problems recently associated with the patellofemoral joint in tricompartmental arthroplasty.

Clinical trial: Between June 1978 and August 1987, 327 knee replacements were performed, mean follow-up 51 months. Of these, 220 were bicompartmental, 75 medial, and 32 lateral. Fifty-two women and 12 men had bilateral arthroplasties, whereas 132 women and 43 men had unilateral arthroplasties. In all, 219 of the knees were arthrotic and 103 rheumatoid. The average age of the patients at surgery was 66 years and the average weight was 67 kg. At surgery, 180 of the knees had an anterior cruciate ligament described as normal, while 116 had damaged or absent ACLs. The PCL was present in all the patients.

Survival analysis: At August 1, 1988, 301 knees had been reviewed at least once at special monthly clinics; the range of follow-up time was 2–103 months. Twenty-four had failed, the Oxford components had been removed, and either a more invasive prosthesis implant or an arthrodesis was performed. On this basis, at 7 years, the cumulative success rate by the method of Kaplan-Meier was 88 percent. The incidence of failure did not depend on age, sex, weight, preoperative or postoperative alignment. Positive risk factors were found to be disease and the state of the ACL. At 7 years, the cumulative success rate was 97 percent in rheumatoids and 83 percent in arthrotics. It was 96 percent in knees with a normal ACL and 81 percent in knees in the which the ACL was damaged or absent.

Clinical results: In the ACL normal group, pain during activity was relieved in 93 percent and the flexion limit was reduced insignificantly from a mean of 105° to 102°.

Discussion: These results indicate that an unconstrained meniscal bearing prosthesis is not suitable in advanced arthritis after the ligaments have been damaged. Total condylar-type arthroplasty is now preferred in such cases. However, in about half the knees requiring arthroplasty, there has been irreversible damage to the articular surfaces; but the ligaments, particularly the anterior cruciate, remain intact. In such cases the meniscal prosthesis provides a conservative, physiological, and reliable treatment. In rheumatoid arthritis, it competes with total condylar arthroplasty. In arthrosis, many

knees in which the ligaments remain intact suffer from unicompartmental disease when the device competes with tibial osteotomy. Its freedom from imposed axes of movement, low wear rates, and the facility to tension the ligaments accurately makes it particularly applicable to unicompartmental replacement.

Uncemented total knee arthroplasty in young adults

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Patients and methods: Totally, 53 uncemented total knee arthroplasties in 42 patients using porous coated implants (PCA) were evaluated. The PCA prosthesis was inserted using the PCA Universal instruments, designed to give good fit of bone to the prosthesis and exact positioning of the prosthetic components and reestablishment of correct alignment of the extremity. The patients were operated on during the period 1982–1986. The patients were evaluated clinically and radiographically.

Results and discussion: Range of motion and pain relief were good. One patient died during the observation period. One patient had the prosthesis removed caused by a hematogenous infection. Another patient was operated on at another hospital. The prosthesis was neither loose nor infected. No loosening of any prosthetic component occurred.

Uncemented PCA arthroplasty provides satisfactory results in younger patients.

Constrained or nonconstrained total knee arthroplasty

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Like the knee joint itself, the design of a knee prosthesis has to allow flexion and extension movements, as well as tibial femoral rotation. Functioning of the subtalar joint is of great importance in terms of load transmission of the knee joint.

Because pronation of the foot is combined with abduction, and supination with adduction of the foot, loading of the leg with the foot in pronation will result in medial rotation of the lower leg, as positioning of the foot in supination causes lateral rotation. These rotational movements mainly take place at the tibiofemoral level, especially when the knee joint is not locked in full extension. Therefore, walking on uneven ground will induce rotational stress on the prosthesis, which will be transmitted to the bone-cement interface, when not compensated for by the prosthetic components. Therefore, a purely constrained knee prosthesis has to be considered as less adequate from a biomechanical point of view.

Accurate radiographic assessment of tibial component migration in Freeman-Samuelson knee arthroplasty

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Introduction: Conventional radiography is a rather blunt instrument for early detection of prosthetic migration due to absence of reference points and different positioning of the knee during the follow-up (1). Radiostereophotogrammetry (RSA) gives an accuracy at least 10 times that of ordinary radiography. The method has been used in several studies of knee and hip arthroplasties, and is excellent for scientific use (2, 3). However, RSA is time-consuming and is therefore hard to use in every-day practice. This paper presents a new method for detecting prosthetic migration that is easier to handle than RSA, but also with great accuracy.

Materials and methods: In order to minimize the error due to different positioning of the knee during repeated radiographs and to obtain exact reference points, markers were placed in the upper tibia and the prosthesis according to Figure 1.

The bone markers are placed approximately 10 mm in the vertical line below the matching prosthetic markers, four pairs of matching reference points are created. The distance between the two matching markers are measured postoperatively and at each follow-up. Subsidence and tilt in the AP and lateral planes can be detected. The error due to different positioning of the knee during repeated radiographic investigations can be calculated. Provided that the difference in posi-

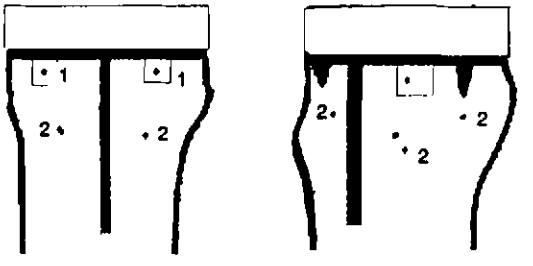

Figure 1.
A–P and lateral view of upper tibia with inserted Freeman-Samuelson tibial component
1. Prosthetic markers.
2. Tantalum bone markers.

tioning is less than 15°and the focal distance is kept constant, the error is less than 0.5 mm. This theoretical calculation was tested in an experimental situation with known prosthetic displacements. The method has been used in a prospective clinical study where the accuracy was tested with RSA. So far, 43 knee arthroplasties in 41 patients have been followed 3–12 months with radiographs taken postoperatively and at 3, 6, and 12 months.

Results: The experimental study showed a good correlation between radiographic results and known prosthetic displacement. The error was less than 0.5 mm for all the cases. RSA has confirmed that this is true also in the clinical study.

Discussion: The described method is reliable and very easy to handle and evaluate, with an acceptable accuracy. We think that it can be used as a routine method with great advantages compared with conventional radiography.

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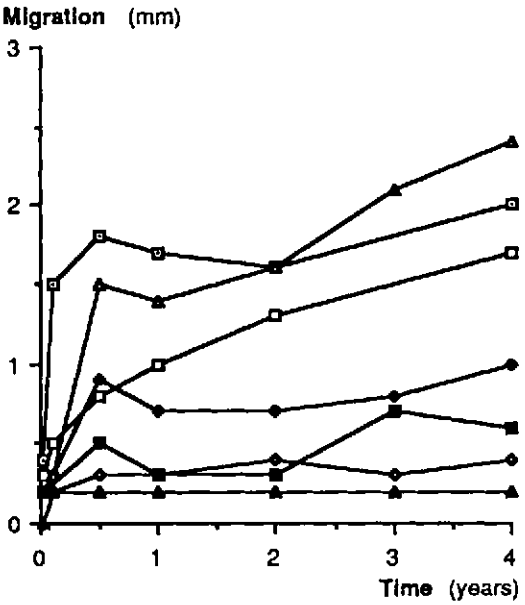

Figure 1.

Micromotion of the tibial component after PCA total knee arthroplasty

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Introduction: The Porous Coated Anatomic (PCA) total knee prosthesis was one of the first devices utilizing the concept of bony ingrowth into porous surfaces for fixation. We have used roentgen stereophotogrammetric analysis (RSA) to measure micromotion of the tibial component.

Materials and methods: Twenty cases of knee arthroplasty for gonarthrosis, Stages III–V, were followed for 4 years. Thirteen tibial components were inserted without cement, whereas seven were inserted with cement because of inferior bone quality. Immediate full weight bearing was allowed. All the cases except one cemented 1 were successful after 4 years.

Micromotion of the tibial component relative to tibia was measured by RSA. The motion was measured longitudinally from the postoperative day up to 4 years (migration) and, after 1 year, and for noncemented components also after 2 years in response to external physiologic forces (inducible displacement).

Results: Migration was found, mostly during the first year in all except 1 cemented case. For the cemented cases (Figure 1), the mean migration was 0.8 mm and for noncemented cases (Figure 2), 1.9 mm at 1 year. After 1–2 years, 9 noncemented and 2 cemented cases stabilized ($P < 0.05$). Inducible displacement was found for all the cases: 0.4 mm for cemented and 0.7 mm for noncemented cases ($P < 0.01$). After 2 years, the mean inducible displacement for noncemented components was 0.6 mm. A correlation ($P < 0.01$) was found between the migration after 1 year and the absolute deviation of the mechanical axis from the ideal 180°, as well as the deviation of the prosthetic position from the ideal 87°in the frontal projection.

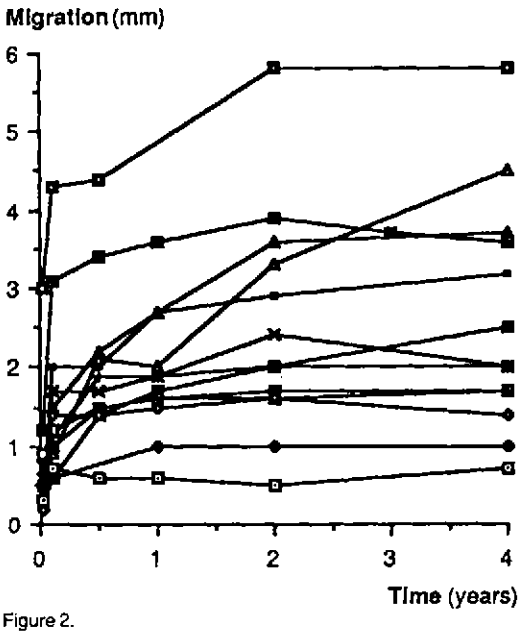

Figure 2.

Discussion: The micromotion found for the cemented cases, both migration and inducible displacement, was similar to that previously found for other types of cemented tibial components, such as the Total Condylar and the Kinematic.

The noncemented components moved downwards, i.e.,

subsided, about 1 mm already during the first week. We believe this is equivalent to simple impaction of the prosthesis with weight bearing. During the remaining part of the first year, these components showed about the same migration as the cemented ones, and this migration is interpreted to correspond to the healing and remodeling of the prosthetic bed. After 1 year, the noncemented components stabilized to a larger extent than the cemented ones, and also to a larger extent than the previously studied Freeman-Samuelson prosthesis. The inducible displacement was also less for the noncemented PCA prosthesis than for the Freeman-Samuelson prosthesis.

We interpret the inducible displacement of the noncemented cases to be incompatible with stable bony ingrowth; instead, it indicates a fibrous tissue fixation. When mature, this interface seems to have sound mechanical properties.

Ideal prosthetic positioning and reconstruction of the mechanical axis are of importance for a favorable migratory pattern.

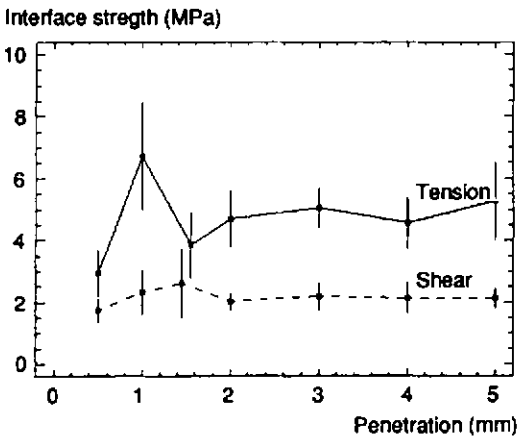

Figure 1. Mean value and 2 x SEM are shown.

Cement-bone interface strength: Influence of bone strength and cement penetration

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Introduction: The cement-bone interface in knee joint prostheses is considered the critical zone at which aseptic loosening takes place. The aim of the present study was to correlate the mechanical properties of the cement-bone interface to 1) the compressive strength of the trabecular bone estimated from its stiffness measured by nondestructive mechanical testing, 2) the bone density determined by CT scanning, and 3) the depth of cement penetration.

Materials and methods: Cylindric specimens (N = 264) from proximal tibial epiphyses of 20 pairs of autopsy knees were used. The stiffness was determined by nondestructive compression to 0.6 percent strain and the bone density by quantitative computed tomography. The specimens were cemented to seven different depths of penetration (0.5, 1, 1.5, 2, 3, 4, and 5 mm) verified radiographically. Finally, the cemented cement-bone specimens were allocated to either tension testing (N = 141) or shear testing (N = 123).

Results and discussion: The *tensile strength* and the *shear strength* of the interface correlated with both stiffness (r = 0.50/0.53) and bone density (r = 0.60/0.65). The maximum tensile strength of the interface was reached at a depth of 1 mm of cement penetration (Figure 1). Penetration beyond 2 mm caused no further increase in the interface strength. At 0.5 mm of cement penetration a clearly reduced tensile strength was apparent due to a cement pull-out mode compared with trabecular fracture failure mode at deeper penetrations. No correlation was found between the interface shear strength and the cement penetration. The interface strength in tension was 2–3 times the strength in shear.

Calculation of the angular correction in high tibial osteotomy for medial gonarthrosis

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Radiographic analyses of preoperative and postoperative whole-limb radiographs of 35 and eight knees treated surgically for medial arthrosis with wedge or dome osteotomy has led to the following guidelines for calculation of the correction in tibial osteotomy.

1. During osteotomy, translation in the lateral direction of the tibial eminence (K) occurs. The degree of surgical correction in wedge osteotomies has therefore to be increased by 1°and in most dome osteotomies by 3-4°. These figures may explain why dome osteotomies are commonly undercorrected.

2. The preoperative degree of varus deformity is reduced for instability of the lateral compartment. If this is not done, overcorrection may occur. By calculating the sum of the femoral and tibial condylar angles and taking into account the stage of arthrosis, lateral instability is assessed to an accuracy of 1°.

3. Overcorrection of more than 2°of valgus will result in reduction of femorotibial translation. In medial arthrosis with lateral instability, this reversal of translation accounts for the phenomenon of increased medial joint space named"cartilage regeneration." Each 3 mm of reduced translation will result in a further 1°of overcorrection and each millimeter of increased joint space in another 1.5°.

4. In all 6 cases out of 35 osteotomies in which the overcorrection exceeded the intended surgical correction (4°of valgus) by at least 2°, the overcorrection was due to underestimation of the lateral instability.

Adduction moment about the knee compared with radiographic and clinical parameters in gonarthrosis

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Fifteen patients with medial gonarthrosis grades I–III, classified according to Ahlbäck, without symptoms from the hip, ankle, or opposite knee were selected for this study. The mean age was 67 years, mean weight 79 kilograms, and mean height 171 cm. Clinical assessment was made according to the British Orthopaedic Association (BOA) knee function chart. Radiographic assessment was made from radiographs of the hip, knee, and ankle in the frontal plane during weight bearing. Both the Hip-Knee-Ankle (HKA) angle and the mechanical axis were determined. The maximum adduction moment and the adduction moment during midstance were determined with a Kistler force plate and a videorecording system. The adduction moment was calculated in newton meters and normalized to body weight in kilograms and height in centimeters. The mean BOA score was 34 (32–37), and the mean HKA angle was 10°(5–18°) in varus. The mechanical axis was located in the medial compartment of the knee in 10 patients and further medially (i.e., outside the knee) in 5 patients. The normalized mean maximum adduction moment was 0.44 (0.08–0.62), and the normalized mean midstance adduction moment was 0.31 (0.03–0.51). Results from this relatively small series of patients indicate no significant correlation between clinical parameters, magnitude of the HKA angle, grade of gonarthrosis, and magnitude of maximal or midstance adduction moment.

Change in adduction moment about the knee after high tibial osteotomy and prosthetic replacement in gonarthrosis

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Fourteen patients with moderate medial gonarthrosis — 7 operated on with high tibial osteotomy and 7 operated on with unicompartmental prosthetic replacement (Brigham) — were studied before and 6–12 months after corrective surgery. Hip-Knee-Ankle angle (HKA angle) was determined from long radiographs preoperatively and postoperatively. The maximum adduction moment and the midstance adduction moment was determined with a Kistler force plate and a videorecording system and normalized to body weight and height. Moments about the knee were calculated before and after corrective surgery and compared with the HKA angle. The mean HKA angle changed from 10 to 2°of varus in the prosthetic group and from 11°of varus to 3°of valgus in the osteotomy group. The mean normalized maximal adduction moment was reduced from 0.47 to 0.34 in the prosthetic group and from 0.47 to 0.26 in the osteotomy group. The mean normalized midstance adduction moment was reduced from 0.31 to 0.17 in the prosthetic group and from 0.35 to 0.15 in the osteotomy group. The attempted surgical correction according to HKA angle was achieved in both groups. The maximum adduction moment and the midstance adduction moment were reduced in both groups after corrective surgery despite increased walking speed.

The natural course of radionuclide bone scanning after total knee replacement

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Introduction: Radionuclide bone scanning (RBS) has in non-controlled studies been described as being an effective method for evaluation of total knee replacement. The aim of the present study was to describe the natural course of RBS after total knee replacement in a prospective and nonselected patient material.

Patients and methods: Forty-one patients underwent RBS after total knee replacement with the cemented Townley prosthesis. The examinations were done 3, 7, 12, and 24 months after surgery. One patient had loosening of the implant; 32 patients completed the whole study. The mean age was 69 years and the female:male ratio was 4:1. The total scintigraphic uptake was assessed in four grades.

Results: A total of 143 scannings were performed. No significant difference between the grades of total uptake at any of the four examinations could be demonstrated ($P = 0.20$, Wilcoxon's rank sum test). Twelve months after surgery, 20 percent of the patients still exhibited increased uptake; and 24 months after surgery 13 percent had definitely increased uptake, and 64 and 66 percent, respectively, had marginally increased uptake.

Conclusion: We find that the increased uptake after RBS that can be seen for a variable and extended period of time limits the usefulness of RBS in the evaluation of total knee replacement.

The Swedish knee multicenter study of arthroplasty of the knee

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In 1975, the Swedish Orthopedic Society agreed to report all arthroplasties of the knee to a central data base. All 43 orthopedic departments report preoperative and postoperative data, complications, and follow-up observations after 3, 6, and 10 years. The object of this prospective investigation is to identify good versus poor combinations of prosthesis and knee conditions, notably types and degrees of arthrosis and rheumatoid arthritis, respectively. Through 1987, 14,000 cases have been reported with a 3- and 6-year follow-up of over 90 percent. Comparisons with local projects indicate that minor complications, e.g., transient nerve injury, have been underreported, whereas serious complications and reoperations have been almost fully reported.

At the 10-year follow-up of 2,253 arthroplasties for arthrosis, 20 percent of the operations had been complicated: 3 percent deep infection and 17 percent mechanical loosening. The risk of reoperation within 6 years was 13 percent, and the risk of loss of knee function by arthrodesis or amputation was 3 percent. Certain combinations of endoprostheses and knee conditions were identified as having a high complication risk; the project has been analyzed continually to provide on-line information to all the participants.

Analysis of the initial 1,000 operations for arthrosis, followed for 6 years, shows that the unicompartmental arthroplasty has caused fewer complications than the total knee arthroplasty, and there has been a higher proportion of satisfied patients. Analysis of prosthetic survival of the initial 6,500 cases indicates that the risk of revision of the dominant types of endoprostheses inserted during the period 1981–86 was only one half of that of the period 1975–80. Nearly 50 percent of the attempts to perform an arthrodesis after a failed prosthesis did not result in union, and this fraction was larger with the larger prostheses and at units with relatively small numbers of patients..

This project will continue because important changes have been introduced in the latest generation of knee prostheses without the support of long-term follow-up.

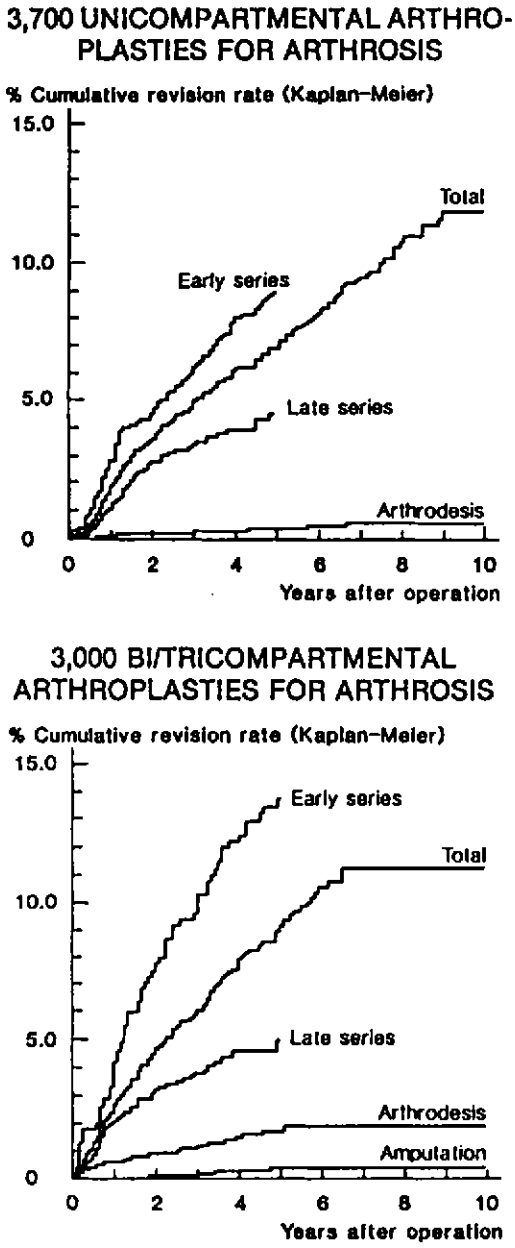

Figure 1. Comparison of early (1976–1980) and late (1981–1986) series of unicompartmental (top) and bicompartmental/tricompartmental (below) arthroplasties suggests that revision within 10 years after operations performed today will be well below 10 percent.

The PCA unicompartmental knee

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Introduction: Unicompartmental knee endoprostheses have been in use for 17 years, and in general the results have been satisfactory, though some criticism has been raised. In the reported materials, however, there are differences in patient selection, diagnosis, and severity of the underlying disease. There are also differences in the various endoprostheses used in relation to anatomic design and use of guide instruments and fixation principles.

Materials and methods: The purpose of this study is to report the early clinical and radiographic results of the PCA unicompartmental endoprosthesis. Because the prosthesis can be used both with and without cement, the results of a randomized comparison with respect to the use of cement is also presented. Totally, 127 knees were operated on with this device for gonarthrosis stages 1–3 according to Ahlbäck.

Results: The clinical findings for 84 arthroplasties, with 1–4 years' follow-up, showed 81 excellent or good results. The mean postoperative HSS score was 91 points. The mean postoperative flexion was 124°.

There were 3 failures, all with persistent pain on walking.

Two failures were among 43 uncemented knees, whereas 1 was among the 41 cemented arthroplasties. Four uncemented arthroplasties had a first steps´ problem despite good or excellent HSS score. There were no infections and no clinical loosening. Reoperation was performed in 1 case, where a symptomatic osteophyte was removed.

The position of the tibial component was in the AP view 86.3°±2.0°(ideal 87.5°), and in the lateral view 89.1°±2.8° (ideal 90°).

Discussion: Compared with our earlier Marmor series, both cemented and uncemented PCA unicompartmental arthroplasties showed better results. A cemented arthroplasty, however, gives better results with a higher frequency of full pain relief. An uncemented arthroplasty is more technically demanding and should still be regarded as experimental and only considered in special situations.

PCA total knee replacement — 3–5-year follow-up

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Introduction. The PCA prosthesis is a semiconstrained total knee replacement that preserves the posterior cruciate ligament, and which can be used with or without bone cement. We report 3- and 5-year results from a prospective study.

Patients and methods: We have used the PCA system since September 1982 at Huddinge Hospital. Cementless fixation has been used when the quality of the bone was considered adequate.

In the first 200 consecutive cases, the diagnosis was degenerative arthrosis (A) in 132 cases; 68 were classified as rheumatoid arthritis (RA). Cemented fixation of the tibial component was used in 19 (14 percent) of the arthrosis cases and 28 (41 percent) of the RA cases. During the follow-up, 8 patients died and 1 tibial component was revised. By January 1988, 21 knees had passed the 5-year and 77 knees the 3-year follow-up.

Results: Clinical findings. Totally 112 of the 1-year, 63 of the 3-year, and 20 of the 5-year group reported complete or almost complete relief from pain. A range of motion of 90°or more was reported in more than 80 percent. The results did not deteriorate between the 3- and 5-year follow-ups.

Radiographic findings. Tibial-component migration or tilting more than 5°was seen in 15 knees. Incomplete radiolucent zones wider than 2 mm were seen in 5 percent of the cases and appeared nonprogressive after 3 years.

Complications. One patient died postoperatively due to cerebral embolism. One uncemented tibial plateau in a patient suffering from RA was revised because of subsidence after 35 months. Deep vein thrombosis, verified by a phlebogram, occurred in 6 cases. Superficial wound healing problems were seen in 5 cases, and all of them healed with antibiotic treatment. Patellar problems, usually due to maltracking with lateral subluxation, were noted in 5 cases, necessitating soft-tissue realignment in 2 cases. One patellar component was replaced. There were no deep infections.

Conclusion: Most of the complications recorded appear to be preventable. Uncemented PCA total knee replacement appears to preserve bone stock and give satisfactory clinical results. The surgeon must respect the need of precise technique and careful judgement of bone quality.

Medial and lateral compartment loading of the knee after Oxford meniscal knee arthroplasty — an in vitro study

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Object: To measure the compressive forces transmitted by the medial and lateral compartments of the knee in vitro after Oxford Meniscal Knee Arthroplasty in simulated single-legged and two-legged stance.

Introduction: In the modern practice of arthroplasty, considerable attention is paid to the correct alignment of the implant in the coronal plane to avoid overloading either the medial or lateral compartments. However, the relationship between load distribution and load direction has not been established.

Methods and materials: Four anatomically normal specimens were taken at autopsy. Oxford Meniscal Knee prostheses were implanted in both compartments, care being taken to ensure that the tibial components lay perpendicular to the tibial axis in the coronal plane. The load taken by each compartment was measured by a flat load cell (Entran) in each meniscal bearing. To simulate flexed knee stance, each specimen was mounted in a 6-degree of freedom rig. The applied vertical load of 8 kg, tending to flex the knee, was balanced by tension in a wire attached to the quadriceps tendon. The line of action of the applied load could be varied by adjusting the alignment of the limb in the coronal plane and could be made to pass in any plane through the ankle from the medial to the lateral edge of the knee. For each of the limb alignments, and hence load directions, the compressive forces in the medial and lateral compartments were measured over the flexion range from full extension to approximately 100°.

Results: The table below gives the percentage of the total compressive force taken by the medial compartment with the plane of the load acting (a) through the tibial eminence and (b) medial to the medial compartment. The figures in brackets give the range of variation from specimen to specimen.

For each of the load directions, the ratio of the sum of the compressive forces (medial and lateral) to the applied load varied from approximately unity near full extension (average 1.39 [1.01–1.65]) at 10° of flexion to approximately seven times the load (average 7.07 [6.78–7.27]) at 90°of flexion.

Discussion: The Oxford Meniscal Knee is a totally uncon-

Table 1. Percentage of total compressive force taken by the medial compartment with the plane of the load acting (a) through the tibial eminence and (b) medial to the medial compartment

Flexion Angle	20°	40°	60°	80°	100°
(a)	45 (34–70)	47 (37–63)	41 (33–52)	39 (32–50)	44 (33–54)
(b)	78 (67–99)	70 (66–87)	59 (52–70)	52 (46–59)	49 (38–59)

strained prosthesis that allows retention of all the ligaments and also allows the accurate restoration of ligament tension by the appropriate choice of bearing thickness. The results obtained from these specimens may therefore have relevance to the intact joint. The contribution of the lateral compartment is quite considerable even when the line of action of the load passes outside the medial edge of the medial compartment. This would suggest that the variation in the loading of the two compartments in the presence of quadriceps force is somewhat less than has been previously suggested.

Short-term results of the PCA total knee prosthesis without cement

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Introduction: The object of this retrospective study was to evaluate the short-term results of the PCA total knee prosthesis without cement.

The PCA prosthesis is an anatomically shaped tricompartmental prosthesis that has a porous-coated surface. The kinematics of the prosthesis are similar to those of the normal knee, including free rotation and an automatic screw-home movement.

Materials and methods: Since 1983, 35 uncemented PCA total knee prostheses have been inserted with a mean follow-up of 36 (30–56) months. All the patients were graded according to the Insall knee rating system: the position of the prosthesis was measured, and the incidence of the extent of radiolucencies was noted.

Results: The mean preoperative/postoperative total score was 48.5/78.9 (Figure 1). Twelve patients scored excellent, 19 good, 2 fair, and there were 2 failures. The mean flexion preoperatively/postoperatively was 101 (40–130)/ 99 (45–125). The mean extension postoperatively was 0 (0–17).

The mean values of position of the components in relation to the femoral and tibial axis were ideal, but the standard deviations were large. In one fifth of the knees the femoral tilting was more than 10°, with a maximum of 20°. In most of the knees, there were small zones of radiolucency, but never more than 2 mm. Nevertheless, in 3 patients, there was a considerable migration of the tibial component, but this had no clinical effect.

Complications: In 1 patient a tuberositas tibiae transposition was performed 2 months postoperatively because of lateral luxation of the patella. In 1 patient an arthrodesis was performed because of persistent pain, and in another patient a revision was necessary because of loosening.

Conclusions: The short-term results of the PCA knee prosthesis without cement are good. A stable interface between prosthesis and bone seems to be possible without cement; but in the first series the ideal positioning of this prosthesis was often not achieved, and this could affect adversely the long-term results.

Short-term results of the PCA revision prostheses in failed knee joint replacements

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Patients and methods: In 21 patients, PCA revision prosthe-

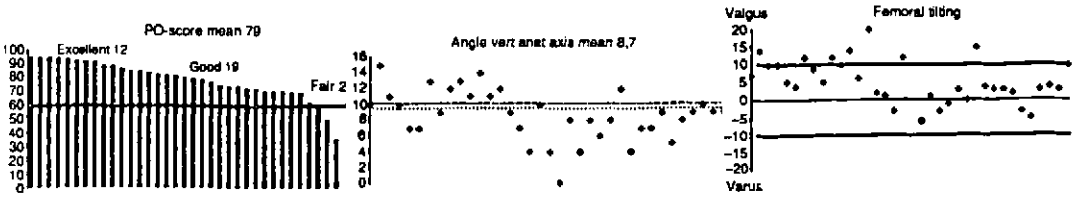

Figure 1. Results in 35 uncemented PCA total knee prostheses

ses were implanted in the period 1984–1988. Fourteen of the patients were operated on because of loosening, 2 patients had malalignment and malpositioning, and 5 patients had infected primary implants. In all the patients, bone loss was compensated for by the special prosthesis, and additionally by bone transplants. Fifteen of the prostheses were cemented with antibiotics added to the cement. In 6 younger patients the prostheses were inserted with primary stability and left uncemented. All the patients were followed postoperatively with a median time of observation of 26 months.

Results: The clinical results were good.

Conclusions: The PCA revision prosthesis is a very good alternative in the treatment of patients with mechanical loosening of primary arthroplasties and especially in patients with malalignment and malpositioning, ligamentous imbalance, and excessive bone loss. The combination of bone transplantation and uncemented prostheses must be the treatment of young patients rather than knee arthrodesis.

Major bone transplantation in total knee arthroplasty

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Introduction: The majority of patients in whom a knee arthroplasty is indicated can be managed by different kinds of uni-endoprosthetic or total knee endoprosthetic designs. In special situations the standard knee endoprosthesis is not sufficient, and revision types are indicated. When this special situation is combined with excessive bone loss, minor or major bone transplantation has to be considered. The aim of the present investigation is to report the early results of total knee arthroplasty in combination with major bone transplantation.

Patients and methods: Five knees in 4 patients were operated on with the PCA total knee revision endoprosthesis in combination with major bone transplantation during 1986 and 1987. There were 3 women and 1 man. The mean age was 66 years. In four of the knees, this was the first surgical procedure due to advanced gonarthrosis (Ahlbäck stage V), whereas the remaining knee was a revision from a failed Marmor knee arthroplasty. The condyles (four tibial and one femoral) were transplanted by an autogenous bone graft covering at least 50 percent of the surface and fixed by screws. The revision prostheses were always cemented.

Results: All five knees have had a successful outcome after 1–2 years. The Bauer score had 4 patients as satisfactory and 1 as acceptable. Scintimetry showed major bone remodeling, and roentgen stereophotogrammetry showed stable implants.

Discussion: In these highly destroyed knees, even an arthrodesis would have been a possible alternative. With this background, it is important to emphasize that all the knees could be managed by a surface type of replacement, and that during the same time period no stabilized knee endoprosthesis has been used by our group. At surgery, all of these knees had excessive bone loss that had to be compensated for. Cement spacing has had drawbacks and is biomechanically unsound. The major autogenous bone transplantation performed here was stabilized by screws; and a cemented long-stemmed revision type of knee endoprosthesis, with many different sizing options, was used. The early results are promising.

A new surgical approach to the knee

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The purpose of this paper is to describe a new surgical approach to the knee for ACL reconstruction and biomechanical experiments that support certain elements in the procedure. In this procedure the donor-site defect in the patellar tendon is used to enter the knee.

By this approach not only a patella tendon graft can be easily put into place in an exact isometric position, but also necessary additional surgical interventions can be performed, such as meniscectomy, meniscus reconstruction, and notch plasty. An isometric position of the transplant can be achieved by an inside-out drilling procedure of the femoral tunnel and by the use of that test ligament. In this manner the isometric fixation points can be identified before drilling the tunnels. Biomechanical experiments in pig cadaver knees have also proved that closing of the defect in the patellar tendon does not add tensile strength to the extensor mechanism, but has only disadvantages, such as creating patella baja and extra tension in the retinacula. In this procedure the defect in the patellar tendon is left open and only covered by a thin layer of fascia that has been spared at the beginning of the operation.

The main advantage of this technique is that an extensive arthrotomy and luxation of the patella during the operation can be avoided, and the profit of this is obvious in terms of rehabilitation. Experience of 85 cases showed no complications from the area of the defect during rehabilitation or later on.

Noninvasive evaluation of the knee: Correlation with anatomic findings, histology, and MR imaging

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Thirty fresh cadaver knees were imaged with magnetic resonance (MR), and then a gross and histologic examination was

performed. MR images were obtained with a 0.5 T superconducting imager. In sagittal and coronal planes, a spin-echo sequence produced contiguous 4-mm-thick images emphasizing T1 tissue characteristics. All the knees underwent surgical examination by an anatomist and orthopedic surgeon; on 27 normal menisci at the gross evaluation, 9 surgical radial sections were made perpendicular to the horizontal anatomic plane of the meniscus and each of them was stained for microscopic examination. The cruciate ligaments (ACL-PCL) and the hyaline cartilage were also studied. MR images and histologic stages were separately evaluated by two radiologists and a pathologist in a prospective blind protocol. All the data were recorded on a computer and results are evaluated on R.O.C. curves. The accuracy of MR technique is high for cartilage evaluation; a very small lesion can be missed. The sensitivity of the method is 89 percent and the specificity 100 percent. For the meniscus evaluation, in comparison with gross examination, the sensitivity of MR was around 70 percent and the specificity 90 percent. In 14 of 25 normal menisci at the surgical evaluation, a high signal intensity was identified; and in these knees the histologic examination showed abnormalities. It is interesting to consider the 100 percent correlation of histologic lesions and MR signal intensity in menisci without macroscopically visible tears. This study shows the advantages of a noninvasive method to evaluate the knee joint and the good predictive value of MR imaging. Gross examination of the menisci (surgically or arthroscopically) cannot completely eliminate a degenerative lesion.

Normal patellofemoral biomechanics analyzed by MRI

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Introduction: Patellofemoral incongruence can predispose to patellofemoral chondromalacia, arthrosis, and to patellar subluxation and dislocation. Axial plain radiographic evaluation of the patellofemoral incongruence requires knee flexion of at least 25–30°. The normal position of the patella in 0° knee flexion and the normal patellofemoral biomechanics during the first 30° of knee flexion is not known exactly, even though it is supposed that biomechanical faults already below 30° of knee flexion can have clinical significance for the development of patellofemoral disorders.

Materials and methods: Ten males and 10 females without knee symptoms were examined. Both sagittal and axial MR images were produced from the patellofemoral joints with the knee flexed 0, 10, 20, and 30 degrees. The axial images were produced through the middle of the patellar articular cartilage. Special equipment was used to support the knee to predetermined flexion angles and to maintain the forefoot in a vertical position. Different patellofemoral indexes were measured from the MR images using a computer-assisted system.

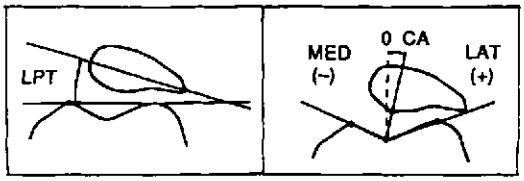

Figure 1. LPT: lateral patellar tilt; CA: congruence angle.

Results and discussion: When the knee was in extension the sulcus angle was greater ($P < 0.001$), the lateral patellofemoral angle was smaller ($P < 0.001$), there was more lateral patellar displacement ($P < 0.001$), the patella tilted more laterally (LPT; Figure; $P < 0.001$), and the congruence angle (CA; Figure) directed more laterally ($P < 0.001$) than in 30° flexion. Some differences between males and females were recorded.

CA was negative (open medially) for one male and no female when the knee was extended. The corresponding figures were 6/4 in 10° of knee flexion, 7/6 in 20° of knee flexion, and 9/9 in 30° of knee flexion. In 30° of knee flexion, CA was zero for 1 male and 1 female. During active isometric quadriceps muscle contraction with the knee in extension, LPT decreased ($P < 0.01$), but the patella moved either medially or laterally.

MRI is a safe and useful tool in evaluating the patellofemoral biomechanics during the first 30° of knee flexion. At the beginning of the flexion the patella normally lies laterally in a somewhat tilted position, but moves to a congruent position during the first 30° of knee flexion.

Long-term follow-up of patients operated on for recurrent dislocation of the patella

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Introduction: Recurrent dislocation of the patella has been treated with well over 100 different types of operations most of which, however, are modifications or combinations of about 10 basic procedures. Early results regarding stabilization of the patella are often encouraging, but less is known about the long-term, overall condition of the operated on knees. The purpose of this paper is to report the status of knees operated on because of a dislocating patella after a long-term follow-up.

Patients and methods: Fifty-one knees, previously operated on at the Department of Orthopedics in Lund were evaluated clinically and radiographically 15 (6–35) years after the operation. The age of the patients at follow-up was 37 (28–72) years. About half of the patients were operated on with a transfer of the tibial tuberosity medially and/or distally. Other procedures included release of the lateral capsule, duplication of the medial capsule, and distal-lateral advancement of the vastus medialis.

Results: Most patients gained stability of the patella after the operation, but 1 of 10 did not improve at all. At the follow-up, less than 2 of 10 were free of pain. The mean Lysholm score was 72 (20–100) points, and the mean activity level was 3 (1–7). Half of the patients had developed patellar arthrosis. The results of the different operative procedures were approximately the same.

Conclusions: Despite an acceptable degree of success regarding patellar stability, the status of these knees after long-term follow-up was poor in most cases, and the patients were compensated by a decrease in the activity to a level supported by their bad knee(s). From this point of view, the problem of the dislocating patella does not seem to be solved.

Radiographic assessment of the patello – femoral joint – normally and after surgical treatment for recurrent dislocation of the patella

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The long-term results of surgical treatment for recurrent dislocation of the patella (RDP)do not appear to be optimal, and almost half of the knees in our series of 51 knees had arthrosis of the patellofemoral joint 15 years (mean) after treatment (see previous abstract).

Therefore, we analyzed these 51 knees for abnormal positions of the patella and compared them with normal patellas by means of four different radiographic methods for determination of patellar height (1, 2, 3, 4). Also, the degree of external rotation of the foot and femoral-tibial end rotation was assessed, using fluoroscopy and CT.

Results: The Insall index (3) is not adequate for evaluating patellar height, and another two methods (1, 4) are influenced by anatomic variations and joint laxity. Therefore, a new method is proposed (2). A variety of abnormal positions of the patella were recorded, but no correlation with the development of arthrosis was found. In most knees with RDP, there was an abnormal, increased external rotation of the lower leg and abnormal end rotation of the knee.

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Late results in high tibial osteotomy related to mechanical axis deviation recorded at 3-month follow-up examination

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Introduction: A previous study suggested that the mechanical axis (M.A.) deviation observed at the earliest postoperative time permitting measurement (after 3 months) might have predictive value as to late clinical results. A study has now been made of the age dependence of this predictive date.

Materials and method: Series A: 66 knees (43 male and 23 female patients, 28–74 years) with *varus* deformity. Series B: 16 knees (9 male and 7 female patients, 17–76 years old) with *valgus* deformity. Clincal 3–4-year results were assessed according to Freeman and graded 100 = good, 85–95 = fair, < 85 = poor. A "favorable range" (±2° in width) of 3-month M.A. was sought in both series, containing no poor results. The frequency of poor results within/outside the said range was statistically tested.

Results: For Series A (varus cases) the favorable range lay mostly, and for Series B (valgus cases) totally, in the area of valgus deviation at 3 months, showing linear shift of respectively 2° and 0.5° per 10 years in the valgus direction. The frequency of poor results differed significantly ($P < 0.001$, chi-square) in Series A between the cases within vs. outside the favorable range (0 vs. 31 percent).

Conclusions: The status (M.A. deviation) of the knee 3 months after surgery appears to furnish good indication of the degree of ultimate success in correction of hemiarthrosis. Obviously the objective to be achieved p.p.i. is *overcorrection* (up to nearly 10° valgus deviation at high age) when correcting varus malalignment, and slight *undercorrection* in all the cases of valgus malalignment.

Hydroxylapatite-bioglass composite as knee condyle prosthesis in the rabbit

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Introduction: Earlier studies have demonstrated bioactive bone-bonding behavior of bioglass and calcium-phosphate ceramics. Our preliminary studies of a new composite consisting of hydroxylapatite (HA) and bioglass (B) gave encouraging results with regard to its capacity to enhance calcified tissue formation and to create firm bonding with bone. Therefore, an experimental study was done to find out if this HA-B composite could be used as a prosthesis and coating material in a knee condyle prosthesis under functional service conditions.

Materials and methods: A condylar prosthesis with a gold-palladium metal frame and HA-B bulk was created. Its articular surface was coated with a B layer (100–200 µm) and HA-B composite (300–500 µm) was sintered on the surface against bone. Twenty-eight prostheses were implanted to replace the medial femoral condyles of 22 rabbits (3–6 months, 3.3–4.0 kg) under general anesthesia. The animals were killed after 3, 6, and 12 weeks. Clinical, radiographic, and histologic examinations, as well as SEM and EDAX analyses, were used to evaluate the results.

Results and discussion: Ten successful cases with unbroken, fixed, and functionally working prostheses were found. Eighteen failures were the result of postoperative infection (8 cases) and improper initial fixation of the prosthesis. In successful cases, histologic examination showed new bone formation with focal areas of fibrotic tissue in the interface between the prosthesis and femoral bone surface. Marked corrosion was found in the HA-B layer of the prosthesis by SEM. Despite the low successful rate obtained, we consider the new HA-B composite as a promising coating material for implants of various purposes.

Central cancellous graft of the leg for long-standing pseudarthrosis of the tibia

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Introduction: The treatment of pseudarthrosis of the tibia may fail because infection and a bone defect form obstacles to union. A method of bone grafting was developed that works irrespective of the length of the tibial defect and does not lead to recurring infection.

Patients and methods: Forty-six patients presented with 47 pseudarthroses of the tibia. All but 2 of the patients were referred from other hospitals, with a mean interval after the accident of 3 years. An AO plate had been used in 28 legs. Deep infection was present at the time of admittance or had been present in 34 legs. The mean number of operations that had been performed before was 3.8 (0–10). In 17 patients the pseudarthrosis had been considered untreatable and amputation had been recommended. All the infected patients had poor skin cover over the subcutaneous surface of the tibia. When infection was present, all the necrotic bone and soft tissues were removed with a wide excision. Complete removal of bone and soft tissues with a marginal viability was deemed important even if this meant creating a larger bone defect. The wounds were left open. The tibia was reconstructed through a lateral approach between the peroneal muscles and the long extensor. The interosseous membrane was dissected from the tibia and fibula and moved dorsally. The tibial and fibular surfaces were roughened with a gouge, and the space between the tibia and fibula was filled with long cancellous strips from the posterior iliac crest. In the cases of a proximal pseudarthrosis, the proximal part of the membrane was excised, carefully saving the anterior tibial vessels and the peroneal nerve. The legs were stabilized in a long walking plaster and the patients were treated with oral anticoagulants.

Results: The average time to union was 6.5 (1.5–24) months. Two patients were grafted twice. One leg was amputated. Knee movement was only slightly restricted. Ankle and foot movements were usually severely restricted at the time of admittance, but recovered to a useful radius. Apart from the one amputation because of recurring infection, no deep infection occurred. Especially in the defect pseudarthrosis, the graft developed into a cortical bone forming a marrow cavity.

Conclusion: Central grafting of the leg is a dependable procedure.

Normal fracture healing in the tibial shaft imaged by magnetic resonance

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Introduction: Magnetic resonance imaging (MRI) is sensitive to flow and to changes of the molecular environment in the tissues. Because of these characteristics, it could be expected to be able to detect deviations in biologic processes, such as long-bone fracture healing. But before it will be possible to evaluate MRI as a diagnostic method in this respect, the MRI appearance of normal fracture healing has to be established first. Delayed union is still a problem associated particularly with fractures of the tibial shaft. In this study the tibial shaft fracture was the subject of the MRI scanning.

Patients and methods: Serial MRI scans were taken of 6 randomly chosen adult patients with solitary, closed fractures of the tibial shaft at 1-month intervals until union of the fracture occurred. The treatment of the fractures was conservative by closed reduction and immobilization in a long-leg plaster cast. An ultra-low field 0.02 T (tesla) magnet equipment with two imaging modalities generating predominantly and less T_2-weighted images, respectively, was used. Transverse, coronal, and sagittal plane images were obtained, and the opposite uninjured leg was always scanned simultaneously for comparison.

Results: All the studied fractures turned out to heal normally, the mean clinical union time being 14 (10–18) weeks. The MRI observations common to all the patients were as follows: The intramedullary cavity initially showed a marked decrease of signal intensity on the less T_2-weighted scans, probably because of interruption of the intramedullary vascular flow. In the cortical bone of the fractured section of the tibia, there was a slight gradual increase of the signal intensity. In the surrounding soft tissues the signal intensity was initially high due to the fracture hematoma and swelling, but decreased considerably within 1 month. At 2 months the soft tissues showed a nonhomogeneous, granular appearance with embedded low-intensity nodules. These corresponded to the first calcifying areas of the maturing callus as could be seen on plain radiographs not until several weeks later.

Conclusions: Serial MRI scans of the healing of tibial shaft fractures normally revealed a characteristic sequence of events compatible with what is known about the histomorphology of fracture healing. MRI seemed to be able to demonstrate calcification of callus earlier than plain radiographs.

Ankle and foot

Roentgen stereophotogrammetric analyses of operated on ankle fractures

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Internal fixation with wires, staples, and pins is probably the technique most often used for ankle fractures in Sweden. The aim of this prospective study is to analyze, roentgen stereophotogrammetrically, the postoperative ankle stability and the ankle mortise mobility 18 months after operation. Thirty-two supination and 28 pronation injuries were randomized to either weight bearing immediately postoperatively (n 30) or from the fourth postoperative week (n 30). During operation, tantalum bone markers were inserted into the ankle mortise.

Results: Stereophotogrammetric analyses revealed only small movements in the ankle mortise during fracture healing. A greater mean dorsal translation (0.8/–0.1 mm) and outward rotation (2.3/0.5 degrees) of the fibula were found among pronation compared with supination injuries, but the clinical results did not differ. No differences were found between ankles with (n 9) compared with those without (n 15) a ruptured deltoid ligament, indicating that repair of the ligament is not necessary. Early and late weight bearing did not differ.

Analyses of the ankle mortise mobility showed an increased rigidity in the fractured ankles (n 57) compared with a reference group of uninjured ankles (n 7). This rigidity was not influenced by type of fracture or time when weight bearing was allowed. No differences were found between ankles with a broken staple (n 12) compared with those with an intact staple (n 45). Thus, extraction of the osteosynthesis devices is in most cases not needed.

The stabilizing effect of the Watson-Jones reconstructive procedure on lateral hindfoot ligament lesions: An experimental study

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Introduction: The aim of the present experimental study was to clarify the stabilizing effect of the Watson-Jones reconstructive procedure on movements in the hindfoot joint complex after a lesion to the anterior talofibular ligament and the calcaneofibular ligament, with special interest for the talocalcaneal joint.

Materials and methods: The experiments were carried out on six osteoligamentous specimens. A kinesiologic testing device with potentiometers and strain gauges was used. The modified Watson-Jones procedure was performed by using the peroneus brevis tendon left inserting in the fifth metatarsal bone. The tenodesis was performed with the hindfoot joints in the neutral position.

Results and conclusions: Following the Watson-Jones procedure, restriction in movements was recorded for all directions measured except external rotation and dorsiflexion, where no stabilization of the ligament lesions was shown for the total hindfoot joint complex or for the talocalcaneal joint. The study demonstrates the Watson-Jones procedure's ability to restrict normal movements in the hindfoot joints. This accords with clinical experience. Moreover, instability in external rotation known to follow a lesion to the calcaneofibular ligament is neither reconstructed in the hindfoot joint complex nor in the talocalcaneal joint.

Activity of the peroneal muscles, the maintenance of balance, and prevention of inversion injury of the ankle: An electromyographic and kinematic study

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Introduction: Gait analysis with electromyography and photography was performed to detect the forces that stabilize the ankle and secure balance in walking individuals.

Subjects: The electrical activity of all superficial leg muscles was sampled with surface electrodes at speeds of 2, 3, and 5 km/h in 20 subjects walking on a moving belt. The walking individuals secured their balance either by external support (hand on railing) or by natural forces. Walking cadence and photographic registration were guided by electronic means once the natural cadence was established.

Results: When the subjects secured their balance by external support, the activity of flexors and extensors of the foot alternated during the stance and sway phase of the walking cycle. Activity of the peroneus longus and brevis muscles was absent.

When balance was kept in a natural way, there were strong bouts of synchronous activity of the peroneus longus and the extensor digitorum longus muscles in the stance phase. A contraction of these muscles shifts the weight-bearing area to the medial structures of the foot and correction of balance in the frontal plane occurs, moving the center of gravity laterally. Alternatively, the tibialis anterior muscle was active in the stance phase, lifting the medial border of the foot, thus shifting the weight-bearing area to the lateral border and moving the center of gravity in a medial direction. Balancing activity might be absent for several steps.

Conclusion: The peroneus longus and brevis and extensor longus muscles are responsible for maintaining balance in the stance phase. Because they are active in part of the stance phase only and are sometimes inactive during several steps,

the foot is not guarded against inversion injury of the ankle by muscle activity of the peroneal group (1). Training the individual to use the peroneal muscles in the prevention of inversion injury of the ankle has a negative effect on the maintenance of balance. When the normal foot is placed on a flat surface, it is stable. Each individual can protect the foot against inversion injury by watching its step.

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The distribution of bone strength at the distal tibia and fibula

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Introduction: Total ankle arthroplasty has not gained widespread acceptance because of an unacceptably high rate of mechanical loosening, especially of the tibial component, from 16 to 30 percent. Only a few studies on trabecular bone strength at the ankle joint have been published. And as far as we are aware, no studies of the distribution of bone strength between the malleoli and the central tibia have been carried out. To determine whether an increasing amount of prosthetic-bearing bone would add appreciable strength to support ankle prostheses, a study on the penetration strength patterns of the malleoli and the central tibia was carried out.

Materials and methods: Eight distal tibial specimens were obtained at autopsy (mean age 72 [49–87] years). All the patients were mobile prior to death. The central part of the tibia was measured at 18 locations evenly distributed over the joint surface. The malleoli were measured at seven measuring points evenly distributed over the joint surfaces. The cartilage at the measuring points was removed before testing. A pointed needle, with a 90°cone, a 2.5-mm projected diameter, and the shaft milled to 2.3 mm to avoid friction along the shaft, was forced into the cancellous bone at right angles to the resection surface. A depth-force curve was obtained. The initial 1.5 mm of the curve, representing increasing contact with the measuring profile, was disregarded. The next 6 mm was divided into three 2-mm intervals. Strength data are reported as average penetration strength = force average over the 2-mm intervals/projected area of the measuring profile.

Results: The bone strength profile at level one at the central tibia had peaks at the anterolateral and posteromedial areas at the central part of the tibia; this pattern was more or less recognized through all levels. At the lateral malleolus a high-strength area was located at the anterior border. No constant strength pattern could be recognized at the medial malleolus. The average strength ratio between both the malleoli and the central tibia was 0.9:1. There was a significant reduction in bone strength with depth through all levels in all parts of the ankle joint (Student's paired test).

Discussion: In estimating the prosthesis-bone contact area, the ratio between both the malleoli and the central tibia is found to be approximately 0.3:1, and the average ratio of bone strength between both the malleoli and the central tibia is approximately 0.9:1. Based on the assumptions above, the results indicate that an increase in the load-bearing capacity of about 20–30°could be obtained by extending the tibial component of the ankle joint prosthesis to cover the malleoli. The reduction of bone strength with increasing distance to the joint surface indicates that great care should be taken when resecting in preparing for the implantation of the prosthesis.

Total ankle joint replacement: A clinical follow–up

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Introduction: In the past 10 years, total ankle arthroplasty has been a realistic alternative to arthrodesis. The advantages of total ankle arthroplasty are rapid remobilization, no need of splinting, and, because joint motion is preserved, no increase in the mechanical stress of the neighboring joints; especially the patients with rheumatoid arthritis would benefit from this.

Patients and methods: Richards' TPR type of total ankle joint replacement was employed in thirty ankles in 25 patients. At follow-up, 2 patients were dead, 5 patients were excluded because of too short a follow-up period. For follow-up, there remained 23 ankles in 18 patients, with a mean age of 62 (37–77) years; 21 ankles had RA and 2 arthrosis. The average follow-up was 5 (3–7) years. The maximum score for function was 50 points, for pain 40 points, and 10 points for motion.

Results: The average preoperative/postoperative score was 19/29 for function, 12/32 for pain, and 2/2 for movement. Seven ankles were totally and another seven significantly relieved of pain. The average walking distance was improved from 260 meters preoperatively to 975 meters postoperatively.

Discussion: In view of our results and results reported by others, we conclude that the overall results of ankle joint replacements when compared with arthrodesis (1, 2) are so poor that it will only be indicated in a very few and carefully selected cases. Unless design and method of fixation are improved, not even the RA patients, who have slightly better results than the arthrosis group, should be offered this procedure before considering arthrodesis.

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Tendinitis: Preliminary evaluation with MRI and soft-tissue radiography

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Introduction: MRI is a noninvasive modality that allows high-contrast imaging of the tendons (1, 2, 3, 4). We prospectively compared MRI with radiography using mammographic technique (5) in 14 patients with tendinitis of the Achilles tendon or the patellar tendon.

Patients and methods: Fourteen sportsmen with clinical tendinitis were evaluated. Nine had Achilles tendinitis and 5 had a tendinitis of the patellar tendon. The mean age was 31 years. All the patients had a radiograph and MRI within 3 weeks. MRI was performed with a 0.35 tesla superconducting unit using spin echo pulse sequence in T-weighted contrast (TR 500 ms/TE 26 ms). We compared each tendon with the tendon of the opposite side. Both examinations were separately interpreted without clinical knowledge. Four patients underwent an operation.

Results and discussion: At MRI the results were three normal tendons, five cases with tendinitis, and six partially ruptured tendons with an exact location of the rupture. Radiographically, the results were three normal tendons, eight cases with tendinitis, and three partially ruptured tendons. Four patients were operated on, and the rupture was confirmed. All the operated on patients had a correct MRI diagnosis; the rupture was found only in 2 patients using radiography. There are not enough patients in this study to definitively and statistically draw a conclusion, but MRI appears to be a modality of choice for studying the pathologic tendons. It is a noninvasive examination that gives a precise diagnosis of the pathology and eliminates other pathology by showing the other anatomic structures.

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The late result of Achilles tendon ruptures

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Introduction: The number of Achilles tendon ruptures has increased in recent years. An important reason for this is the steady increase of sports activities. Ten years ago, we operated on about 10 patients annually with an Achilles tendon rupture, whereas in the past year, we operated on 25 patients with the same condition.

Patients and methods: We report 273 cases of Achilles tendon rupture between 1970 and 1985. The proportion of athletes was about 70 percent, and the cause of injury mostly soccer and other ball games. Complete subcutaneous ruptures were found in most cases. When possible, we chose the tenosuture, with a tenoplasty of the M. plantaris; in the other cases, we operated with direct suturing, whereas in a few cases, we twisted a flap from the proximal tendon stump 180° (Umkipplastik). The complication rate after operation was low. No reoperation was necessary. Postoperatively, we used a below-knee plaster for 7–9 weeks followed by mobilization by intensive physiotherapy.

Results and discussion: A follow-up about 4 years after operation showed good functional results, but 20 percent of the patients had muscular atrophy of the lower leg of 1.5–2 cm. We assume that muscle training after removal of the plaster is very important for the late result. After intensive postoperative physiological training, the patients are fully rehabilitated and are able to engage again in their sports activities. We found no significant difference between the different methods concerning late results.

In vitro studies of a new method of Achilles tendon repair

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Introduction: The mechanical factors in Achilles tendon repair have been studied, and a new design for increasing the tensile strength of the repair has been developed. The new technique does not constrict the blood supply of the tendon.

Materials and methods: Laboratory experiments were carried out to modify a continuous six-stand suture (CSSS) technique for Achilles tendon repair.

Ten tests each of Bunnell, Mason, and CSSS tendon repair were carried out. The tensile strength was measured in a tensiometer, and the gaps appearing between the tendon ends under load were measured. A Ticron® 0 suture was used in all the cases.

Results: In the autopsy study, the Bunnell suture had a tensile strength of 7.7 (5–11) kg, the Mason suture 4.5 (2–6) kg, and the CSSS suture 26.3 (16–30) kg. The gap between the two tendon ends at a load of 6 kg was on an average 19 mm when sutured by the Bunnell method, more than 30 mm by the Mason method, and 4 mm by the CSSS method.

Conclusion: A continuous six-stand suture of a tenotomized Achilles tendon had three times the tensile strength, and minimized the gap between the tendon ends to one fourth in comparison with the Bunnell and Mason techniques.

Synovial changes in ankles with chronic lateral instability

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The histopathologic synovial changes were prospectively studied in 70 patients with 75 ankles having clinically and radiographically verified chronic lateral ankle instability. After operation with a peroneus brevis tenodesis, all, except 1 patient, claimed to have benefitted from the operation. The microscopic changes were divided into degrees of none, slight, moderate, and extreme.

Results and discussion: Twenty-eight of the 75 ankles had moderate or extreme degrees of synovitis. The degrees of ankle instability did not influence the severity of the changes. The degree of synovitis was more pronounced among men than among women, but the difference was not significant. Factors that significantly influenced the degree of synovitis were 1) duration of instability of more than 48 months, 2) accompanying degenerative changes, such as old bony avulsions, calcifications, chondral fibrillation, and clefts, and 3) ankles having continuing stress and load applied, i.e., sports-active patients.

To reduce symptoms and possibly prevent the development of arthrosis, we recommend ligamentous repair in active patients suffering pain in connection with long-standing lateral instability and with degenerative changes in or around the ankle joint.

Chronic ankle instability and peroneus muscle function

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Introduction: In the treatment of chronic lateral ankle instability, the use of the peroneus brevis tendon is described in many operative methods, but very little is known about the influence on the peroneal muscle activity. The aim of this study was to evaluate the function of the peroneal muscles before and after a static and a dynamic repair.

Patients and methods: There were 33 prospectively studied patients with chronic lateral ankle instability. Twenty-six patients were operated on with a static repair with use of the whole peroneus brevis tendon, which was transected proximally at the muscle belly. Seven patients had a dynamic repair using only the anterior half of the peroneus brevis tendon transected at the base of the fifth metatarsal bone. Three weeks before and a median of 10 months after the operation, the peroneal and the medial gastrocnemius muscles were examined with an integrated surface EMG. The EMG responses and curves of movements were simultaneously registered on a four-channel MFE recorder.

Results and discussion: In the whole material, there was a great variability in the EMG responses, but the elapses of the EMG curves for the different movements were quite characteristic and independent of sex, healthy or diseased leg, time of examination, and type of operation. The maximal peroneal EMG response was significantly higher in men than in women, which was also the case for the proportion between the peroneal and the gastrocnemius muscles. Neither preoperatively nor postoperatively were there significant differences between the healthy and the diseased leg of the same patient. After the operation, there was an increased peroneal activity in plantar flexion in both legs. Dynamically operated on patients had a higher response during dorsal flexion and heel raising. No other differences were found.

Functional instability in mechanically unstable ankle joints

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Introduction: The most common and serious residual disability after lateral ligamentous injuries is functional instability. The exact pathophysiologic entity responsible for functional instability is still unknown, although several theories have been proposed. Four possible causes of functional instability have been mentioned: viz., mechanical instability, peroneal weakness, tibiofibular sprain, and proprioceptive defect. The purpose of this study is to examine the proprioceptive system in mechanically unstable ankle joints compared with stable joints.

Materials and method: An apparatus to simulate ankle sprain was constructed. It consists of a trapdoor that can be tilted to 30° from the horizontal plane. Surface EMG electrodes were placed over the peroneus brevis and peroneus longus muscles. The time from tilting of the plate to the first muscular response on the EMG is defined as the reaction time. The reaction time corresponds to the ankle sprain. Twenty individuals with one stable and one unstable ankle joint were tested. The mechanical stability was evaluated with standardized radiographs, with measurement of anterior talar translation (ATT) and talar tilt (TT).

Results: The ATT in the stable ankles (mean [SD]) was 5.9 (0.9) mm and 12.2 (3.5) mm in the unstable ankles. The TT was 3.2 (0.8)° in the stable ankles and 10.5 (1.6)° in the unstable ankles. The reaction time was 68.8 (4.5) ms for the peroneus longus and 69.2 (4.1) ms for the peroneus brevis in the stable ankles compared with 77.3 (6.1) ms for the peroneus longus and 75.2 (5.7) ms for the peroneus brevis in the unstable ankles. The difference was significant ($P < 0.001$) in all the ankles for the peroneus longus and peroneus brevis.

Discussion: The results imply that the muscular response is slower in mechanically unstable ankle joints than in stable ankle joints. Functional instability might be due to a combina-

tion of mechanical instability, i.e., increased ATT and TT and proprioceptive defect, that is, increased reaction time during an inversion torque. Increased reaction time can be due to the mechanical instability in the functionally unstable ankles. However, functional instability is a complex syndrome due to more than one functional and mechanical factors.

Surgical reconstruction of inveterate ligament damage in the ankle joint

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Several techniques for restoring the function of insufficient lateral ankle ligaments have been presented, usually by using a tendon graft as a ligament substitute. We report on a new surgical procedure used in patients with chronic lateral ankle instability.

Patients and methods: During the period 1979–86, 76 patients (83 ankles), age 16–55 years, with chronic lateral instability of the ankle were treated by a simple reconstructive operation. A transverse periosteal incision was made just distal to the tibiofibular ligament and distally extended along the posterior margin of the malleolus. The periosteum with the attached anterior talofibular and calcaneofibular ligaments, as well as the retinaculum, was separated from the tip of the malleolus. The released flap was then reattached by osteosutures in a more proximal position on the decorticated malleolus. Seventy-five patients (82 ankles) were examined with a mean of 23 (12–70) months following surgery.

Results: In 66 ankles the result was excellent, with fully restored stability and preserved normal range of motion. In 12 ankles the result was good, with improved, but not fully restored, stability in nine ankles and persistent intermittent pain and swelling in two. Deterioration with recurrence of instability occurred in one ankle following a severe reinjury 2 years after surgery.

Conclusion: The technique described in the present study is easy to perform and could be recommended as surgical treatment of chronic unstable ankle joints where both the anterior talofibular and calcaneofibular ligaments are insufficient.

Biodegradable fixation in chevron osteotomy for hallux valgus

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Introduction: Biodegradable implants for internal fixation of malleolar fractures were introduced in 1984 at our department. The experience obtained from more than 100 patients has been satisfactory. In March 1986, chevron osteotomy for hallux valgus using biodegradable fixation was introduced, and the results are analyzed.

Patients and methods: Seventy-five osteotomies were performed in 61 patients (59 women and 2 men with an average age of 35 [14–65] years). An angle of more than 10° between the first and second metatarsal bones and pain at the first metatarsophalangeal joint were the indications for surgical intervention. The 4–5 mm lateralization of the metatarsal head was secured with a 2-mm by 25- or 30-mm cylindric polydioxanone (PDS)-coated, self-reinforced polyglycolide (PGA) rod.

Results: When 50 out of the 75 osteotomies had been followed up for at least 6 months, no failures of the fixation were observed. The bony union proceeded uneventfully in all the cases. The preliminary functional results were satisfactory. As a complication, there occurred one superficial infection, and in 3 patients a sinus in the scar without any bacterial growth was formed. The sinuses healed within a few weeks, with no influence on the radiographic or functional results.

Conclusion: A fixation of the chevron osteotomy is, in our opinion, necessary to maintain the achieved position until union. The technique used in this method is simple. No major complications were seen, and no removal of the fixation material is needed.

Metatarsal head resection in the rheumatoid foot

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See Abstract in Proceedings of the Netherlands Orthopedic Society, *Acta Orthop Scand* 1988;59(2):226.

The first branch of the lateral plantar nerve and heel pain

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The course and fiber composition of the first branch of the lateral plantar nerve has been studied in four fetal and in 34 adult feet. In this study, attention has been paid to the possible relationship of this branch with the heel pain syndrome. From its point of origin, this branch runs just distally to the medial process of the calcaneal tuberosity in a lateral direction to the proximal part of the abductor digiti minimi muscle. A narrow passage through a tough fascia could not be found. A possible

site for entrapment may be located between the abductor hallucis muscle and the medial head of the quadratus plantae muscle. Because indirect evidence is provided that this branch may be of a mixed type, the severe pain complaints of the heel pain syndrome may arise from compression of sensory fibers.

Upper extremity

Arthroscopic resection of the acromion

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Introduction: Arthroscopic technique reduces the operating trauma compared with open methods. Open resection of the acromion is quite common, and a method for arthroscopic resection was developed and used.

Patients and methods: Twenty-seven patients underwent arthroscopic resection of the acromion. The patients were placed in the lateral position. The shoulder joint was inspected for injuries. Resection was then carried out with a Dyonics motorized intraarticular, surgical equipment (abrader) inserted in the bursa subacromialis laterally and the arthroscope posteriorly. In an experimental study, 20 cadaver shoulders were operated on prior to this in the same manner. Postoperative preparations confirmed that adequate bone resection was possible.

Results: One to 20 months after the operation, 21 patients were free of pain and 6 still had pain. One patient was back at work 2 days after the operation, and 15 patients were back at work 4 weeks after the operation. The remainder were out of work 4–8 weeks.

Conclusion: In short-term follow-up, the result of arthroscopic resection of the acromion seems comparable to the open method.

Subacromial impingement decompressed with anterior acromioplasty

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Introduction: Subacromial impingement of the tendinous part of the rotator cuff is a well-known entity of surgical pathology of the shoulder joint. Reduced volume beneath the coracoacromial arch and the unyielding nature of the coracoacromial ligament are considered causative factors of chronic shoulder pain.

Patients and methods: Sixty shoulders in 56 patients with a symptomatic (Stage II) impingement of the rotator cuff against the coracoacromial arch were treated with anterior acromioplasty. The mean age of the patients was 43 years. The diagnosis was based on the patients' personal history, with chronic shoulder pain aggravated by overhead activities. Arthrography of the shoulder joint was routinely performed to eliminate a tear of the rotator cuff. Anterior acromioplasty as described by Neer was done with the removal of a possible bony prominence of the undersurface of the acromion or the acromioclavicular joint. The rotator cuff was always examined. The follow-up period averaged 48 months. Sixty-degree oblique radiographs of both shoulders were taken to evaluate the acromial shape. The result was rated according to the functional assessment key of Neer.

Result: The result was excellent or satisfactory in 73, unsatisfactory in 19, and poor in 8 percent. The majority of the patients recovered within 6 months. The surgical observations confirmed the high prevalence of osteophytosis on the undersurface of the acromion. The degree of degeneration of the tendinous part of the rotator cuff accorded with pathologic findings of the coracoacromial arch.

Discussion: Decompression of the coracoacromial arch is the treatment of choice for patients with a chronic subacromial impingement syndrome. A critical patient selection is crucial. Because the acromial shape plays a role in a resistant impingement syndrome, attention should be paid to patients with Type III of acromial inclination. The surgical procedure should include a thorough examination of the subacromial space, taking notice of all the pathologic findings in the subacromial arch, as well as in the underlying soft tissues. Failure to recognize the associated bony pathology, as well as soft-tissue subacromial pathology, was a frequent cause of failure in surgical decompression.

Rotator cuff reconstruction with routine decompression and early motion

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Introduction: The principles of repair to as near normal anatomy as possible, decompression and early passive motion developed by Neer were adopted by the author. This is a report on the first 100 patients treated in this fashion.

Materials and methods: From 1981 to September 1987, 142 patients with cuff defects were seen including 14 patients who had progressed to Cuff Tear Arthropathy (CTA). One hundred patients were operated on during this period. The origin of the defect was traumatic in 51 percent, nontraumatic in 37 percent, associated with dislocation in 8 percent. Average age at surgery was 60 (37–89) years. An anterior acromioplasty (Neer) was part of the exposure through a Gardner approach in most patients. Rotator cuff attachment was reconstructed as close as possible to the greater tubercle, with the arm to the "side." The shoulder was mobilized starting on Day 3 and the arm was held in neutral rotation and 30° of abduction in a foam splint for 6 weeks between exercises (5 times daily).

The defects/tears encountered were Grade 0 (incom-

Overall results	Good	Improved/ satisfactory	Unsatisfactory	n
in CTA	1	1	3	5
all other	43	9	5	57
defects by size				
Gr 0–III	40	7	3	50
Gr. IV	3	2	2	7

plete/covered with bursa) in 15, Grade I (small with side length < 1.5 cm) in 19, Grade II (medium with side length 1.5–3.0 cm) in 20, Grade III (large, side length < 5.0 cm) in 28, and Grade IV (massive, with side length > 5.0 cm) in 18 patients – the latter including 4 cases with CTA.

The defect was not closed in 1 patient (CTA, satisfactory result with pain relief), closed with bursa in 2 patients (CTA and Group IV, both unsatisfactory), closed with dura patch in 1 patient (CTA, unsatisfactory). The tendon of LHB and the coracoacromial ligament were used as graft material in 9 patients, subscapularis was transposed in 8. In 1 patient with CTA, a Neer II total shoulder was used in the reconstruction (good result).

Results: Of 62 patients, 5 had a follow-up time of 8–12 months and the remainder of more than 12 months.

Complications: Drainage from subcutaneous tissue in 2 patients, small abscess in deltoid in 1 patient, partial denervation of infraspinatus in 1 patient, rerupture of subscapularis in 1 patient, and a Grade I defect due to a fall on ice after repair of Grade IV defect 6 weeks postoperatively in 1 patient. Neer's criteria were slightly modified and used to evaluate the overall results. Pain, function, and power were graded using the system of the American Shoulder and Elbow Surgeons.

Discussion: The cutoff between tears of up to 5.0 cm side length is obvious. The correlation between tear size and overall result seen in an earlier study was confirmed. Defect size had a linked influence on surgical technique and this had a linked influence on the overall result. Closure by dura patch or bursa is useless. Age at the time of surgery and preoperative duration of symptoms were not related to the overall result. There was a trend towards larger defects with longer duration of symptoms. In patients with preoperative pseudoparalysis of external rotation and marked infraspinatus atrophy, recovery of active external rotation was poor. Obviously this is also linked to defect size.

Prospective study of the results of the operative treatment of recurrent anterior dislocation of the shoulder

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Introduction: We present a prospective study of operative treatment of recurrent anterior dislocation of the shoulder as suggested by Sanders in 1978. In particular, we were interested in the limitation of external rotation, the scar, and the aftertreatment.

Patients and methods: In all the patients operated on in the period 1976–86, the following principles were used: 1) A lazy-S incision was made from the coracoid process to the skin crease in front of the axilla . An intracutaneous skin closure, left 3 weeks in situ, was done. 2) Through an arthrotomy, the Bankart lesion was identified and obliterated with a Blount staple. 3) The capsule and subscapularis muscle were shortened in such a way that during the operation the external rotation ability was 0°. 4) Postoperative immobilization was carried out for 3 weeks either by a sling or a Velpeau bandage. 5) The patients were allowed to return to sports activities 3 months postoperatively. Totally, 49 shoulders were operated on , 14 of which were in females. Nineteen of the shoulders were operated on the left side and 30 on the right side. In all the cases an arthrotomy was performed, and in 38 cases a posterolateral defect was found. In 31 cases, there was a Bankart lesion that was obliterated with a Blount staple (after roughing the anterior border of the glenoid).

Results: There were no cosmetically unacceptable scars except in 3 patients who all had a postoperative wound infection and debridement. Limitation of external rotation less than 50 percent was not noticed by the patients. Only the 3 patients who had a wound infection complained about limitation of function. Twenty-four patients returned to work within 8 weeks, whereas twelve patients did not return to work within 12 weeks. Complications: three wound infections and one recurrent dislocation 2 years postoperatively. Forty-one patients were satisfied, 5 patients were moderately satisfied, and 3 were not satisfied.

Conclusion: The operative treatment of recurrent anterior dislocation of the shoulder following the previous suggestions show a good result in function of the shoulder, cosmetically very nice scars, and a rapid return to work and sports activities.

Recurrent posterior shoulder dislocation treated by transposition of the pectoralis minor tendon to the lesser tubercle of the humeral head

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Introduction: Recurrent posterior shoulder dislocation is a rare condition, and its treatment has proved difficult. In 1976, the senior author started to treat these patients with transposition of the pectoralis minor tendon to the lesser tubercle of the humeral head. The transposed muscle exerts a forward and medially directed force on the humeral head. Internal rotation increases this force, which furthermore augments the effect against posterior dislocation.

Patients and methods: From 1976 to 1987, 23 patients (8 females and 15 males) were operated on for recurrent posterior shoulder dislocation. Nothing is known about the present condition of 3 of these patients. The remaining 20 patients

with 30 operated on shoulders have been followed for 6.6 (1–11) years postoperatively. The average age at operation was 20 (12-46) years. Seventeen dominant and 13 nondominant extremities were involved. Only 2 cases had a history of trauma.

Results and discussion: At follow-up, 9 shoulders were completely stable and showed excellent function with no discomfort. Eleven shoulders had no longer any instability problem. These patients were all satisfied with the result, although 2 patients had some pain during heavy exercise. The remaining 10 shoulders had recurrence of instability. However, none of the patients had more complaints than before their operation. In two shoulders the instability gradually increased from 1 to 2 years after the operation. One shoulder was initially stable, but had a traumatic rupture of the transposed tendon after 6 months. This patient was reoperated on with transposition of the long head of the biceps to the neck of the scapula, but this had no effect. The other seven shoulders became unstable within 6 months after the operation. Eight shoulders have been reoperated on with a posterior bone block, five of them in our clinic. Of these five shoulders, three became stable after the operation. However, all the reoperated on patients complained of pain and restricted range of motion. It seems evident that transposition of the pectoralis minor tendon to the tuberculum minor of the humeral head can stabilize a shoulder with recurrent posterior instability. The operation is simple, and the risk of harmful effects on the shoulder is minimal.

Long-term results after the Putti-Platt operation for recurrent anterior shoulder dislocation

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Introduction: In this retrospective study, we wanted to study the long-term results after the Putti-Platt procedure.

Patients and methods: Totally, 101 patients, 72 males and 29 females, were operated on with the Putti-Platt technique at our hospital between 1973 and 1981. Eighty-nine of these patients were followed up. Forty-three of them were evaluated with a clinical examination, establishing the range of motion and the functional score. The functional score evaluates symptoms, such as instability and pain. Thirty of the patients were randomized for strength evaluation with the Cybex dynamometer. The remaining 46 patients were interviewed by telephone. The mean follow-up time was 8 ±2 years.

Results: For patients under the age of 26, the frequency of recurrence was 29 percent; and in the age group above 26 years, it was 13 percent. The total frequency of recurrence was 20 percent, appearing 1 to 11 years after the operation. Despite the length of time since the operation, a decrease in strength in the operated on shoulder was found in abduction and in external and internal rotation. A decrease in range of motion was also found, most significantly in external rotation. Most patients had a high functional score, i.e., relatively few symptoms.

Conclusion: The recurrence rate of dislocation is unacceptably high, especially in the younger age group. We believe that the Putti-Platt method can be recommended only for patients older than 26 years of age.

Surgical treatment of recurrent anterior dislocation and subluxation of the shoulder

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Introduction: Alvik (1951) modified the Eden-Hybbinette operation for anterior instability of the shoulder. The anterior glenoid was reconstructed with an iliac bone graft placed in a preformed wedge-shaped groove in the neck of the scapula.

Patients and methods: Sixty-five patients (66 shoulders) were examined clinically and radiographically, with a mean follow-up of 6 (2–15) years.

Results: Redislocations occurred in 2 patients and an occasional subluxation in 1. Forty-five of the 57 radiographically examined cases showed a bony healing of the transplant. Nonunion occurred in 6 patients and resorption in another 6. Twelve patients had mild and 7 moderate arthrosis. The patients rated the operation as good in 61 cases, fair in 4 cases, and poor in 1 case.

Discussion: The rate of redislocations compares favorably with other more common procedures. There was a high rate of osseous union of the bone graft and a low frequency of reoperations. Twelve percent showed moderate arthrosis, but only 1 of these patients was symptomatic. The rate of arthrosis following shoulder dislocation is unknown, and our frequency is therefore difficult to evaluate.

Distal instability of the shoulder joint after severance of capsule and ligaments: An experimental study

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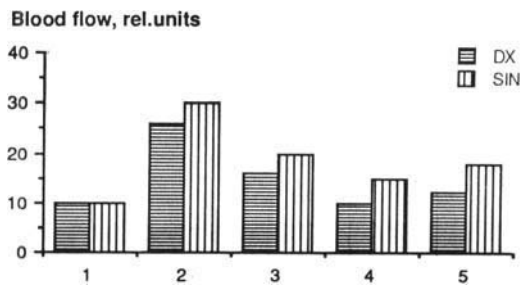
Multidirectional shoulder instability may occur from a specific traumatic episode or from repetitive microtraumas resulting in either a specific capsular and ligamentous lesion or an increased capsular volume, especially concerning the inferior part of the capsule. The object of this study was to measure the distal instability continuously during the abduction movement after sequential severance of capsule and ligaments.

Materials and methods: The experiments were carried out on 10 osteoligamentous shoulder specimens obtained from autopsy. All the specimens were tested in the following sequence: a) intact ligaments and capsule, b) cutting the coracohumeral ligament, c) severance of the subscapular muscle and the proximal third of the anterior capsule, and d) cutting the proximal part of the posterior capsule.

Results: There was a significant distal instability after severance of the coracohumeral ligament. Further cutting of the subscapular muscle resulted in an increased distal instability. The maximum distal instability of 13 mm was measured at an abduction angle of 20–30°.

Discussion: The distal instability of the shoulder joint is usually diagnosed by gentle traction on the upper arm with the patient upright and the humerus in the neutral position. According to our data, this test should be performed with the arm in 20–30° of abduction and neutral rotation.



1. Subcutaneous fat. 2. Muscle fascia. 3. Muscle. 4. Same; contraction. 5. Same; post

Figure 1. Blood flow recordings in a 23-year-old woman with work-related chronic myalgia of 3 years in the right trapezius muscle and who was unable to work the last 12 months. Biopsy normal on left side; mitochondrial damage on right side.

Morphology and blood flow in the trapezius muscle in work-related chronic myalgia

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Introduction: Previous studies showed morphologic and biochemical changes in the descending portion of the trapezius muscle in patients with localized chronic myalgia related to static load during very repetitive assembly work (1). The findings indicated mitochondrial damage in the type 1 fibers, which were significantly increased in frequency; and further, there were significantly reduced amounts of high energy phosphates (ATP and ADP). The aim of the present study was to correlate complaints, morphology, and blood flow by studying the right and left trapezius muscles in female assembly workers.

Subjects and methods: Thirteen women with a mean age of 38 (21–58) years were studied. Mean exposure time at work was 14 (2–28) years and symptom duration 5 (1–10) years. Eight patients had long-term sick leave. With local anesthesia of the skin and under surgical conditions, blood flow was recorded (2) by a laser Doppler flowmeter (Periflux®). Subcutaneous fat, muscle fascia, and muscle were assessed in the descending portion of the trapezius muscle, the tender region and corresponding contralateral site. Thereafter, biopsies were taken bilaterally.

Results and discussion: Evidence of mitochondrial damage ("ragged-red" fibers on Gomori staining, as well as with NADH tetrazolium reductase) was seen in 6 patients and in another 3 suspicious changes, showing good correlation with the most painful side. The most painful muscle had lower blood flow than the contralateral one in the basic condition, at isometric contraction, and at postcontraction rest. Almost as good a correlation was found for the muscle fascia, whereas the subcutaneous fat showed no consistent changes. The findings suggested that a reduced muscle blood flow may play a central role as pathomechanism for the occurrence of work-related chronic myalgia and associated mitochondrial disorder.

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Light-microscopic and biochemical muscle changes in work-related chronic myalgia

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Muscle biopsies from the descending portion of the trapezius muscle were studied in 9 healthy subjects and in 10 patients with localized chronic myalgia related to static load during very repetitive assembly work. The mean exposure time was 16 (10–31) years. The mean sick leave was 10 (4–26) months at the time of biopsy. Routine histopathologic and histochemical methods showed in both categories normal or borderline conditions, such as occasional abnormal muscle fibers with internally situated nuclei, isolated atrophic fibers, a certain variation in fiber diameter, fiber splitting, and even "moth-eaten" fibers. In contrast, "ragged red" fibers were exclusively found in the patients (8 out of 10) indicating myopathy. The phenomenon was confined to the type 1 fibers with distinct

Table. Work-related chronic myalgia. High-energy phosphates in the trapezius muscle

	Controls	Patients	
ATP	23.9 ± 1.0	18.6 ± 2.3	$P < 0.001$
ADP	3.3 ± 0.30	2.7 ± 0.24	$P < 0.001$
AMP	0.12 ± 0.03	0.15 ± 0.05	NS
TA	27.3 ± 1.16	21.4 ± 2.45	$P < 0.001$
ATP TCr	199.0 ± 8.7	168.0 ± 16.4	$P < 0.001$

ATP, adenosine triphosphate.
ADP, adenosine diphosphate.
AMP, adenosine monophosphate.
TA, total adenine nucleotide pool.
TCr, total creatine
(mmoles/kg of dry muscle)

zones of the fiber showing abnormal mitochondriae. The frequency of type I fibers was significantly increased. Biochemical analyses showed significantly reduced levels of ATP and ADP and a tendency towards low PC and TCr. Lactate, pyruvate, and glycogen were normal.

These changes associated with work-related chronic myalgia have not been reported earlier, and are quite different from those seen in acute muscle pain due to overload from physical training.

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Shoulder pain in middle age, occupational work load and psychosocial factors

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Introduction: With increasing age, degenerative changes occur in the acromioclavicular joints and in the rotator-cuff tissues. In a sample of 574 fifty-five-year-old subjects, we have studied the relationship between shoulder pain and social background, intelligence test, level of education, job satisfaction, social network, and occupational work load.

Subjects and methods: Totally, 319 men and 255 women, all residents of the city of Malmö, Sweden, and participants in the Malmö Longitudinal Study with background data collected since 1938, with information on the result of an intelligence test at the age of 10, social background, level of education, income, job career, and job satisfaction. The subjects were divided into three groups according to estimated physical demands on the job. A follow-up study was done one 1 year later on the 79 subjects who reported shoulder pain at the primary examination.

Results and discussion: The prevalence of shoulder pain was 14 percent (men 13 percent and women 15 percent). Women more often had symptoms of myalgia with local tenderness on palpation of the muscles around the shoulders and symptoms of rhizopathia-brachialgia, whereas men had their shoulder symptoms mainly located in the actual shoulder joints. Three percent of the subjects had been on sick leave due to shoulder pain in the year preceding the examination, and in 5 percent we found a reduced range of shoulder joint motion related to the shoulder pain. Subjects with shoulder pain were less satisfied with their jobs and had been less successful in the childhood intelligence test. No difference could be demonstrated between subjects with or without shoulder pain in estimated overall work load, but women with signs of supraspinatus tendinitis more often had jobs with physical demands. In a follow-up examination less than half of the subjects still had symptoms of shoulder pain after 1 year. Sick leave due to shoulder pain seemed related to work loads, because only men with moderate or heavy demands in their jobs had been on sick leave during the year preceding the examination. Shoulder pain also seemed related to intelligence among men in this study, for the more talented men had less symptoms from their shoulder joints. In women, we found no significant relationship between intelligence and shoulder pain, but on the other hand, a relationship to low job satisfaction. Women with moderate physical demands in their jobs more often had signs of supraspinatus tendinitis, which implies that women possibly are more sensitive than men to static load on their shoulders.

Table 1. Occupational work load among men and women with and without shoulder pain at the first examination

Group	I N (%)	II N (%)	III N (%)
Subjects with shoulder pain	31 (40)	38 (49)	8 (11)
Subjects without shoulder pain	244 (50)	199 (41)	42 (9)

Table 2. Intelligence test in 1938 at the age of 10 IQ-scale with a mean of 100 and a standard deviation of 15 units. IQ = 100 (mental age/chronologic age).

	Number	Mean score ± SD
Subjects with shoulder pain	78	94 ± 16
Subjects without shoulder pain	489	99 ± 15
Total number	567	

Total arthroplasty of the shoulder with the Neer prosthesis

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Sixty-four shoulders in 60 patients were treated with total arthroplasty using the Neer prosthesis. Thirty-eight of the patients, 34 with seropositive and 4 with seronegative rheumatoid arthritis (RA), underwent a Neer II replacement arthroplasty. Proximal humeral fractures (FR) were treated with arthroplasty in 22 patients.

In the RA patients, indications for the shoulder arthroplasty were disabling pain and impaired function caused by the severely restricted mobility of the shoulder with advanced radiographic destruction (Larsen's stages III–V). In fracture patients, four-part fracture with splitting of the humeral head was the main indication for primary arthroplasty in fresh fractures. In 5 cases the arthroplasty was made in later stages owing to pseudarthrosis or avascular necrosis of the head of the humerus. The average follow-up time for RA was 21 months and for FR 12 months.

In RA cases the relief of pain was excellent in all the cases, and the range of motion increased as well. Overall evaluation revealed an excellent or good result in 16 RA shoulders. Fifteen were ranked as satisfactory and 10 as nonsatisfactory. The most frequent radiographic inconvenience at follow-up was superior subluxation of the humeral component, which was moderate in 9 cases and severe in 4.

The average pain indicator in Neer's scoring was 25.5 points for FR cases (max = 35 = painless). Flexion and abduction movements more than 100° were measured only in 4 patients, 80–100° in 8, and less than 80° in 10 patients. The total functional score was 56.8 ±14.2.

The benefits of shoulder replacement with a total prosthesis in decreasing pain, especially in RA patients, are excellent; and the average pain score (25.5) in FR patients is at least at the same level as seen after other methods of treatment of these severe and compound fractures. The functional end result with RA patients was far better than that with the FR patients. The operation, however, with the FR patients is technically more demanding, with precise reduction of the fracture fragments.

Indications for hemiarthroplasty of the rheumatoid shoulder

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Introduction: Many orthopedic surgeons have no treatment to offer the RA patient with severe shoulder pain.

Materials and methods: Sixty-three shoulders in 57 patients were staged radiographically and operated on with a hemiarthroplasty using a humeral head prosthesis. Fifty-two shoulders were Stage 2 (attrition and erosions of the humeral head), and were operated on with a humeral head cup. Eleven shoulders were Stage 3 (severe destruction of the humeral head), and seven of these needed a stemmed humeral-head prosthesis. Postoperative physiotherapy was started immediately with the aim being that the patient would be able to reach the face, the back of the neck, the opposite axilla, and the perineum. The hospital stay was 2.3 weeks followed by 2–3 weeks of rehabilitation at another hospital or ambulatory physiotherapy. Twelve shoulders with a cup hemiarthroplasty were followed with roentgen stereophotogrammetry to detect migration (early loosening). The median follow-up period was 2 (1–7) years.

Results: All the patients were satisfied because their glenohumeral joints were painless, and function had improved with reference to dressing and personal hygiene. There were no complications. One shoulder cup had migrated 0.5 mm at the end of 1 year, but no migration was found in 11 shoulders.

Conclusion: Hemiarthroplasty of the shoulder is a successful operation. The majority of RA shoulders may be treated with cup hemiarthroplasty, which is a bone-saving procedure with good intermediate results.

Total shoulder replacement: Results with the Kessel prosthesis

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Introduction: There are few reports on total shoulder replacement in patients with rheumatoid arthritis, and only two publications based on small series of patients with a short follow-up on the use of the Kessel prosthesis (1, 2). The aim of this report is to present our 5-year experience with the Kessel prosthesis.

Patients: Between 1982 and 1985, 22 patients (23 shoulders) were operated on with the constrained Kessel total shoulder prosthesis. All the patients had rheumatoid arthritis and suffered from severe shoulder pain and very restricted shoulder motion. The mean age was 54 years and 19 were females.

Methods: An anterior surgical approach was used. The rotator cuff was left alone. Postoperative exercises were started within 1 week. In 1987, a review was carried out by an independent observer using a questionnaire to assess pain relief and ADL functions. At regular intervals, all the shoulders were examined radiographically. Radiolucent zones were measured in a standardized manner.

Results: Three patients had their prostheses extracted because of loosening. Three patients underwent exchange arthroplasty. Thus, 17 shoulders in 16 patients were left for study. All the patients reported pain relief. There was general improvement in ADL functions; none was made worse. Passive range of movement was slightly improved, but active movement remained unchanged. All the patients stated benefit from the operation. Radiographically, radiolucent zones developed around all the scapular components within 1 year, but only around one humeral component.

Conclusions: In rheumatoid arthritis, total shoulder replacement with the Kessel prosthesis was found to give good pain relief and improved shoulder and arm function. A high

incidence of radiographic glenoid loosening was observed, and was interpreted as a feature of the constrained design.

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Biomechanical analysis of surface-cup arthroplasty in the shoulder

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Introduction: Surface replacement in the rheumatoid shoulder has shown to be a clinically rewarding procedure (1). However, little is known about long-term risks of loosening. Earlier experiences with hip-surface replacement have not been favorable due to elevated stress peaks at the cup/bone interfaces, liable to cause disruption, relative micromovements and bone resorption (2). The purpose of the present project was to investigate whether these same phenomena could be expected to occur after surface replacement of the humeral head.

Methods: Using the Finite Element Method (FEM), a model was constructed, similar to the one used earlier to study the hip (2). Loading characteristics represented maximal forces for normal arm functions, with and without a 1-kg weight in the hand, for a 70°abduction range. Humeral head properties were varied to simulate the presence of cysts, subchondral bone retention, and removal. Bone and interface stresses were determined in all the cases.

Results: The cup/bone interface shear, tensile, and compressive stress patterns were similar to those in the hip, whereby the actual stress-peak values depended on the shoulder-joint force. Overall, these stress values were 40–70 percent lower in the shoulder in normal arm functions, but closely approximated those in hip-surface replacement when a 1-kg weight was carried in the hand. The highest stress peaks occurred near the inferior and superior cup edges, and were somewhat reduced by retention of the dense subchondral bone layer. They increased again when cement-filled cysts were present.

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Normal standards for collum humeri retroversion

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Present knowledge of retroversion of the collum humeri and glenoid tilt is based on a few studies on small series of subjects. The aim of this study was to determine collum humeri retroversion and normal range of shoulder rotation.

One hundred shoulders in 50 healthy subjects (25 women, 25 men) with no history of injury or surgery to the shoulder joint have been examined clinically and radiographically. None of the subjects suffered from generalized joint laxity according to criteria presented by Carter and Wilkinson. The mean age was 29 (22–40) years. The passive range of shoulder motion was examined in the standing position with a goniometer. Rotation was investigated in the adducted and the 90°abducted position.

A method has been developed to determine the collum humeri retroversion from a radiograph in a semiaxial view. Determination of the angle with this method has been checked with the use of computed tomography, and a high correlation has been found.

Results: The average angle for collum humeri retroversion was respectively 33°and 28°for the dominant and nondominant sides. No difference was found in the retroversion angle between the sexes. The mean value for external rotation in the 90°abducted position was 108°in the frontal and 120° in the scapular plane. The women had a larger external rotation: viz., respectively 111°and 120°in the frontal and scapular planes versus 103°and 111°for the men. There was a relationship between a large angle of retroversion and a large range of rotation. Women had a more pronounced rotation ability than men.

Biodegradable fixation in intraarticular fractures of the elbow joint

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Introduction: Biodegradable implants for internal fixation of malleolar fractures have been used at our department since 1984. In March 1986, an advanced study on the treatment of other intraarticular fractures with this new method was started in which fractures concerning the elbow joint were included.

Patients and methods: In this study, 30 adult patients with fresh intraarticular fractures of the elbow joint were treated using polydioxanon (PDS)-coated polyglycolide (PGA) cy-

lindric rods. There were 19 women and 11 men. The mean age of the patients was 34 (14–68) years. Fifteen had a fracture of the radial head, 11 of the olecranon, 3 of the capitellum humeri, and 1 of the medial humeral epicondyle.

Results: The reduction obtained could be maintained until union in 25 cases. In one fracture of the olecranon the fixation failed and a reoperation (AO tension wire) was needed. An insignificant secondary displacement was seen in 3 patients with a fracture of the olecranon and in 1 with a fracture of the radial head. No infections were seen, but a sinus formation of the wound without bacterial growth was observed in 4 patients. The functional result after a follow-up time of at least 6 months was deemed satisfactory in all the patients.

Conclusion: Our preliminary impression is that biodegradable fixation can be used successfully in the treatment of displaced intraarticular fractures of the elbow joint. It seems especially suitable for fractures of the radial head and the humeral capitellum. The atraumatic transarticular technique and avoiding the removal procedure of the fixation materials are the main advantages of the method.

The Pritchard Mark II elbow prosthesis in rheumatoid arthritis: 2–6-year follow-up

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Introduction: The elbow joint is frequently affected by rheumatoid arthritis, and the resulting pain and stiffness often produce significant limitation of function. Nonprosthetic treatments have failed to produce satisfactory results, and the results with the early hinged total elbow prosthesis were poor, with an unacceptable high rate of aseptic loosening. The semiconstrained elbow prosthesis was designed to reduce the high rates of loosening. This study presents the results of a 2–6-year follow-up of 28 elbow arthroplasties with the Pritchard Mark II elbow prosthesis.

Patients and methods: A prospective study contained 28 consecutive elbow arthroplasties in 24 patients with a minimum of 2 years follow-up. The diagnosis in all the cases was rheumatoid arthritis. A scoring system (from the Hospital for Special Surgery) was employed to analyze the preoperative and postoperative data, and the elbows were studied for radiographic signs of loosening. The average follow-up time was 3 (2–6) years.

Results and discussion: All the patients improved markedly in all aspects, but pain relief was the major benefit of the procedure. The total score improvement varied between 14 and 63 points. There were radiographic signs of loosening of the humeral component in one fourth of the elbows, and two of the implants had been exchanged because of additional pain. The cement packing along the humeral stem was found deficient in some of the cases, whereas the fixation of the ulnar component seemed to be without problems. The Pritchard Mark II elbow prosthesis provides a stable, painless joint with a good range of motion; and it seems to be a good solution for the painful arthritic elbow in the rheumatic patient with severe bone destruction, joint instability, and low activity level.

Extensive posterior approach to the elbow for internal fixation of complex fractures of the distal humerus

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The elbow joint may be exposed by a number of techniques. In complex traumatology, a large exposure of the distal humerus is necessary. The medial or lateral approach avoids the obvious neurovascular dangers, but gives limited access to the joint. The posterior approach gives the best possible exposure to all the surfaces of the joint, but it usually requires an interruption of the triceps mechanism either by a musculotendinous section or by an osteotomy of the olecranon. Such approaches may account for weakness of the triceps mechanism and proper complications of another so created fracture in the case of an olecranotomy. The authors developed a modified posterior approach that preserves continuity of the extensor apparatus of the elbow: the triceps muscle is split in the midline, the extensor mechanism is reflected in continuity with the forearm fascia-ulnar periosteum complex, and the joint surfaces and the two columns of the distal humerus can be exposed. This approach can also be extended to the midshaft of the humerus, to the radial head, and to the ulnar shaft. We have used this approach for 3 years for open reduction and plate fixation of complex distal humeral fractures. We have always obtained an excellent exposure to control the reduction of the surfaces of the joint, and a precurved plate is fixed on the lateral border of the humerus. The repair always allows an immediate postoperative motion. This approach became a new standard for us in the management of complex elbow trauma. No specific complication occurred, so we gave up the transolecranon technique.

External fixation of displaced fractures of the proximal humerus

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Introduction: The management of displaced fractures of the

proximal humerus is still under debate, and the need for evaluating alternative methods has been emphasized. The aim of this study is to present a new technique consisting of transcutaneous reduction and external fixation (1) and to report the technical and functional results of the first 25 cases.

Patients and methods: The operative technique was as follows: With the patient under general anesthesia, a Steinmann pin was introduced transcutaneously, under image-intensifier control, into the major head fragment and was used to help reduce the fracture. Two half pins were drilled into the humeral head and three into the shaft laterally. A bar was applied. Functional exercises started early, and the pins were removed in the outpatient clinic after 4 weeks.

Results and discussion: Following transcutaneous reduction, good or satisfactory reduction was obtained in 23 cases. No vascular injuries, but 2 cases of temporary paresthesia were seen. In 4 cases the pins were removed before 4 weeks because of infection (3 cases) or aseptic loosening (1 case). This rate of early complications or failure of technique is comparable to different methods of internal fixation. Chronic alcoholism and severe osteoporosis were found to be major risk factors. Of the remaining 21 patients, 1 had died and 2 were lost to the 1-year follow-up. Functional results were assessed as excellent in 6 cases, satisfactory in 6 cases, unsatisfactory in 4 cases, and poor in 2 cases. These results are thus found superior to those reported in most series of closed treatment, as well as of different methods of internal fixation.

Considering the risk of injuring the remaining blood supply to the humeral head by performing a wide surgical exposure, the technique described is found to be a useful alternative in the treatment of fractures not suitable for closed treatment.

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Displaced diaphyseal forearm fractures in children: Classification and evaluation of the early radiographic prognosis

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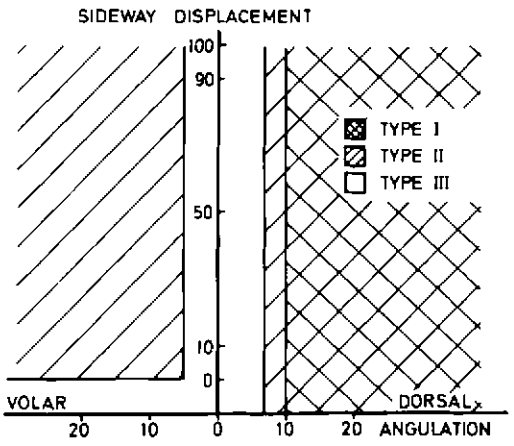
In a retrospective study of 83 diaphyseal forearm fractures, we measured the radiographic angulation and sideway displacement initially, after reduction, at 1 week, and at union. A statistical analysis was performed using a multivariate log-linear regression model to evaluate the correlation between variables.

The initial displacement of the fracture and the age of the patient had minor influence on the position at union. A classification system was constructed using the measurements initially, after reduction, and at 1 week, and a "prognostic index"



was calculated as the chance of achieving a radiographic union with less than 10° dorsal or volar angulation. It was demonstrated that the prognostic value of the classification system could be improved during the period of treatment.

The classification system based on the radiographic measurements after 1 week (five fractures re-reduced before 1 week):

Type I; 16 fractures: prognostic index 19 percent.
Type II; 19 fractures: prognostic index 53 percent.
Type III; 43 fractures: prognostic index 86 percent.

It is recommended that all displaced diaphyseal forearm fractures in children should have a radiographic control after 1 week and also after 2 weeks, unless the 1-week radiograph shows anatomic position.

Dorsally angulated solitary metaphyseal greenstick fractures in the distal radius: Results after immobilization in pronated, neutral, and supinated positions

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Patients and methods: In a prospective study, 60 consecutive patients, 20 in each group (pronation, neutral, and supination) were evaluated. Manipulation was accomplished on day 1 and after 2 weeks in all the cases with dorsal angulation of 20° or more and in some cases with less displacement. All were immobilized in an above-elbow cast. The dorsal angulation after immobilization on day 1 and at 2 weeks and 6 weeks when the plaster was removed was measured on accurate lateral views.

The three different groups did not differ with regard to age, side, location of the fracture or degree of angulation immedi-

ately after the cast was applied. There were more males in the supination group. The mean dorsal angulation at day 1 in POP with or without previous manipulation for the different groups was pronation 9±7.1, neutral 8±4.1, supination 7 ±3.9. The mean increase of dorsal angulation between day 1 and at 2 weeks was the same in the group treated in pronation (4.5±6.0) and in the group treated in the neutral position (4.1±5.8), but less ($P < 0.05$) in the group treated in supination (0.9 ±5.2).

Between 2 and 6 weeks, there was no further dorsal angulation (pronation –0.1 ±3.9, neutral 0.4 ±2.1, supination –0.5 ± 1.5) whether manipulation at week 2 had been performed or not, and there was no difference between the groups. The figures do not deny that remodeling had already started 6 weeks after immobilization.

Conclusion: The results support the theory that inactivating the brachioradialis muscle by supinating the forearm helps to prevent recurrent deformity and that these fractures therefore should be immobilized in supination.

Basal joint arthrodesis of the thumb: Long-term results

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Introduction: Arthrodesis of the basal thumb joint is reported to provide pain relief and excellent power to the thumb. However, controversy exists on what functional impairment a stiff basal thumb joint creates and how the neighboring joints are influenced.

Patients and methods: Ninety-three patients with advanced primary arthrosis of the basal thumb joint, operated on during the years 1974–84, were available for follow-up examination 7(3–12) years after the operation. There were 78 females and 15 males. Fourteen patients were operated on bilaterally. Thus, the total number of operations was 107. The dominant hand was operated on in 58 cases and the nondominant one in 49 cases. The mean age at operation was 59 (43–72) years. Pain was the dominating symptom. The operation was performed through a dorsal longitudinal incision. The joint surfaces were resected. A Kirschner wire and a cerclage or staples were used for fixation. No bone grafting was performed. The thumb was immobilized in a cast for 6 weeks.

Results and discussion: Radiographically, 80 joints had healed with ankylosis, whereas 27 cases had developed a pseudarthrosis. The results regarding pain relief were better in patients with fused joints; 68 had little or no pain compared with 17 in the group with pseudarthrosis. In both groups the pain relief lasted the whole follow-up period. Four patients with fused joints, and 8 with pseudarthroses had severe pain. The power was excellent in the painless thumbs, and reduced in thumbs with pain. The mobility of the first metacarpal in relation to the palmar plane measured radiographically was nearly the same for the group with joint fusion when compared with the group where fusion had failed. However, in the plane perpendicular to the palm, the thumbs with pseudarthrosis had a better range of motion. Thirty-one of the patients with fused joints had difficulties performing precision work Radiographically, peritrapezial degenerative changes increased during the observation period. However, this process was the same in the unoperated on hand and in cases with pseudarthrosis. Arthrodesis of the basal joint of the thumb provides effective and lasting pain relief with an acceptable range of thumb motion.

Functional results following hand replantation/recirculation

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Introduction: Since the first successful case of a forearm replantation was performed in Shanghai in 1963, advances in surgical technique, refinements in preoperative and postoperative management, and better patient selection have contributed to an improved survival rate for replants. Simultaneous progress in free tissue transfer has further expanded the scope of the microsurgical team in reconstruction following amputations of the hand. Until recently, progress in functional results has been less impressive than that in the survival rates.

Patients and methods: Twenty-one consecutive replantations/recirculations in 20 patients (1 female and 19 males) were performed at our hospital between October 1983 and October 1987. The mean age was 36 (6–75) years. The amputation level was graded according to Tamai. In 10 cases, it was a transmetacarpal amputation, in 4 transcarpal, and in 7 cases a distal forearm amputation. Eight amputations were complete and 13 were incomplete.

Results and discussion. All the replants survived. However, 15 single digits did not survive because they were not replanted in cases of double-level amputation or they had been crushed too much. The functional results, on an average 27 (5–52) months after surgery, were graded according to Chen. Six hands achieved the criteria of grade I (excellent), 7 hands belonged to grade II (good), 4 to grade III (fair), and 4 were grade IV (poor). The patients with the poorest results (grade IV) were better off with the replant than with a prosthesis. The cosmetic results were good. Hand replants have a good potential for sensory reinnervation and motor return. Patient motivation and a skilled hand rehabilitation program are important factors that contribute to satisfactory functional results.

Second toe transfer in hand reconstruction following trauma

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Introduction: The advantages of the toe transfer compared with other reconstructive methods in hand reconstruction are that there is a potential for motion, adequate sensibility can be anticipated, appearance is good, and only one surgical procedure is required in most cases.

Patients and methods: Between November 1983 and October 1987, we transferred 20 second toes to the hand in 19 patients (3 females and 16 males; mean age 34 [14–65] years). One male patient had two transfers to the same hand with failure of vascularization both times. In one case the toe was transferred to the ulnar side of a hand that had been amputated at the carpometacarpal joint with a residual stiff thumb metacarpal. In the remaining 19 cases the toe was transferred to a thumb stump. In 9 of the thumb cases, there was an additional serious injury to the hand.

Results and discussion: In 4 cases the revascularization of the transfer failed. The remaining 16 toes healed (follow-up 5–52 months). Bony union occurred within 6 weeks in all 16 cases. No significant donor site problems were seen. The general function of the transferred toes according to the Tamai score for digit replantation was on an average 86 points (13 excellent and 3 good). The CMC joint was uninjured in all the thumb cases and in 9 of them even the MP joint, which contributes to the favorable results. Hammer toe/buttonhole deformity of the PIP joint developed in 4 cases and was treated successfully by an arthrodesis. In the latest seven transfers, we made a temporary pin transfixation of the PIP joint combined with a tenodesis of the short extensor tendon. This seemed to prevent the development of buttonhole deformity. We conclude that second toe transfer is a valuable procedure in total thumb reconstruction.

Colles' fractures treated by external fixation, functional bracing in supination, or dorsal plaster immobilization: A long-time follow-up

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A radiographic and functional evaluation of 40 patients treated by external fixation (EF), 28 patients treated by functional bracing in supination (FUSU), and 38 patients treated by dorsal plaster immobilization (DPI) was performed 2.5–7.5 years after fracture of the wrist.

The fractures were classified according to Older et al. (1965), and the statistical analysis was performed using multiple contingency tables and a log linear regression analysis.

The rate of initial complications was 53 percent after EF and 22 percent and 14 percent after FUSU and DPI. The most frequent complication was damage to the cutaneous branch of the radial nerve. The radiographic examination showed significantly better results after EF than after nonoperative treatment, but the frequency of late arthrosis was the same in the three series.

The functional evaluation using a modification of the scoring system described by Gartland and Werley (1951) demonstrated significantly better results after EF than after FUSU and DPI, whereas no difference could be demonstrated between the latter two treatments.

We concluded that EF gives significantly better radiographic and functional results after a Colles fracture, but the rate of initial complications is higher. A modification of the operative technique might reduce the number of complications.

Spine

Mobility of the lower lumbar spine after posterolateral fusion determined by roentgen stereophotogrammetric analysis

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Introduction: Spinal fusion may yield pain relief in symptomatic spondylolysis, disc disorder, and facet joint arthrosis in the lower lumbar spine. Residual mobility between the fused vertebral segments can be detected with high accuracy by roentgen stereophotogrammetric analysis (RSA; Olsson et al. 1977). However, the effect and the need of wearing a lumbar orthosis postoperatively are disputed (Lantz and Schultz 1986). In an attempt to determine when maximal intervertebral stabilization occurs, RSA was used in this study of posterolateral fusions in the lower lumbar spine.

Patients: Six men with a median age of 43 (24–52) years had a posterolateral fusion, including application of tantalum indicators for the RSA, between L4–L5, L5–S1, or L4–S1. A lumbar orthosis was used until 5 months after surgery. Four patients had spondylolysis-olisthesis, and 2 had an intervertebral disc disorder with lumbar and/or radiating pain.

Methods: All the patients were followed with RSA monthly for 6 months. In 4 cases, RSA was also performed 1 year postoperatively. At each RSA the patients were examined in the supine and erect positions, and the movements of the vertebrae between these positions were calculated. Conventional radiographs were taken 6 months and 1 year after surgery.

Results: The flexion movements between the fused vertebral segments decreased to 1–2°5–6 months after surgery in 3 patients with osseous fusion radiographically. The same pattern was seen in 1 patient with poor osseous fusion. In 2 patients with poor osseous fusion, the flexion increased after 5 months (to 16°) and 1 year (to 8°), respectively. Lateral deviation and rotation were mostly below 1°, and did not change with time. The preoperative pain disappeared in 5 patients. One patient with osseous fusion had persistent pain in the lower back and legs, and a general neuromuscular disorder is suspected.

Discussion: The mobility of the lower lumbar spine decreases within 6 months after a successful posterolateral fusion (Olsson 1977). This seems to be verified by our study, in which decreased intervertebral movements could be visualized by RSA 5–6 months after surgery. A radiographically healed posterolateral fusion permits a few degrees of flexion, probably exerted through a springing effect. However, osseous fusion was not necessary for pain relief, which indicates that fibrous fusion might give a good enough reduction of intervertebral mobility to yield pain relief. The need of wearing a lumbar orthosis postoperatively is still uncertain. The study is continuing, and new patients will be added.

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Electrical surface stimulation versus Boston-brace treatment in adolescent idiopathic scoliosis

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Introduction: The different attitudes in the nonoperative management of idiopathic scoliosis include brace treatment, electrical stimulation, and solely observation until surgery might be needed. Most recent reports indicate that up to 90 percent of progressive curves can be halted by Boston-brace systems (1) compared with a 75 to 88 percent success rate when using electrical stimulation (2). Significant compliance problems have been demonstrated in both treatment groups (3), and may account for the poorer results also reported (4). The aim of our present study was to evaluate the treatment results following lateral electrical surface stimulation (LESS), using the newest generation of stimulator and electrodes, in a case control study versus Boston brace in idiopathic adolescent scoliosis.

Patients and methods: Twenty-two patients were prospectively selected for LESS using the inclusion criteria idiopathic scoliosis, documented curve progression, curve magnitude of 20–45°(Cobb angle), and > 1 year growth assurance. Initiation of LESS took place during admission to the hospital. A Skolistim 2 stimulator with memory was used for 8 hours with nightly stimulation with up to 60 mA, 35 Hz uniform impulses through electrodes placed in the posterior axillary line on the convex side of the main curves. In case of curve progression > 8°, treatment was changed to random stimulation. Using curve magnitude, location, and bone age as matching criteria, we selected 22 patients of 256 treated with the Boston brace from 1975 to 1980 using the same inclusion criteria.

Results: The initial Cobb angle of the main curves was, on an average, 31° in the LESS group versus 33° in the Brace group. The correction in the prone position during LESS was 54° compared with 49° during Cotrel traction in the brace group (NS). During the initial treatment period of 12 months, significantly better curve correction was achieved in the brace group when comparing in-brace curves with unstimulated curves in standing patients ($P < 0.05$). At 15 months, there was no difference. Three patients did not cooperate fully in the LESS group due to social problems, whereas the majority showed a high level of compliance. Minor skin problems were found in both groups in 3 patients. Random stimulation arrested curve progression in 2 of 4 patients.

Conclusion: So far, we find LESS to be an acceptable alternative to brace treatment. A 23 percent early curve progression was found. Our experience shows that close contact with the patients is necessary to prevent noncompliance, although a high level of motivation and acceptance was noticed in the LESS group. Random stimulation might offer an alternative stimulation modality in case of curve progression in idiopathic scoliosis.

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Radioanatomic assessment of spinal metastases with cryoplaning, CT, and MRI

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Introduction: Advances in diagnostic imaging and improvements of oncologic treatment and surgical techniques have led to more active management. The spine is rarely autopsied, and little is known about the growth of spinal metastases.

Methods: Scintigraphy was used for screening the spine. MRI and CT, including thin-section, contiguous multiplanar reconstruction with high-resolution algorithms, were targeted on the affected region. The MR studies were repeated at intervals. Irrespective of conservative or surgical treatment, an

autopsy was performed; the metastatic spine segments were prepared with arterial injection, freezing in situ, and careful positioning. After embedding the frozen specimens together with a reference system, high-resolution CT was carried out directly in the sagittal plane, which renders superb spatial resolution. The frozen specimens were then cryoplaned on a large sledge cryomicrotome, and photographs were taken with a pin-registration camera at 1-mm intervals. Cylinder biopsies were taken under direct vision of the metastasis. Evaluation included comparison of the in vivo MR and CT studies and scintigrams with the post-mortem CT scans and pathoanatomic images.

Results: The mechanical failure of vertebral segments with metastases was primarily due to fractures, not gradual bony collapse. The boundaries of the periosteum and the dura were rarely transgressed; erosion of the arteries was not observed. The metastatic disease was predominantly located in the vertebral bodies. Regions first to be weakened were the vertebral body vascular channels, notably the foramina of the Batson plexus. Yielding of the vertebral end plates, Schmorl-node formation, and extrusion of soft-tissue-hinged end plate fragments into the vertebral canal were common findings.

Back pain in pregnancy

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Introduction: Back pain is often present in normal pregnancy. An incidence of 45 percent has been reported, with severe pain in one third of the cases. There is little information about the type of pain and when and in whom it occurs, and if it changes during pregnancy. The purpose of this paper is to report on back pain in 950 pregnant women followed from the 12th week of pregnancy through delivery.

Patients and methods: All the pregnant women attending one maternity care unit in Gothenburg over a 1-year period were studied. The information was based on a large questionnaire, filled out by the women during the 12th week of pregnancy, requesting information about previous and present back pain, as well as several other items. Women with ongoing pain were given a more detailed questionnaire, and they also reported the distribution and quality of pain on a pain drawing. The intensity of pain was registered on visual analog scales. Whenever the pain changed, a new questionnaire was filled out.

Results: Forty-nine percent complained of back pain at some time during pregnancy. By means of 2,000 pain drawings, we found three different types of back pain, which developed differently during the pregnancy. As pregnancy advanced, patients with pain above the lumbar area and patients with pain in the sacroiliac area increased in number while patients with pain in the lumbar region decreased in number. The point prevalence of back pain was quite constant throughout pregnancy, about 25 percent. The intensity of pain increased from the beginning to the end of pregnancy.

Conclusion: Back pain is a significant problem in pregnancy, and is not one single diagnosis. There are three different regions of pain, with pain in the sacroiliac area dominating. Moreover, pain in pregnancy is ubiquitous in time, with a rather constant rate of 25 percent.

Repeat chemonucleolysis

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Introduction: For 10 patients out of a linked series of 750 patients who were treated with chemonucleolysis because of a HNP, the indication for a repeat chemonucleolysis was made on the basis of a recurrent HNP.

Patients and methods: This group consisted of 6 men and 4 women with an average age of 38 years. The diagnosis was confirmed by myelography, CT scan, and discography. The first chemonucleolysis was performed three times on the L4–5 level, three times on the L5–S1 level, and once on the L4–5 level, as well as L5–S1, and twice on the L3–4, L4–5, and L5–S1 levels.

The results after the first chemonucleolysis were four times very good, four times good, and twice reasonable. Recurrent complaints started after an average of 3 years. The repeat chemonucleolysis was performed four times on the L4–5 level and six times on the L5–S1 level. Before the operations, all the patients were pretreated with H1 and H2 antagonists in view of possible allergic reactions. No such reactions occurred.

Results and discussion: After the repeat chemonucleolysis, it generally took longer for the patients to recover and start working again. With an average follow-up of 15 months, the results were very good, in 1 case, good in 4 cases reasonable in 3 cases, and moderate in 1 case. The eventual result was mainly determined by persisting low back pain.

Compared with the results of the first chemonucleolysis, 5 patients remained in the same class, 4 went to a lower class, and 1 patient to a higher class. No reoperaitons have been indicated, and so far no recurrences have been seen. No major allergic reactions were seen.

Conclusions: Recurrent HNP after chemonucleolysis may occur. Chemonucleolysis belongs to the treatment possibilities. The results are less good than after the first chemonucleolysis, mainly because of persisting low back pain.

Neurophysiologic and microvascular changes in spinal nerve roots of the pig cauda equina induced by experimental, graded compression

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Compression injury of spinal nerve roots is very common. The pathogenesis of nerve root compression syndromes is, however, poorly understood. In the present study, we have developed a model for experimental, graded compression of spinal nerve roots in the pig cauda equina. With this model, we have studied the effects of such compression on blood flow, edema formation, and impulse propagation.

Materials and methods: Sixty pigs were anesthetized with Hypnodil® and ventilated on a respirator. The nerve roots were exposed by a laminectomy of the first and second coccygeal vertebrae. A small balloon, fixed to the spine by two L-shaped pins and a plexiglass plate, was placed across the spinal canal. When the balloon was inflated by a compressed air system, the nerve roots were compressed between the balloon and the corresponding disc and vertebrae. Compression-induced changes in the blood flow of the intrinsic vessels of the nerve roots were studied using a vital microscopic technique. Edema formation was studied with a fluorescence-microscopic technique using Evans' blue-labeled albumin as the tracer. The changes in impulse propagation were studied with specially designed neurophysiologic equipment. The temperature and humidity of the preparation were controlled by irrigation with warmed saline.

Results: The average minimum pressure required to stop the arteriolar blood flow was found to be slightly lower (129 mmHg, SD 23, n 27), and correlated with the mean arterial blood pressure (150 mmHg, SD 14, n 12). The corresponding pressure for the venules was 32 mmHg (SD 17, n 51), and for the capillaries 36 mmHg (SD 14, n 7). An intraneural edema formation was seen even after compression of 50 mmHg for 2 min. After compression at 100 mmHg for 2 hours, there was a 75 percent reduction in amplitude for the sensory nerve roots and 45 percent for the motor nerve roots. The recovery of the motor nerve roots was also found to be more rapid than for the sensory nerve roots.

Discussion: The model in the present study thus allows a detailed analysis of various parameters of the normal physiology of spinal nerve roots that might be affected by an acute compression injury. The capillary blood flow was stopped even at very low pressures, which probably will negatively influence the normal function of the nerve roots during prolonged compression. Formation of an intraneural edema will impair the local transport of nutrients to the nerve fibers, and may thus affect the nerve function more permanently than the compression itself. Such edema was found to develop even after very mild compression. The results of this study also suggest a greater sensitivity of the sensory than of the motor nerve roots to acute compression. This may explain the clinical occurrence of sensory deficit and/or pain without motor dysfunction in spinal nerve-root compression syndromes.

Preoperative and postoperative instability in lumbar spinal stenosis

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Introduction: In an earlier investigation, we found a correlation between postoperative instability and unsatisfactory results of decompressive operation for spinal stenosis. In this follow-up study, we wanted to analyze the importance of some preoperative parameters and the extent of the operation for the postoperative instability and the outcome.

Patients and methods: Included in the study were 61 patients (40 men and 21 women) operated on for spinal stenosis. Preoperatively, all of them had a plain radiograph of the spine and a lumbar myelographic examination. Excluded from the study were patients with an AP diameter of the dural sack >11 mm and patients with impaired circulation in the legs. The mean age was 65 (38–80) years, the mean duration of symptoms 27 (1–180) months, and the mean follow-up time 51 (12–156) months.

The decompression was achieved by laminectomy and more or less radical facetectomy. No fusion was performed. Preoperative and postoperative vertebral slipping was measured on plain radiographs without provocation. In 51 patients, functional myelography was performed. The AP diameter in flexion and extension was measured and the difference calculated. Also, the slipping between the vertebrae in flexion and extension was measured and the difference calculated. Preoperative and postoperative olisthesis < 2 mm was not counted. The degree of decompression was estimated with CT. Patients operated on with laminectomy and total facetectomy were designated radically decompressed.

Results: Thirty-six patients assessed the result of the operation as good or excellent, the "good" group. The other 25 patients, the "poor" group, felt unchanged or worse. The mean age in both groups was 65 years. The mean duration of symptoms was 28 months in the "good" group and 25 in the "poor" group. The mean AP diameter was about 4 mm in both groups. Twenty-eight of the men, but only 8 of the women, had good results ($P < 0.05$). Degenerative olisthesis was found in 13 women and 17 men, and in 17 patients in the "good" group and in 13 in the "poor" group. Postoperative slipping was found in 26 patients (10 men and 16 women). Eight belonged to the "good" group. Thirty-five patients showed no slipping; and in this group, good results were found in 28 cases. Thus, postoperative slipping was twice as common in the "poor" group as in the "good" group ($P < 0.001$). During functional myelography, the AP diameter varied more in the "poor" group than in the "good" group at the L3–L4 ($P < 0.01$) and L4-L5 levels ($P < 0.02$). Patients with

postoperative slipping had more sagittal mobility between the vertebrae at the L4–L5 level during functional myelography than patients without slipping ($P < 0.05$). The "poor" group ($P < 0.05$), women ($P < 0.01$), and the "slipping" group ($P < 0.001$) were more radically decompressed as compared with the "good" group, men, and the "nonslipping" group, respectively.

Compression: In spinal stenosis, preoperative instability, as revealed by functional myelography, seems to be a poor prognostic sign. Radical decompression, without stabilization, enhances the risk of postoperative slipping and a poor outcome. Postoperative slipping worsens the prognosis. Women run a greater risk of poor results after operation.

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Simultaneous 3-dimensional motion analysis of the cervical spine: A clinical method

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Introduction: Up to now, 3-dimensional motion analysis of the cervical spine has been done exclusively on cadaver specimens using radiography and internal markers, such as tantalum balls. In view of the complexity of the motion pattern and the clinical variability of various pain conditions and lesions, we have developed a clinical method for simultaneous 3-dimensional motion analysis to describe in detail the normal features, as well as the pathological ones, with advancing age and different clinical disorders. The aim of the present study was to describe the equipment, the precision and reproducibility, and, somewhat, the clinical applicability.

Patients and methods: The range of motion, as well as the motion pattern, of the head relative to the uppermost part of the thoracic spine was examined using five electrogoniometers recording the motion in the three planes. An outer rod rested on the acromion and was connected to the head via an adjustable band fixed on the skull. The rod was applied in a vertical position passing the center of the outer ear. It was connected to a plexiglass dorsal plate firmly attached to the thorax. The equipment gave very precise and reproducible values when qualibration was performed using a special doll made for this purpose. On patients, the values of the motion in the sagittal plane corresponded very well with those obtained by registration with an inclinometer (Myrin). This was found also for motion in the frontal plane. The inclinometer was not suitable for registration of the motion in the horizontal plane (rotation). The signals of the five electrogoniometers were recorded graphically with the aid of a 6-channel writer.

Results and discussion: In clinical use, the reproducibility of the results was quite satisfactory. Some of the test individuals showed results deviating from one examination to another, whereas the majority could reproduce their recordings quite satisfactorily. No significant differences were obtained between recordings made with a 1-week interval. At simultaneous radiographic examinations performed in 10 patients with complaints from the cervical spine, good correspondence was obtained between our recordings and the range of motion measured on the radiographs provided that the electrogoniometers had been positioned properly at carefully defined sites. The pattern of simultaneous movements was found to be disturbed in patients with pain syndrome of the cervical spine.

Surgical treatment of atlantoaxial subluxation in rheumatoid arthritis

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Introduction: Atlantoaxial subluxation (AAS) is a well-known complication of progressive rheumatoid arthritis (RA). Most frequently, dislocation occurs in a horizontal plane and fortunately the more serious, and at operation more technically troublesome, vertical instability is rather uncommon, but needs an earlier surgical intervention. We present a retrospective study of 19 patients suffering from RA showing AAS.

Patients and methods: Nineteen patients were fusioned according to the original method of Gallie, modified by McGraw and Rusch (1). Three parameters were used: pain, neural deficit, classified according to Ranawat et al (2), and disability using the American Rheumatism Association for Functional Classification. Regular check-ups were done 6 weeks, 3 months, and 6 months postoperatively. The patterns of instability were visualized through the regular radiographs, maximum flexion/extension; and vertical subluxation was ruled out through Redlund-Johnell's (3) modification of the method of McGregor (4), i.e., the distance between the palato-occipital help line to the lower end plate of the second cervical vertebra, which rules out the condition of dens axis.

Results and discussion: Clinically, all but 1 patient were completely relieved of pain, and all but 2 patients had no persistent neural deficit after the operation. Most patients remained in their original functional class. Three patients required refusion because of redislocation exceeding 10 mm, and 1 patient developed vertical subluxation in spite of successful primary fusion, but no patient showed clinical symptoms. The primary fusion success turned out to be 12/18 patients, and after refusion 15/17 patients, which gives a pseudarthrosis rate of 2/17 patients. A relatively low mortality rate was found, 2/21 operations, and there was no case of infection. Fusion failure was often due to the development of pseudarthrosis between graft and laminae — spinous process of axis, whereas bony healing readily occurred to the atlas. An

explanation could be a firmer contact between the arch of the atlas and the transplant through more efficient steel-wire compression than to the spinous process of the axis. We believe that fusion might be used to a somewhat wider extent than stated earlier, especially when dealing with progressive horizontal dislocation with neural deficits and/or vertical subluxation.

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Anterior atlantoaxial subluxation in RA is caused by involvement of the cervical spine ligaments

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Method: Peroperative biopsies from anterior AAS patients were processed for immunohistochemical demonstration of inflammatory cells, neurofilaments, and neuropeptides by the ABC method. In all, 162 rheumatoid cervical spine patients were screened radiographically for the presence of anterior AAS caused by ligamentous laxity alone without involvement of cartilage or bone.

Results: Patchy infiltrates of inflammatory mononuclear cells were observed in 4/8 ligamentous samples from the structures between the posterior arch of the atlas and the spinous process of C2. Neural elements containing cytoskeletal neurofilaments and neuropeptides, such as CGRP and substance P, were present in the ligamentous samples studied. Further, 14/162 anterior AAS patients had this condition without involvement of cartilage or subchondral bone.

Conclusions: Although peroperative biopsies of transverse ligaments could not be obtained, we concluded that in anterior AAS 1) ligamentous laxity is caused by an immune-inflammatory involvement of the ligamentous tissue; 2) pain may be caused by involvement of the local nerves and not always by entrapment of C2 roots; 3) anterior AAS is caused by ligamentous laxity alone, although this in long-standing cases is also accompanied by erosions in the occipito-atlantoaxial area.

Spondylodesis using the Hartshill rectangle for low back pain

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Introduction: The Hartshill technique for spondylodesis, a modification of the Luqués segmental fixation, developed by Dove (1), is based on immobilization of the part of the spine to be fused by means of a rectangle of steel rods. The immobilization, which promotes the formation of stabilizing bone bridges between the vertebrae, is brought about by fixing the neural arches to the rectangle with steel wires introduced about the laminae. The bone removed from spinal processes and facet joints is used for bone grafting, and no external bone transplantation is needed. In cases with symptoms of pressure on nerve roots, decompression was performed.

Patients and methods: We have applied this technique in 22 (12 females and 10 males) carefully selected patients with chronic low back pain including disc disease, instability, spondylolisthesis, and spinal stenosis. The indication for surgery was focal spinal pathology diagnosed by clinical examination, routine radiography, computed tomography, and injection of local anesthetic into the facet joints. All the patients had been followed for a long period, and most had had previous spinal surgery. The median age of the patients was 40 years, and the follow-up 5 to 20 months. The fusion was mostly performed on two disc levels — on one disc level in 4 cases and on three disc levels in 1 case. The operation time varied from 100 to 240 minutes and bleeding from 150 to 5,500 ml. The patients were mobilized on the first or second postoperative day with a light external support. The hospital stay was 6–12 days. Return to work was not allowed for 10 weeks after the operation.

Results and discussion: At follow-up a bilateral breakage of steel wires indicating lost stability and development of pseudarthrosis was observed in 1 patient, who was, however, satisfied. Unilateral broken wires, however insignificant, as indicated by the extension-flexion radiographs, were seen in 3 patients. Two too long rectangles were removed. The result was good (no or only moderate back pain) in more than two thirds of the patients. Only 1 patient experienced unchanged pain postoperatively. We consider this technique for spinal fusion useful in selected patients who have a reliably identified local pathology as a cause of their chronic low back pain.

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Normal range and age-related changes of the vertebral wedge angle

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The wedge angle (WA), i.e., the angle between the superior and inferior vertebral end plates was determined in lateral radiographs of the thoracic and lumbar spines for each vertebral body (T3–L5) in 150 normal women aged 34–67 years. The anterior and posterior vertebral heights and widths were measured with direct reading Vernier calipers (accuracy 0.05 mm). The WA was derived from the expression

$$WA = 2 \sin^{-1} \frac{\text{anterior height} - \text{posterior height}}{2 \text{ widths}}$$

Table 1. The mean and SD of the WA for T3–L5

	Mean	SD		Mean	SD
T3	4.1°	3.1°	L1	3.2°	3.2°
T4	3.4°	3.0°	L2	1.8°	3.5°
T5	4.1°	3.0°	L3	0.5°	3.9°
T6	5.1°	2.7°	L4	−1.4°	4.1°
T7	5.6°	3.0°	L5	−6.0°	4.5°
T8	5.2°	2.9°			
T9	3.9°	3.2°			
T10	3.5°	3.5°			
T11	4.2°	3.0°			
T12	4.1°	3.1°			

For each vertebra, the normal range (mean ±2 SD) of the WA was calculated (Table 1). For T3–T12 the mean WA was between 3°and 6°, with the upper normal limit (+2 SD) above 9° for all the thoracic vertebrae.

In the thoracic spine, there was no significant correlation between WA and age. For L1, L3, and L5, weak ($r = -0.20$), but significant ($P < 0.05$), negative correlations between WA and age were found. This was caused by a slight decrease of the posterior vertebral height with age ($P < 0.05$). The cumulative posterior height of the lumbar vertebrae averaged 5.6 mm lower in the age group 56–67 compared with women aged 34–44 years. There was no significant change of anterior height or width with age.

The results suggest that normal aging does not result in a progressive anterior vertebral wedging as seen in spinal osteoporosis. The normal range of the WAs for each vertebra may be used in the diagnosis of vertebral wedge fractures. The observed normal range of WA questions the previously suggested use of a 5°WA in three thoracic vertebrae as diagnositic criterion for Mb Scheuermann.

Correlation between compression characteristics and bone mineral content measured by dual-energy CT in normal and metastatic vertebral bodies

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Introduction: The aim of the present study was to correlate bone mineral content, measured by dual-energy CT and biomechanics characteristics in normal and metastatic vertebral bodies.

Materials and methods: The investigations were performed with a CT scanner of the third generation with dual energy (96 and 125 kV). First, we evaluated 41 fresh human vertebral bodies of the thoracic and lumbar spine, and the bone mineral content of spongious and cortical bone was calculated. The biomechanics investigations were performed on an electronic compression machine (10 mm/min). The same procedure was done with 14 vertebrae with osteolytic and five with osteoblastic metastases.

Results: The relationship between fracture load and bone mineral content of the normal vertebral bodies can be described as a logarithmic function ($r^2 = 0.9$). The breaking load was higher caudally. In vertebral bodies with osteolytic metastases, the breaking load was less than would be expected from BMC determination.

The destructive character of the osteolytic metastases is more important for the fracture risk in vertebral bodies than the bone mineral content. The bone mineral content of osteoblastic metastases is higher than in normal vertebral bodies, but the breaking load is less.

Prediction of vertebral strength with computed tomography (CT)

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Introduction: It is important to be able to predict bone strength and fracture risk with noninvasive methods. We performed computed tomography determinations of vertebrae in order to predict vertebral strength.

Materials and methods: We studied 18 cadavers. The vertebral column was excised and radiographs were obtained from all the specimens prior to further analysis. The excised spines were placed in a container filled with water, and were studied in a Siemens Somatom-2 CT Scanner. The scanning was done at 125 kVp and 96 kVp (460 mAs and 600 mAs). Using a materials testing apparatus (MTS, Minneapolis, Minn), we compressed the vertebrae between freely movable plates at a speed of 5 mm/min. The ultimate compressive load was determined from the peak of a load-deflection curve. All the vertebrae were ashed at 700 °C for 12 hours, and the ash was weighed under standardized laboratory conditions. Vertebral bodies and posterior elements were treated separately.

Results: We found about the same amount of mineral in vertebral bodies and posterior elements, but considerable individual variation existed. Regardless of energy level used for the CT determination, single energy determination of the central portion of a vertebral body was not acceptable for the prediction of the load at failure. By multiplying the CT result with the surface area of the vertebral body, the prediction improved; and by multiplying the effect of atomic number obtained by dual energy determination with the surface area, acceptable results were obtained ($r = 0.74$). By also including the periphery of the vertebrae in the CT determination, it is possible to further improve predictions. We also compared data where the surface area of the end plate or the transverse area of the vertebral body at the middle had been excluded. In addition, results can become more accurate if the result from using the squared CT finding multiplied by the surface area is used.

Discussion: This study shows that determination of mineral content in the central portion of a vertebral body using single-energy CT is not sufficient for predicting vertebral strength. Dual energy methods are available in many hospi-

tals, and adequate prediction of vertebral strength can be made if the surface area of the vertebral body is also considered in a determination based on dual-energy CT.

Movements of the sacroiliac joints: A stereophotogrammetric analysis

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Introduction: The role of the sacroiliac joint as a pain-producing structure is poorly understood. Earlier analyses are postmortem studies or with error of the method as big as half the maximal estimated movement. The aim of this study was to describe movements in the sacroiliac joints under different physiological loads and to compare the movements of symptomatic joints with asymptomatic ones

Patients and methods: Outpatients at the Department of Orthopedics were referred to a group consisting of an orthopedic surgeon, a doctor of chiropractic, and 2 physiotherapists. Patients who were regarded as having a sacroiliac syndrome and who agreed to permit study of the mobility with roentgen stereophotogrammetry were included in the study. There were 21 females (aged 19–45 years) and 4 males (aged 18–45 years) who had tantalum balls inserted percutaneously. Two weeks later, they were examined with stereophotogrammetry (Selvik 1974) in the following positions: supine, prone with hyperextension of the left and right legs, respectively, and standing and sitting with straight knees.

Results: The total movement around the X-axis between extreme positions was, on an average, 2.5 ±0.5 (1.6–3.9)°. The rotation around the X-axis was about 80–90 percent of the resultant or the total rotation, Around the X-axis the motion was symmetric, and the innominates moved as a unit around the sacrum. The motion around the Y- and Z-axes were inconstant and inward, and outward, respectively, probably due to the shape of the articulation. There was no decrease in mobility with age. The mobility of symptomatic joints was, on an average, equal to the mobility of asymptomatic joints around the three axes.

Conclusions: The identical movements of the symptomatic and asymptomatic joints clearly demonstrate that analyses of the mobility under physiological load cannot identify a sacroiliac disorder.

Traumatic sacroiliac joint dislocation: Internal fixation through an anterior approach with a special square plate

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Introduction: Sacroiliac joint dislocation usually is the result of a high-energy, but blunt, trauma to the pelvis. The dislocation is often combined with severe damage to the large pelvic vessels, the urinary tract, peripheral nerves, and even the gastrointestinal tract.

Patients: During the last 6 years, we have treated 19 patients, aged 26 (15–45) years, with dislocation of one or both sacroiliac joints. Thirteen patients also had other fractures or lesions as well. Neurologic injuries were present in 7 cases; in 3 of them the injuries were bilateral. One patient had both a perineal and a rectal injury.

Method: The sacroiliac joint was reached through an anterior retroperitoneal approach. This made it possible to clean the joint of injured cartilage and also to reduce the dislocation under direct vision. The internal fixation was performed with four cancellous bone screws placed in a square-shaped plate, which was especially made for sacroiliac joint fixation. Postoperatively, 11 patients were mobilized to gait with crutches within 4 weeks, and all but 1 within 12 weeks. The mean follow-up time for this series was 27 (12–68) months.

Results: All the joints were considered clinically healed; however, 2 patients had some residual back pain. There was no gait problem, and a leg length discrepancy of 2 cm was found only in the patient who also had a sacral fracture on the opposite side to the sacroiliac joint. The neurologic defect was completely restituted in only 2 of the patients with such an injury, and on one of the sides in 2 of the patients with bilateral neurologic injury. However, all the neurologic injuries showed improvement. Eleven patients returned to work within 6 months and another 4 within 12 months.

Conclusion: An anterior approach to the dislocated sacroiliac joint gives good reduction and fixation possibilities. Adding a limited external fixation support allowed early mobilization. The residual disability concerning pain, walking, and sitting difficulties, as well as working capacity, was limited.

Spinal fractures

Deformity after thoracolumbar fractures and fracture dislocations treated by Harrington's instrumentation

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Introduction: There are today many new methods for managing thoracolumbar spinal injuries. We wanted to evaluate our methods and results in this study.

Patients and methods: Between 1980 and 1985, we operated on 21 patients (average age 28 years) with unstable thoracolumbar fractures using Harrington's instrumentation. To

determine the loss of the reduction after removal of the instrumentation, we measured the angles of kyphosis and scoliosis, sagittal and lateral dislocations, and anterior wedge compression. The instrumentation was removed within a year of operation, and the average follow-up period was 3.8 years. Bony injury was assessed radiographically on admission, after reduction, and at the last follow-up in 1987.

Results and discussion: In our patient group, there were only two loosenings of Harrington's instrumentation without any neurologic symptoms. The neurologic state of 4 patients improved during the follow-up. The gibbus angle and anterior wedge compression were nearly the same at follow-up after the removal of the rods as before reduction: the gibbus angle even increased (17.1° before reduction and 22.3° at last follow-up); the anterior wedge compression was 37.2 percent and 31.1 percent, respectively.

Our results demonstrate that primary reduction is not stable. To avoid late deformity, it is useful to make an anterolateral intercorporeal spondylodesis and to use an extension brace until healing.

Experiences with transpedicular internal fixation and transpedicular grafting of unstable thoracolumbar fractures

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Introduction: The use of a transpedicular internal fixator in the treatment of unstable thoracolumbar fracture makes anatomic or close to anatomic reduction possible. Only two segments are included in the osteosynthesis, and lumbar mobility is optimally preserved. The patients can often be mobilized without external support. The method can be combined with transpedicular bone grafting of postreduction defects in burst fractures. Posterior fusion is performed over the damaged segments only.

Patients and methods: Thirty-seven patients, 29 males and 8 females, with an average age of 37 years, with 31 burst fractures and six fracture dislocations were operated on. Twenty-one patients had neurologic deficits, 2 of these complete paraplegias. One fracture dislocation was at the Th6–7 level, 18 injuries were at the thoracolumbar junction (Th11–L1), and there were 17 lumbar fractures. The compression deformity, measured as the average anterior vertebral height, was 59 percent of the estimated original height. The average local Cobb angle was 11° kyphosis. Ten patients had a kyphosis of more than 20°. At operation, 24 patients had bone paste taken from the posterior iliac wing grafted through the pedicle into the postreduction defect. In 10 patients, a partial laminectomy was done to check or improve the reduction of the anterior vertebral wall. The decompression was evaluated by peroperative myelography and/or postoperative CT. In 2 cases, anterior decompression had to be done as a secondary procedure. One patient was reoperated on due to insufficiency of the transpedicular device. Postoperatively, about half of the patients were mobilized without a brace and about half of them with a three-point brace. All the patients in this group have been followed for at least 1 year.

Results: The average postoperative vertebral height was 88° of the estimated original height, and the average postoperative Cobb angle was 1° lordosis. The loss of anterior vertebral height during this first year was 5 percent — from 88 to 83 percent. The average loss of correction at follow-up was 5° lordosis, mainly due to narrowing of damaged discs. Three technical failures substantially contributed to the loss of reduction. Neurologically, all the patients improved except the 2 paraplegics. One year after the injury, half of the patients were back at their original work. The device was usually removed after 1 year. Twelve patients, all bone grafted transpedicularly, have been followed for at least 6 months after removal of the device. During these 6 months, no further loss of anterior vertebral height has occurred. The kyphosis angle has increased by 4° owing to further narrowing of damaged discs.

Treatment of vertebral fractures and dislocations of the thoracolumbar area

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Introduction: CT evaluation of fresh traumatic injuries of the spine improves our understanding of spinal injuries. Transpedicular screwing gives us a sufficient method for the treatment of unstable vertebral fractures of the thoracolumbar area.

Patients and methods: Between 1983 and 1985, we treated 193 patients with fractures of the lower thoracic and lumbar spine. At first, we analyzed the fractures, if necessary by CT. For simple stable fractures, we chose early functional treatment or an early mobilization in a three-point brace. The method of transpedicular screwing (Roy-Camille) and the internal fixator (Dick) gave us a practical method of instrumentation for unstable fractures with or without neurologic symptoms. The advantage of this method is the possibility for early mobilization.

Results and discussion: We found in no case a deterioration of the neurologic symptoms, but in many cases an improvement of an incomplete paraplegia. In cases with complete paraplegia, the operation allowed an early rehabilitation.

Conclusion: We conclude from our results of a follow-up study that the functional and the three-point brace treatment gave good results for stable fractures. In unstable fractures, the transpedicular instrumentation is a sufficient method to stabilize the fracture and to mobilize the patient early.

Current treatment of thoracolumbar fractures

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The registration of motor function and sensibility of the extremities immediately after the accident, with a detailed case history, is important. Plain radiographs, lateral tomograms, and CT scans are obtained in all the patients. In some cases a myelogram is necessary to demonstrate a compression of the spinal cord.

Stable vertebral fractures without neural involvements are treated conservatively. Unstable vertebral fractures, especially those with neural involvement, are treated operatively with internal fixation and fusion.

The operation is undertaken as soon as possible, even during the night, and under general anesthesia. In the thoracic spine and at the thoracolumbar junction, the operative reduction is performed with Harrington's distraction equipment and distraction rods. Fractures of the L3 and L4 vertebrae are treated with Dick's transpedicular equipment. In fractures of L5, Harrington's distraction rods with a distal horizontal bar is used instead of lower hooks. In all the cases the procedure is completed by local fusion of the injured segment, usually three dorsal arches, with iliac bone grafts.

If narrowing of the neural canal is still present after reduction and internal fixation, and if compression of the spinal cord is verified radiologically, an anterolateral decompression operation with interbody fusion is undertaken during the following days.

The patients are kept in bed for 2–6 weeks. Mobilization is started with a hyperextension brace, and the brace treatment is continued for an average of 3 months. After surgery the patients participate in a full rehabilitation program. The Harrington rods and Dick equipment are removed after 9–12 months.

Trigeminal sensory impairment after whiplash injury of the cervical spine

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Introduction: A whiplash injury is defined as a soft-tissue lesion of the cervical spine. The possibility of damage of other structures than the musculoskeletal system, such as a subtle lesion of the cervical medulla and even intracranial contents, has been proposed. The purpose of the present study was to evaluate quantitatively the cutaneous thresholds for vibration and temperature over the ophthalmic and mandibular division of the trigeminal nerve in patients with disabling symptoms after a whiplash injury.

Patients and methods. Thirty patients with a whiplash injury due to car accidents were investigated at a minimum of 6 months after the trauma. Seventeen healthy individuals served as a control group.

Warm and cold thresholds were determined with a 30 x 30-mm metallic plate thermostimulator. Vibration thresholds were determined with a hand-held vibrator with a 13-mm probe (Vibrameter, Somedic AB).

Results: Patients with chronic symptoms showed significantly increased thresholds for cutaneous vibration over the ophthalmic ($P < 0.001$) and mandibular ($P < 0.01$) division of the trigeminal nerve as compared with asymptomatic patients. The cutaneous thresholds for temperature were significantly increased over the ophthalmic division ($P < 0.001$), but not over the mandibular division.

Conclusion: The trigeminal sensibility for vibration and temperature seems to be impaired in patients with chronic symptoms after a whiplash injury, which is possibly due to a lesion in the trigeminal tract at a high cervical level.

Cervical spine injuries treated with the halo vest

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Introduction: The "halo" was described by Perry and Nickel as a cervical spine fixation device in 1959. It rapidly became a commonly used nonsurgical alternative for treatment of cervical spine injuries (CSI). There have been several reports in the literature of the efficacy of the halo-vest apparatus, especially in patients with upper CSI, but concern has been expressed about its use in patients with neurologic impairment. The aim of the present study was to report our experience with the use of the halo vest in a series of unselected patients treated for CSI (with or without tetraparesis).

Patients and methods: Eighty-three consecutive patients with unstable CSI were treated with a halo vest between 1976 and 1985. They were treated prospectively according to a specific protocol with a halo vest for 12 weeks. Forty-four patients (53 percent) initially had neurologic deficits, 26 of whom had tetraparesis. The age range was 13–89 years, and the male-female ratio was 2:1.

Results and discussion: Three patients died within 1 year after their injury: 2 patients died during the halo-vest treatment, and a third patient died 6 months after the injury. Two patients were lost for follow-up. Seventy of the remaining 78 patients healed without delay (90 percent). The nonunions occurred in fracture types known to be prone to nonunion. Complications during the treatment were usually minor, with pin problems being the most frequent ones (pin loosening was 60 percent). Except for urinary tract infections, there was no significant difference in complication rate between patients with or without tetraparesis. We recommend the halo vest as a primary treatment method in all cooperative patients with unstable CSI.

Late results after cervical spine injuries treated with the halo vest

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Introduction: The halo-vest apparatus has been part of the routine therapeutic armamentarium for patients with unstable cervical spine injuries ever since its introduction in 1959. However, no attempts have been made to evaluate the late results in patients with these injuries treated with the halo vest. This was the purpose of the present study.

Patients and methods: Eighty-three patients with cervical spine injuries were treated in a prospective consecutive series with a halo vest. Two years after the trauma, 6 patients had died and 8 patients had been surgically stabilized. Sixty-seven of the remaining 69 patients were followed up 3 (2–7) years after the trauma. The follow-up included a questionnaire about residual complaints, clinical examination, and radiography. The radiography included radiographs in flexion-extension and side bending. The motion of the neck was measured radiographically with the exception of axial rotation, which was measured with the aid of a compass placed on top of the head.

Results. No nonunions were diagnosed at the follow-up. Approximately four fifths of all the patients, regardless of neurologic deficits, had complaints of local neck symptoms, pain at the extremes of neck motion, and stiffness, which was the most frequent complaint. The symptoms were regarded as being mild by most patients, and they did not usually have any major impact on return to work or leisure activities. Neurologic recovery was as good as in series with other treatment alternatives. The patients also had a significant decrease of rotation and side bending of the neck, but normal flexion-extension motion when compared with a series of 70 normal subjects. Patients treated with the halo vest for more than 11 weeks had a significantly larger decrease of neck motion when compared with patients with a shorter period of time with the halo vest. Thus, shortening the treatment period from 12 to 8 weeks, which we believe is possible in most cervical spine injuries, seems to be favorable.

Stable internal fixation of traumatic cervical spine injuries

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Fractures and dislocations in the cervical spine cause various degrees of instability and in some cases injuries to the spinal cord or nerve roots. Early decompression and stabilization should facilitate the rehabilitation and minimize the risk of permanent deformities and progressive myelopathy.

Sixty-four patients (50 males and 14 females) with dislocations or fractures in the cervical spine have been operated on with reduction and stable internal fixation. The mean follow-up time was 6 months. Ten patients had injuries in the CO-C2 region and 54 in the C3–Th1 region. Twenty-six of the patients had tetraparesis or tetraplegia. In the upper cervical spine four screw fixations of the dens according to Böhler, four Gallie fusions, and two fixations with Roy-Camille plates were performed. In the lower cervical spine the procedures consisted of 15 anterior fusions with bone grafts and Orosco plates, 19 posterior reductions and fixations with cerclage wires or screws and plates. In 20 cases anterior and posterior operations were combined. In 12 cases the first operation was insufficient, and was therefore completed with a second procedure.

All the injuries united without deformity or progress of the neurologic damage. Two patients had transient hoarseness and two had dysphagia. Two patients died in the postoperative period of myocardial infarction and respiratory insufficiency with pneumonia. The program for treatment of cervical spine injuries has proved to be safe and effective. In spite of early mobilization without external support, the injuries have united solidly and without redislocation.

Postlaminectomy deformities in the cervical spine

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Kyphotic deformities appear very often after laminectomy, a procedure which implies that the posterior tension-stabilizing structures of the spine have been excised. The following cases bear witness of such sequelae.

The series consisted of 5 cases operated on with an extensive laminectomy on three to six cervical vertebrae because of various diagnoses such as Klippel-Feil's deformity, trauma, tumor, and infection. All the patients had developed a pronounced kyphotic deformity with its vertex within the centrum for the laminectomy. Two of the cases were tetraplegic and 3 had myelopathy with spastic and motor disturbances.

The treatment consisted of decompression, reduction, and fusion. This was done with an anterior or posterior approach, and in 1 case with a combination of these. In one of the cases a successive slow reduction was performed with a halo-pelvic device.

The 2 tetraplegic patients, whose main symptom was local pain, were completely relieved after the stabilization. They also became better candidates for an active rehabilitation program. Two of the myelopathy patients became completely rehabilitated. The third one recently operated on is slowly restituting. One of the patients who had developed a pronounced swan-neck deformity gained a normal head and neck position.

Extensive laminectomy without a stabilizing procedure

will lead to a kyphotic deformity of the cervical spine. Because of compression of the cord, a myelopathy will easily develop with impaired neurologic function below the injury. It is considered important not to destroy posterior-tension stabilizing structures without a compensating, stabilizing procedure, a posterior or anterior fusion, or both of these operations. Posterior cervical surgery may also cause a denervation of posterior muscles, which also may play a role in developing the kyphotic deformity.

Pediatric orthopedics

The etiology of congenital luxation of the hip

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Several factors are important for the development of a manifest congenital dislocation of the hip (CDH), e.g., the prenatal and postnatal positions of the legs, the shape of the acetabulum, and the mechanical properties of the joint capsule. It is known that patients with CDH often are born in the breech presentation. Recently, it has been shown that the position in utero with flexed hips and extended knees is of more importance than the actual breech presentation. The effect of postnatal position of the legs has also been known for a long time. The incidence of CDH is high among Lapps and Indians, where the infants were carried with straight and adducted hips. Also a low incidence of manifest CDH is recorded when neonatally unstable hips are treated in abduction and flexion, as in Scandinavia. It has also been reported that the acetabular angles in unilateral cases have been larger than in controls, and that relatives also have steeper acetabula. However, in the thesis of Fredensborg the acetabular angle was not steeper in the adult age than in controls, and the dysplasia is probably an effect of subluxation rather than a cause of CDH. That there is a generalized disorder of the connective tissue also persisting in young age is suggested by the persistent joint laxity. In the umbilical cord the content of collagen is decreased and the content of type I collagen is lower than the type III collagen. Also, an increased incidence of inguinal hernia has been observed. In a recent study in Malmö, we found an increased incidence of hernia in children with CDH, especially during the first 3 months of life, where the risk for boys and girls was respectively 6.6 and 11.2 times greater. The girls with CDH accounted for one fourth of all hernia operations in girls during the first 3 months of life. The level of serum relaxin during pregnancy is higher in patients with pelvic instability. Because relaxin stimulates collagenase, it is possible that this can explain the increased risk for hernia, the decrease of collagen in the umbilical cord, and the neonatal pelvic instability in children with CDH.

Ultrasound screening of the hip joints in newborns

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The value of ultrasound in screening for congenital hip joint dysplasia and dislocation in newborns is for the time being unsettled, and the purpose of the present study was to throw some light on this matter.

Subjects and methods: Two thousand newborns were examined consecutively during the period January to October 1987. Clinical and utrasonographic examinations were performed on one of the first 4 days of life. With the infant in the supine position, the ultrasound transducer was placed on the lateral aspect of the hip and kept parallel to the long axis of the body. We measured the distance from the acetabular floor to the lateral bony rim of the acetabulum, and from the same point of the acetabular fossa to the lateral joint capsule. The measurements were taken along a line perpendicular to the long axis of the transducer. The percentage of the first distance to the latter was called the Bony Rim Percentage (BRP). This value is an expression of the percentage of the femoral head that is covered by the bony acetabulum.

Results: The mean BRP was 55 percent in girls and 57 percent in boys, and the lower normal limits (mean –2 SD) were 44 and 47 percent. The difference between girls and boys was significant. Instability was shown by ultrasound in 20 hips of 17 infants (0.9 percent), and the mean BRP of these hips was 40 (29–44) percent. In infants with normal clinical findings, the BRP was below the normal limit in one or both hips in 28 cases (1.4 percent). These were followed up at 2 and 4-5 months. The hip joints became normal without any treatment in 23 infants, whereas in 3 others the ultrasound findings were still uncertain, and these may later need treatment. In 2 infants, abduction treatment was started at 5 months because subluxation was revealed by ultrasound and radiography.

Conclusion: Evaluation of the hip joints in newborns by ultrasound using the BRP seems to be an appropriate method in screening for hip joint pathology. Newborns with clinically normal hip joints and a degree of covering of the femoral head below the normal limit at ultrasound should be regularly followed to determine whether they spontaneously normalize or need abduction treatment.

Evaluation of sonography for diagnosis of NHI

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Since 1983, sonography has been used for detection of neonatal hip instability (NHI). The sonographic diagnosis has been

related to physical examination in two consecutive studies, one of 109 healthy newborns and another with 108 newborns admitted for suspected hip instability. The clinical evaluation was in these studies found to be highly inaccurate, with a vast overdiagnosis of hip instability. Moreover, the clinical investigator could fail to detect gross instability. At our hospital, all the newborns with the slightest suspicion of hip abnormalities or with risk factors, such as heredity for NHI or breech presentation, are routinely referred by an experienced pediatrician for a sonographic examination. The annual birth rate is 1,800. Since 1984, this policy has produced 1 late CDH in the group of children not referred for sonography. In the group examined with ultrasound, no cases of late CDH have been detected. In addition, the introduction of ultrasonic diagnosis has considerably decreased the number of children treated for NHI. Further, as the process of stabilization of the joint can be closely monitored, it has been possible to reduce the time in an abduction splint to 4–6 weeks. These two effects alone will produce a substantial reduction in society's costs for prevention of late CDH.

At present, we feel that sonographic screening of all newborn infants is a most urgent step in evaluation of the future role of sonography in NHI.

Sonography in the diagnosis of neonatal hip instability

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Introduction: In Scandinavia, 5–20 times more children are treated for neonatal hip instability than the expected incidence of manifest congenital dislocation of the hip (CDH) without early screening. During 1987, we have used sonography in an effort to reduce this overtreatment.

Patients and methods: All the children born in Malmö from 1980 through 1987 in whom pediatricians had noted hip instability are included in the study. The instability was categorized into four degrees: possible sliding, definite sliding, dislocatable hip, and dislocated hip. The children were referred to the orthopedic department for further treatment and follow-up. During the period 1980–85, an experienced orthopedist saw 64 percent of the children. During 1987, one of three specially trained orthopedists examined 93 percent of the children together with one of three specially trained radiologists. The hips were provoked according to Barlow and the degree of mobility in reaction to the acetabulum was measured with ultrasound of 4.5 mHz. Children with a hip instability exceeding 30 percent were treated with a splint. The hips of all the children were radiographed at the age of 3 and 12 months. Only 1 girl, born in 1985, with a grade 2 instability that was not treated in a von Rosen splint later developed a manifest dislocation of the hip. Otherwise no failure of the program of treatment occurred.

Results: The material is tabulated below.

	Number born	Number referred	Number of grade 4	Number of grade 3	Number in splint
1980	2 337	104	2	29	82
1981	2 360	107	0	40	57
1982	2 303	82	3	23	48
1983	2 370	78	2	22	42
1984	2 343	63	6	23	28
1985	2 515	62	10	25	37
1986	2 559	53	1	20	37
1987	2 611	71	10	22	37

The experienced orthopedist treated 157/319 children with a von Rosen splint (49 percent), whereas the other orthopedist put 164/228 children in a splint (72 percent). Using sonography, 34/66 children were treated in a splint (52 percent).

Discussion and conclusions: Compared with an experienced orthopedist, the sonography did not reduce the incidence of children treated in a von Rosen splint. However, the ultrasound technique facilitates the training because you can correlate the feeling of the hands with the observation of your eyes and more easily differ true hip instability from a pelvis that moves together with the femoral head. We feel that without ultrasound we would have treated more children with a von Rosen split.

Current role of sonography in late CDH

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We divide the orthopedic management of infants with late congenital dislocation of the hip (CDH) into four phases: diagnosis, reduction, retention, and normalization of delayed skeletal development. Except for a primary radiograph, we rarely use radiographic examinations in the first three phases. Instead, the hip is visualized by an anterior sonic projection with the transducer in the groin and the infant in the "frog position" (Dahlström et al. 1986). This projection provides excellent information regarding the anatomy, position, and stability of the joint. A comparative study with arthrography and CT showed that ultrasonic investigation alone provided all the relevant information given by the two radiographic methods. In addition, sonography is harmless and does not require anesthesia of the child. During the phase of skeletal remodeling, ordinary radiographic examination should be complemented by sonographic investigation using a lateral approach according to Graf (1986). This view will visualize the unmineralized lateral parts of the acetabulum and gives valuable information regarding the potentials for a spontaneous normalization of the acetabular socket.

The increased information gained by sonographic evaluation has provided a sound base for conservative treatment of the disease and have in most instances abolished the indications for surgery.

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CDH diagnosed at 2–12 months of age: Treatment and results

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Introduction: Reduction of late diagnosed congenital dislocation of the hip (CDH) must be carried out gently to avoid avascular necrosis of the proximal femoral epiphysis. Retainment of the femoral head within the acetabulum ensures normalization of dysplasia. We present a 10-year material treated according to these principles.

Patients and methods: The basic principles for treatment of CDH diagnosed between 2 and 12 months of age at our department are 1) skin traction for decreasing the adduction contracture; 2) peroperative arthrography, and in cases with persisting adduction contracture, tenotomy of the adductor and psoas tendons; 3) plaster cast with hips in adduction and flexion for 8–12 weeks; and 4) abduction frame until normalization of the acetabular dysplasia.

Through 10 years (1976–1985), we treated 42 children with nonteratologic CDH diagnosed at 2–12 months of age. In a clinical and radiographic follow-up investigation 2–11 years after diagnosis, 40 of these children were included; 2 had moved to other parts of the country. The mean age at diagnosis was 5 months. Of the 40 children followed up, 37 were girls. Nineteen dislocations were left-sided and 21 were right-sided. Open reduction was carried out in 2 patients.

In the follow-up radiograph, signs of necrosis were recorded and the acetabular angle was determined. Discrepancy in leg length and hip joint mobility was searched for in the clinical investigation. A questionnaire regarding the treatment was answered by the majority of parents.

Results: Radiography. Thirty-eight hips were normal, i.e., no signs of dysplasia and an acetabular angle differing < 3° from the healthy hip. Two patients showed the picture of coxa magna. *Clinical findings.* Four children, including the 2 with radiographic complications, had a leg length discrepancy of 1–2 cm. Four children had limitation of hip mobility > 10°as compared with the healthy side in one direction of mobility. *Questionnaire.* The treatment method used was considered uncomplicated by the parents. Three of the parents regarded their children as late in motor development for up to 6 months after discontinuation of treatment. At the time of follow-up, no child was considered to have a retarded motor development. Of 21 children wearing an abduction frame on their first birthday, 13 had learned to walk while the splint was on.

Conclusion: The treatment program described gives a high frequency of normal hips radiographically, as well as clinically, and is, at least in retrospect, not regarded as strenuous by the parents.

Treatment of congenital dislocation of the hip in children more than 1-year old

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Introduction: The treatment of congenital dislocation of the hip (CDH) in children over 1 year of age is long lasting and the results are satisfactory. The purpose of this study was to review our experience with treatment of these children.

Patients and methods: Sixty-three patients (14 boys and 49 girls) with 79 dislocated hips started treatment in our hospital during the years 1969 to 1979. There were 47 unilateral and 16 bilateral dislocations. The average age at diagnosis was 19 (12–54) months. The average follow-up was 13.5 (6–18) years.

Results: Reduction by skin traction succeeded in 74 hips, and five required an open reduction. The average duration of traction was 4 (1–10) weeks. Concentric reduction was achieved in all the hips. After reduction the hips were immobilized in a bilateral hip spica cast for an average of 9 (1–19) months. In addition, a brace/cast that allowed mobilization was used for another 7 (2–13) months. None of the hips developed avascular necrosis.

Proximal femoral varus derotation osteotomy was done in 34 patients, 31 bilaterally (19 with unilateral dislocation). Innominate osteotomy was done in 13 hips, five of which also had a derotation osteotomy. Three hips had a second varus osteotomy, and one of these also had a acetabuloplasty simultaneously. Twenty-three patients had no secondary procedures. On clinical evaluation, 73 hips were rated as excellent. Radiographically, 57 hips were rated as Severin group I, 5 group II, 13 group III, and 4 group IV. There were none with a secondary acetabulum or dislocation.

Discussion: The results in our series are similar to the results of other studies and far below the results when treatment starts shortly after birth or before the age of 1 year. It is of great importance to encourage hip examination at the child welfare clinics.

Dynamic splint for treatment of congenital dysplasia of the hip

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Introduction: A device to treat dysplasia of the hip must satisfy the following conditions: a) eliminate the influence of the

contracted iliopsoas muscle by flexing the hips, b) avoid extreme passive abduction to prevent ischemic necrosis of the femoral head, c) retain the mobility of the hip joints to keep the joint cartilage in optimal condition, d) provide proper centralization of the femoral head in the acetabulum to restore the anatomic architecture of the joint by means of the inductive effect of the femoral head, and e) must be"mother-proof."

Subjects and methods: A prospective review of 224 cases of dysplasia of the hip treated between 1980 and 1985 with the dynamic splint is presented.

A dysplastic hip was defined as a stable hip that required acetabular remodeling. Dysplasia was diagnosed in cases with a steep acetabular angle according to the criteria of Tönnis and Brunken.

The dynamic splint is made of nonsensitizing materials and is easy to clean. It satisfies all the above-mentioned requirements. It is fixed by straps around the belly and thighs. Hinges permit abduction between 20 and 80°and flexion of more than 90°. Once applied, the splint was worn day and night for 3 months. After 3 months, an anteroposterior radiograph of the pelvis was taken. If the acetabular angle was restored within the limits given by Tönnis and Brunken, the treatment was discontinued. If there was no satisfactory improvement of the acetabular angle, treatment was continued for another 3 months.

Results and discussion: Of the 224 hips treated for dysplasia, none developed total or partial changes in the femoral head compatible with ischemic necrosis. Restoration of a normal acetabular angle occurred in all the cases — in 80 percent within 3 months, in 15 percent within 6 months, and in 5 percent within 9 months.

Routine treatment with the dynamic splint is justified because of the simplicity of design and the ease of application. The device is readily accepted by parents and patients and does not affect normal routines of nursing and diapering.

Rebuilding of the hip joint after conservative treatment of congenital dislocation

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Totally, 1,008 hips treated with the Frejka pillow were evaluated radiographically. The treatment was started between 1 and 24 months of age. An early evaluation was done immediately after the end of treatment at the age of 15–36 months and a late evaluation of 530 hips at the age of 14 (10–21) years. The total number of examinations, including the indirect ones, was 3,005. The evaluation was based on 4 or 6 radiographic parameters and a total point assessment.

On the basis of the results´ distribution in the course of growth of children, the rate of radiographic rebuilding of the hip joint in different periods of life has been determined. In this way the indications for surgical treatment of residual dysplasia have been determined as well.

Development of the hip joint with avascular necrosis after conservative treatment of CDH

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Each year about 250 children with CDH are treated at our department. The most serious complications of this treatment are still redislocation and avascular necrosis. To evaluate the influence of avascular necrosis on the development of the hip during growth, 61 hips with such changes were reviewed both clinically and radiographically. The hips were selected from patients treated for CDH during the period 1957 to 1969. The age of the patients during final examination was 20 (17–26) years. In the radiographic examination the generally accepted indexes were used.

The difference in results depended on the localization of avascular changes in the proximal femoral end. The classification of avascular necrosis based on the results is proposed as follows:

Type I: irregular contour and structure of the ossification center.
Type II: capital center of ossification fragmented and recognizable by fragments or as a flat strip.
Type III: involvement of the physis and lateral part of the metaphysis.
Type IV: involvement of the physis and medial part of the metaphysis.
Type V: total involvement of the physis and metaphysis.

The radiographic changes in the femoral neck, seen in some cases of avascular necrosis, were observed in most cases with severe deformity; but they did not always allow prediction of the final deformity.

Functional treatment of Perthes´ disease

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Introduction: Whilst the natural history of Perthes´ disease is well known, the initiating agent remains unidentified. Treatment is, therefore, empirical. Containment appears to allow the capital femoral epiphysis to reform to give acceptable congruency. Many abduction orthoses produce containment, but also restrict the function of the hip. It was to use the motion of the hip joint to give a moulding effect that the Trans Pennine Splint (TPS) was designed.

Materials and methods: The TPS consists of a polythene body jacket with a hip abduction flexion hinge, a plastic thigh cuff, a second knee flexion hinge and calf cuff. These are held

in place with "velcro" fastening. To date, 32 boys and 8 girls have been fitted. All of Catterall's groupings have been treated. The children have full clinical assessment with plain radiographs and a weight-bearing radiograph at initial fitting to check containment. Adjustments are made as necessary. There were two monthly clinical and radiographic follow-ups.

Results: A number of children have been allowed to discard the splint. The sphericity of the femoral head assessed by Mose's criteria gave fair or good results in the majority of patients, and most hips had a full range of movement.

Conclusions: The patient tolerance of the orthosis has been remarkable, and good early results have been obtained.

Femoral anteversion decreases with age in children with intoeing gait

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To what extent increased femoral anteversion in children with intoeing spontaneously decreases with age is a controversial issue. The aim of the present study was to provide reliable data concerning this matter.

Patients and methods: The study, which was prospective, was started in 1976, and 30 children referred for an intoeing gait were followed at least until 15 years of age. All the children were examined three times during growth. The mean age at the first examination was 7 years, at the second 10 years, and at the third 16 years. The mean observation time was 9 years. At each examination, hip rotation and any intoeing gait were recorded, and the femoral anteversion (AV) was measured radiographically using the method of Dunlap-Rippstein.

Results: The mean AV angle at the first examination was 42°, at the second 36°, and at the last examination 28°. The mean reduction of the AV angle was 1.5° per year, with a considerable range: 0.3–2.9°. At the last examination, 35 hips in 20 children had AV values above the upper limit of normal for age.

The mean value of internal hip rotation decreased from 74° to 53° during the observation period, and external rotation increased from 18° to 37°.

All 30 children had an intoeing gait at the first examination. At the second control, 21 children had intoeing, and at the last examination intoeing had disappeared in all but 5 children.

Conclusion: Increased femoral anteversion in children spontaneously decreases with age. However, the AV angles still were above the upper normal limit in more than half the patients at 15–16 years of age. The attending intoeing disappeared with age in most children.

The significance of hemarthrosis of the knee in children

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Introduction: Hemarthrosis of the knee is generally considered a manifestation of serious ligamentous injury in adults, but the pattern of injuries associated with hemarthrosis of the knee in children is less well known.

Patients and methods: Forty consecutive patients, median age 14 (10–15) years, with hemarthrosis of the knee were examined arthroscopically on the day following injury.

Results: Twenty-three of the injuries were related to low-energy trauma during sports participation. Eighteen patients had a rupture of the anterior cruciate ligament. Only 2 of these had an avulsion fracture of the tibial spine. Seven patients had a partial rupture of the anterior cruciate ligament. Seven patients had a midsubstance rupture of the anterior cruciate ligament. Eleven patients had a dislocated patella. Six patients had minimal capsular disruptions as the cause of hemarthrosis. Three patients had osteochondritis dissecans of the knee, and 2 patients had isolated ruptures of the medial collateral ligament. Twenty-eight of the patients underwent some form of operative repair. The clinical diagnosis was only confirmed at arthroscopy in 17 cases.

Conclusions: Hemarthrosis of the knee in children generally signifies a serious knee injury, most commonly a rupture of the anterior cruciate ligament. The full amount of damage is not appreciated at the clinical examination. Arthroscopy should be carried out because the diagnostic accuracy is improved.

Tibial torsion determined by computed tomography

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Introduction: Measuring tibial torsion has been an unsolved problem. Previous authors have presented the use of computed tomography (CT) to measure tibial torsion; and in this report, we present our way of determining tibial torsion by the use of CT.

Methods: CT scans of the femoral condyles were chosen for the reference line as the dorsal tangent to the condyles. Tomograms through the ankle joint were used for measuring the tibial torsion. A measuring point was assigned to the center of the medial malleolus and a second to the center of the lateral malleolus. The line through these points was drawn, and the angle formed between this line and the reference line was used to determine the tibial torsion. This was measured in 16 females and 15 males.

Results: In the females the angle was found to be 38 ±11° on the right side and 37 ±11°on the left side. In the males the figures were 45 ±5°and 44 ±7°, respectively.

Discussion: In this study, we used the dorsal tangent to the femoral condyles as the reference line, and this construction has been generally accepted for measurement of femoral anteversion. It has been claimed that increased femoral anteversion is frequently associated with compensatory external torsion of the tibia. The present method should, therefore, be especially valuable in the evaluation of such conditions.

Leg lengthening with the Ilizarov technique

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Elongations of limbs have been performed since the beginning of this century, but the early results were discouraging. The breakthrough came with the Wagner method in the late 1960s, in which gradual distraction, bone grafting, and plate fixation are used. The Ilizarov method was introduced in Western Europe in the early 1980s. No bone grafting is necessary. An external fixator, consisting of metal rings is attached to the bone with K wires.

Since 1985, 12 patients with 18 segments have been lengthened at our department. The total amount of lengthening exceeds 1 meter. In 1 case the distraction was stopped because the patient could not cooperate. Complications have been angular deformities, decreased joint motion, pes equinus, refracture, minor transient nerve impairments, and pin-tract infections.

We believe that leg lengthenings are preferable when one deals with leg-length inequalities, but there are contraindications. Ilizarov's technique has many advantages compared with Wagner's method. Finally, leg lengthenings should be centralized to a few hospitals.

Nerve entrapment

Nerve entrapments: Pathophysiologic aspects

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Compression of a peripheral nerve trunk may result in various neurologic disturbances, varying from slight paresthesiae to complete loss of sensory/motor function. The character and extent of dysfunction reflects intraneural pathophysiology. Already moderate compression may interfere with intraneural microcirculation and anterograde, as well as retrograde, axonal transport. Pressure of higher magnitude may result in myelin damage and ultimately axonal degeneration.

Animal studies performed by Rydevik, Dahlin, and others have helped to define certain critical pressure levels. Already at compression of 30 mmHg there is an interference with microvascular fluid and axonal transport, which is reversible when the pressure is released. Block of *anterograde* axonal transport may deprive a distal axonal segment from essential products synthesized in the nerve cell body. Block of *retrograde* axonal transport may interfere with the supply of peripherally synthesized trophic substances normally transported to the nerve cell body.

In human controls the tissue pressure in the carpal tunnel is around 2 mmHg, whereas the corresponding pressure in carpal tunnel compression patients is about 30 mmHg. This tissue pressure, monitored around the median nerve in cases of CTS, corresponds well with the critical pressure levels defined in animal models, as delineated above.

It is concluded that data from experimental studies, as well as clinical studies, indicate that even mild nerve compression syndromes may be associated with considerable changes in intraneural microcirculation and axonal transport.

Atypical carpal tunnel syndromes

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With emphasis on the clinical symptoms and signs, CTS in children and in patients with persistent median artery are described.

The children present with a lack of use of the median nerve-innervated fingers, atrophy of the fingers, and atrophy of the thenar eminence. Electromyography under general anesthesia may establish the diagnosis when the patients are too young to cooperate in a clinical examination.

A persistent median artery may give rise to thrombosis, with sudden onset of a painful CTS. Without thrombosis, the typical signs are mostly present during work. The patients are fairly young, often with a palpable pulse in the median artery and a normal electromyography. Resection of the artery is recommended after ensuring an adequate arterial supply to the fingers.

Reoperation in carpal tunnel syndrome

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Six patients who were referred after unsuccessful carpal tun-

nel release were analyzed in an attempt to ascertain the cause of failure of the primary operation. In 4 patients, injury to the palmar branch of the median nerve was strongly suspected. In 1, cervical spondylosis, with engagement of relevant intervertebral foramina, was found to be the cause, or at least was a strongly contributing cause of the patient's symptoms. In 1 patient, a volar carpal ganglion was finally found to be compressing the carpal tunnel. The 6 patients had been operated on totally 15 times with carpal tunnel release; 1 of the patients had been operated on five times. The findings emphasize the importance of avoiding injury to the palmar median branch by making the incision ulnar to the palmaris longus tendon. Repeated carpal tunnel release seems to cause recurring fibrosis around the nerve. Therefore, it is important to rule out other possible causes for recurrence before rerelease is considered.

All the patients were treated with scar excision, neurolysis, and replacement of the hypersensitive skin with a skin flap. Four were improved, but only 2 returned to their previous occupation.

Colles' fracture and carpal tunnel pressure

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To investigate the pressure in the carpal tunnel in the acute phase after a Colles fracture, a group of 13 patients were compared with a control group of 10 healthy volunteers. The initial pressure after injection of a local anesthetic into the fracture hematoma, as well as the effects of increased volar flexion of the wrist, was measured. The pressure was significantly higher in the fracture group than in the control group ($P < 0.001$).

After injection of a local anesthetic into the fracture hematoma, the pressure increased significantly ($P < 0.001$).

A correlation was found between high increases of pressure due to volar flexion of the wrist and high initial pressure. Further, a correlation was found between high initial pressures and large pressure increases after injection of a local anesthetic. Administration of a local anesthetic solution to the fracture hematoma increases the fluid content of the carpal tunnel and raises the pressure.

Volar flexion of the wrist decreases the space in the carpal tunnel, which also increases the pressure.

Reoperation in high ulnar nerve entrapment

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Ulnar nerve entrapment without any luxation of the ulnar nerve or anatomic aberrations in the elbow region are generally treated with neurolysis. This is successful in 70–80 percent of the patients. When unsuccessful, reoperation might be indicated. It can be a subcutaneous or submuscular transposition of the nerve. Submuscular transposition can also be considered after unsuccessful subcutaneous transposition. A retrospective study of secondary and tertiary operations was made. There were 20 operations on 16 arms of 14 patients with a mean follow-up time of 8 months. The primary operation was neurolysis in 18 arms and subcutaneous transposition in 2. In the secondary operation, 3/8 patients were improved and 5 remained unchanged. After submuscular transposition, 6/8 were improved, 1 unchanged, and 1 was worse. Thus, secondary operation gave about a 50 percent chance of improvement. Submuscular transposition was more successful than subcutaneous transposition. Pain, paresthesia, and weakness can be improved; 3/3 patients with a claw hand were not improved. In the tertiary operations, all submuscular transpositions, 2/4 were improved; thus, these results were similar to those of a secondary operation.

Entrapment lesions of the ulnar nerve: A 15-year experience

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Our experience of treating ulnar nerve compressions surgically was reviewed. Special attention was paid to different clinical features and prognostic factors after nerve release in the two main groups of ulnar compressive lesion: Idiopathic Cubital Tunnel Syndrome (CTS) and Ulnar Posttraumatic Neuritis (UPN).

Sixty-two patients were operated on between 1970 and 1985. There were 56 cases of nerve compression at the elbow. Out of these, 34 presented a UPN and 15 were diagnosed as CTS. Three patients had a nerve entrapment at the wrist level (Guyon's canal) and another 3 at the hand level. Surgical treatment was performed at the elbow by using neurolysis (N), anterior transposition (AT), or a combination of both procedures. For compression at the wrist and hand level, nerve release and N were the standard procedures. The mean follow-up was 3 years.

As a whole, excellent results were obtained in 30 cases with nerve lesions at the elbow. When the outcome was related to the duration of symptoms, cases with CTS had a better recovery if the delay of surgery was less than 1 year ($P < 0.05$). This did not apply to cases with UPN. However, patients with UPN more often recovered full motor and sensory function than those affected with CTS. As to surgical technique, N associated with AT was the most useful treatment for cases with more than 12 months of symptomatology. Satisfactory results were obtained in all the cases with nerve compression at the wrist and hand level. The current review

shows that good results can be obtained by using N, AT, or both combined when they are properly performed and on correct indications. The presence of symptoms for more than 1 year before operation significantly diminishes the chance of satisfactory recovery in the cases with CTS.

Entrapment of the superficial peroneus nerve

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Introduction: The purpose of this study was to determine the effects of operation on clinical symptoms and conduction velocity of the superficial peroneal nerve (SPN) entrapment.

Methods: Twenty-four legs of 21 patients with entrapment of the SPN were treated by neurolysis and fasciotomy of the lateral compartment of the lower leg. Intramuscular pressure was measured with the Myopress catheter and the microcapillary infusion method. Conduction velocities of the SPN were performed preoperatively, and between 6 and 12 weeks following surgery. The diagnositic criteria for entrapment of the SPN were 1) local pain and decreased sensibility over the dorsum of the foot at rest or during exercise, 2) pain and paresthesia during different provocation tests, and 3) abnormal nerve conduction velocity and/or fascial defect at the site where the nerve emerges from the compartment.

Results: Nineteen of the 21 patients were followed up at 37 months. Nine were satisfied with no or few symptoms. Of the 10 unsatisfied patients, 6 were improved, 3 unchanged, and 1 was worse compared with their preoperative condition. Their physical actvities were unlimited or increased in 13 and unchanged in 6. The conduction velocity of the SPN increased from 28 (SD = 18.5) m/s to 40 (17) m/s following operation. During surgery a waist (c) on the nerve was seen in 12 legs, poststenotic swelling (d) in 5 legs, impingement in 6 legs, fascial defects in 12 legs, a peroneus tunnel (a) exceeding 3 cm in 10 legs, and an anomalous course of the nerve was seen in 6 legs. Entrapment of the SPN was combined with chronic lateral compartment syndrome in 2 patients and followed trauma to the lower leg in 5 of the patients.

Discussion: Local tenderness and sensory abnormality by clinical examination following an exercise test are useful signs in the diagnosis of SPN entrapment. Decompression relieves pain and sensory abnormality in half of the patients, improves symptoms in one fourth of them, but is less effective in athletes with high demands on physical activity. Patients with entrapment of the SPN without chronic lateral compartment syndrome could possibly have been treated by local fasciectomy and partial fasciotomy.

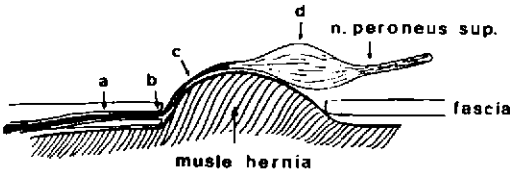

Figure 1. Schematic drawing illustrating.
(a) peroneus tunnel
(b) impingement
(c) waist and
(d) poststenotic swelling

Axillary nerve entrapment

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Introduction: Entrapment of the axillary nerve in the quadrilateral space is one cause of chronic shoulder pain. The axillary nerve is surrounded by the teres major and minor and triceps muscles and by the humerus in the quadrilateral space. Although injury of the axillary nerve related to shoulder dislocation is common, entrapment in the quadrilateral space without any major injury is a rather unusual entity.

A dull ache over the posterior area of the axilla is a typical symptom of axillary nerve entrapment. In advanced cases, wasting of the deltoid muscle can be observed. In clinical examination, tenderness over the quadrilateral space in the posterior part of the axilla is an invariable sign. Operative management is easy and gives good results.

Patients and methods: Six operated on patients (3 females and 3 males, mean age 32 years) are presented. The time between the onset of symptoms and the operation was 3.5 (0.5–11) years. In 1 case, volley ball playing, in 1 case javelin throwing, and in 2 cases shoulder distension were presumable provocative factors. Nerve conduction time was prolonged in all the cases. Deltoid atrophy was found in only 2 cases. Treatment was external neurolysis of the axillary nerve.

Results and discussion: In all the cases the axillary nerve was adhered to or compressed by scar tissue in the quadrilateral space. All the patients recovered. The pain disappeared promptly. Deltoid atrophy recovered in 1 year in 2 cases.

A more extensive material concerning axillary nerve entrapment has not been presented. However, this entity is undoubtedly more frequent than is suspected, and it may be responsible for disabling symptoms in the shoulder region. Axillary nerve entrapment should be considered as a differential diagnosis in a patient with aching in the posterior region of the shoulder or axilla.

Nerve entrapment lesions of the upper extremity as a result of posttraumatic or iatrogenic scarring

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From January 1970 through December 1985, a total of 312

cases of nerve lesions of the upper extremity were treated at our department. Of these, 30 (9.6 percent) presented clinical signs of an entrapment neuropathy, with a short history of trauma or surgical procedure performed over or in the proximity of the course of the involved nerve. In all 30 patients the continuity of the nerve was demonstrated by methods, such as electromyography or sweat testing, and was confirmed during the surgical treatment. The ulnar nerve was implicated in 14 cases, the radial nerve in 10 cases, and the median nerve in 6 additional patients. Motor disability and sensory disturbances were carefully assessed before and after the operation by using the scoring system adopted by the Nerve Committee of the British Medical Research Council. All the lesions were treated by neurolysis.

Motor function was completely recovered in 15 of the 21 patients with initial dysfunction. Recovery from sensory disturbances was reached in 21 of the 26 patients with preoperative impairment. When the functional recovery was related to the presence or absence of associated lesions, significantly better results ($P<0.01$) were noted for those without concomitant neural, vascular, or tendinous damage. Taking all the lesions together, satisfactory results were obtained after neurolysis in more than two thirds of the cases. Radial nerve lesions responded better to surgical treatment than those involving the other nerve trunks. Ulnar nerve lesions had the worst prognosis. The evaluation of our results, with a high percentage of motor and sensory recoveries, substantiates the value of neurolysis for cases with nerve entrapment lesions caused by posttraumatic fibrosis or iatrogenic scar tissue in the upper extremity.

Bone tumors

Fine needle aspiration cytology of soft tissue tumors

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Fine needle aspiration and cytodiagnosis (aspiration cytology, AC) is a valuable tool in the preoperative diagnosis of a soft tissue tumor.

Fifteen years' experience from the Orthopedic Oncology Center in Lund has shown that it is possible with a fine needle (0.7–0.8 outer diameter; gauge 21–22) to obtain a sufficient number of cells for cytodiagnosis from more than 95 percent of unselected soft tissue tumors.

As a screening method, AC separates benign lesions/tumors from sarcomas in more than nine tenths of the patients.

Correlative histologic and cytologic studies on a number of histogenetically well-defined tumor types has defined the cytomorphology of these tumors making it possible to diagnose them in an aspirate smear. A specific tumor type diagnosis is thus possible.

In the majority of sarcomas it is possible to determine whether the sarcoma is low-grade malignant (corresponding to histologic malignancy Grades I–II) or high-grade malignant (corresponding to Grades III–IV).

Diagnostic pitfalls: The majority of false cytodiagnoses have been related to the following entities:

Benign lesion/tumor	Wrong diagnosis
Atypical lipoma Fatty tissue with reactive, inflammatory changes	Low grade liposarcoma
Ancient neurilemmoma	Sarcoma
Fibromatosis	Monophasic synovial sarcoma
Intramuscular myxoma	Low grade myxofibrosarcoma

By the combination of cytodiagnosis and clinical and radiological findings, several benign and malignant tumor types can be readily diagnosed without surgical open biopsy. By primary surgery of sarcomas the margins necessary for a low risk for local recurrence can then be kept smaller than otherwise recommended. This is especially of importance in deep-seated tumors.

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DNA content and clinical course in soft tissue neoplasia

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In a prospective study of 119 soft tissue tumors, treated at the Orthopedic Oncology Section at the Karolinska Hospital between from 1980 through 1986, the relationship between cellular DNA content and histopathologic classification was analyzed. The prognostic significance of DNA content as compared with histologic malignancy grading was also investigated.

Cell material was obtained from fresh surgical specimens. Nuclei were stained with ethidium bromide and analyzed in an ICP 11 flow cytofluorometer. Human lymphocytes were used as staining controls of the normal (diploid)) DNA content. Tumors were classified as diploid or hyperploid (abnormally increased DNA content).

The benign series included 38 tumors. DNA analysis of six lesions was inconclusive due to insufficient cellular yield. The remaining 32 tumors were all diploid. In the malignant series, 30 tumors were diploid and 51 hyperploid. There was a clear relationship between ploidy and histologic grade in the sense that most low-grade (I–II) lesions, i.e., 14 of 16, were diploid, whereas most high-grade lesions (III–V), i.e., 49 of 65, were hyperploid.

The clinical course in soft tissue sarcoma was analyzed in relation to ploidy level and histologic grade for 74 patients, who were free of metastasis at presentation. The mean follow-up was 4 (1–7) years. Three-year metastasis-free survival was determined by life table analysis according to Kaplan-Meier. For patients with low-grade tumors, the rate was 0.80 and for those with high-grade tumors 0.55. According to ploidy level the corresponding rates were 0.82 for those with diploid lesions and 0.42 for those with hyperploid lesions. Closer analysis of the 65 high-grade lesions showed no difference in 3-year metastasis-free survival between patients with grades III and IV tumors, i.e., 0.49 and 0.50, respectively. However, according to ploidy level of the same tumors, the rate was 0.78 for patients with diploid tumors as compared with 0.41 for those with hyperploid tumors.

The present study of soft-tissue tumors shows that, regardless of histogenetic type, all benign and most low-grade lesions are diploid, whereas the majority of high-grade lesions are hyperploid. Of particular interest are the exceptions to this relationship between histology and ploidy. Thus, among soft tissue tumors of histologic high grade, DNA analysis may be used to detect diploid variants associated with an equally good prognosis as tumors of histologic low grade. Our results indicate that DNA analysis provides prognostic information beyond that obtained by histologic assessment.

The necessity of open biopsies in extracompartmental sarcomas

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During 1986 and 1987, 85 patients were operated on by biopsy or radically for suspected sarcomas in our department. Eighteen of the patients had metastases from other malignancies. Twenty-eight patients had sarcomas. Two patients had Ewing´s sarcoma and were primarily treated with cytostatic drugs. Eleven patients were operated on radically without biopsy; only 4 of these patients had the tumor in an extracompartmental site. Thirty-nine patients had benign tumors. Ten were operated on radically without biopsy.

Five patients had benign tumors that at first had been suspected of being malignant. In 3 of these patients, the tumor was extracompartmental and the biopsy was necessary to plan the further treatment. Because we have not seen any increased risk of local recurrence following biopsies, we find this procedure motivated to avoid extensive surgery for benign lesions.

MRI in the planning of operative treatment of soft tissue tumors

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Until recently, computed tomography (CT) has been the technique of choice in the planning of operative treatment of musculoskeletal soft tissue tumors. During the last few years, several studies have shown that magnetic resonance imaging (MRI) has certain advantages over CT. At our hospital, MRI has been used in the diagnosis and in the planning of operative treatment in 20 malignant or possibly malignant soft tissue tumors since August 1986. In order to evaluate the method, CT and angiography have been performed as supplementary investigations in most cases.

From a surgical point of view, the major advantage of MRI has been the precise delineation of the extent of the tumors by direct coronal, sagittal, and transverse imaging. Compared with CT, which allows only transverse imaging and indirectly reformed pictures in the sagittal view, the MRI gives the surgeon superior information about the extent of the tumor related to muscular compartments and to adjacent structures. Also, the higher soft-tissue resolution of MRI contributes to a superior delineation of a tumor compared with CT. Furthermore, the MRI method visualizes major vessels. The specificity of MRI is rather poor. Hence, MRI does not give any detailed information about the tissue composition of a tumor, except that fat tissue is well identified. However, nonhomogeneous appearance and irregular delineation indicate malignancy.

Due to the described characteristics of MRI, the following conclusions are drawn: MRI gives the surgeon excellent information about the localization and delineation of soft tissue tumors that is superior to that available from other preoperative investigations. MRI enables a more adequate planning of the operative procedure, and at least partly eliminates the need for angiography. MRI should be the primary imaging method in the evaluation of soft tissue tumors.

The Scandinavian Sarcoma Study Group

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The Scandinavian Sarcoma Study Group was formed in Oslo in 1979. All the members meet once a year to analyze ongoing studies and to develop new projects. The group has started the following projects.

SSG I. A multicentric, prospective, randomized study for evaluation of adjuvant chemotherapy with Adriamycin in patients with high-grade malignant soft tissue sarcoma. The study started in 1981 and was terminated in 1986 after the inclusion of 240 patients.

SSG II. A program for combination chemotherapy in extremity localized osteosarcoma without metastases, started in 1982. A total of 85 patients have entered the study.

SSG IV. A program for combined modality treatment of Ewing's sarcoma, started in 1984. Thirty-six patients have entered the study.

SSG V. This is a Scandinavian, multicentric, prospective study for evaluation of prognostic factors in soft tissue sarcoma patients. This study started in 1987.

SSG VI. A multicentric, prospective, nonrandomized study of combined treatment with preoperative and postoperative chemotherapy, surgery, and/or radiotherapy for osteosarcoma metastases. This study started in 1987.

A centralized registration of all sarcoma patients in Scandinavia was started in 1986. The aim of registration of patients with bone and soft tissue sarcoma is twofold.

1. For each participating center a data base of its own patients is created. "Free boxes" in the form can be used for the recording of data other than those specified in the form. Such data are specified by each center.

2. The common registration of data allows for multicenter studies addressing treatment results and prognostic factors for local recurrence, metastasis, and survival in patients with bone and soft tissue sarcoma. Such studies are necessary to further define the best treatment for these patients; the 100 percent follow-up possible in Scandinavian countries makes our position unique.

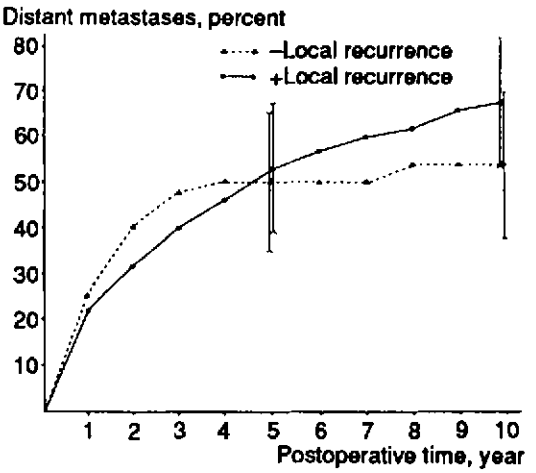

Figure 2. Distant metastasis related to local recurrence in high-grade malignant sarcoma localized to extremities. Only primary operable cases included.
No local recurrence — 49 patients.
Local recurrence — 60 patients
I = 95 percent confidence interval.

Local tumor control and survival in soft tissue sarcoma

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Patients and methods: The influence of radical surgery and local recurrence on survival were retrospectively analyzed in a consecutive sarcoma series from a tumor center serving a population of 2 million people. From 1962 to 1984, 406 cases were seen. All of the histologic preparations were graded using a 3-grade system: 1 representing the low-grade malignant and grade 3 the high-grade malignant tumors (1). From 1962 to 1978, conservative surgery was performed (series A). Of 261 cases presented in this period, 230 were found to be operable; and of these, 207 were submitted to local excision and 22 to amputation. From 1979 to 1984, radical surgery according to surgical staging system (SSS) was performed (series B). Of 145 cases, 125 were operable; and of these, 32 were submitted to wide excision, 60 to compartmental excision, and 33 to radical amputation. Series A and B were found to be comparable according to histologic grade, tumor size, tumor localization, age, and sex.

Results: The recurrence rate after conservative surgery was in histologic low-grade cases 45 percent and in high-grade cases 66 percent. After radical surgery, these figures

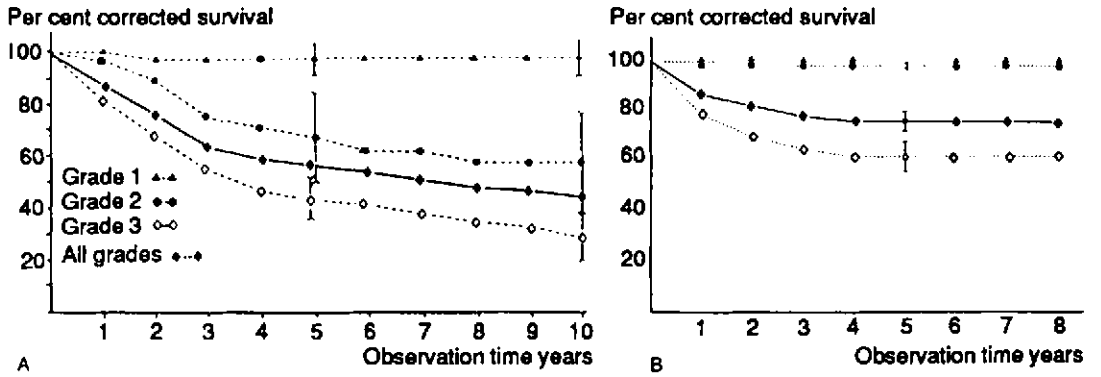

Figure 1. Survival in 355 primary operable cases of soft tissue sarcomas.
A. Conservative surgery — 230 patients.
B. Radical surgery — 125 patients.
I = 95 percent confidence interval.

changed to 11 percent and 25 percent. In 25 cases admitted without previous surgery, the recurrence rate was 0. The survival was better after radical surgery (Figure 1). The relation between local recurrence and metastasis in the high-grade malignant tumor cases was analyzed, and there was no significant relation between local tumor control and metastasis (Figure 2).

Discussion: In the low-grade malignant tumors the prognosis after radical surgery is good (2); but in the high-grade malignant tumors, some authors feel that the prognosis, to some extent, may be determined already at the time of diagnosis (3). The equal incidence of metastasis in cases with and without local recurrence after conservative surgery on high-grade malignant tumors (Figure 2) indicates that local tumor control was less important in survival. On the other hand, the higher survival rate after radical surgery on high-grade malignant tumors (Figure 1) indicates some, at least temporary, effect of local tumor control.

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The surgical treatment of and prognosis for extremity soft tissue sarcomas

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Introduction: In the light of the general experience that soft tissue sarcomas frequently recur locally when they are treated by local surgery alone, many centers for musculoskeletal oncology advocate the combination of limb-saving operations with local adjunctive treatment. Good results in terms of both preserved function and local control of the tumor disease can, however, be achieved in many patients by local surgery alone. A prerequisite for this seems to be that the patient is referred with the tumor in a virgin state, so that unnecessary open biopsies can be avoided.

Patients and methods: Using a multivariate statistical analysis, including hazard function tests, 137 patients treated surgically for a soft tissue sarcoma in an extremity were studied. The influence of various clinical and morphologic factors on prognosis was analyzed. The minimum follow-up time was 6 years. Eighty-nine patients were referred with the tumor in a virgin state (primary series), whereas 48 patients were referred after biopsy or with local recurrence after previous surgery (secondary series). In 73 patients in the primary series, a local, function-preserving operation was performed without incisional biopsy; the surgery was based on clinical diagnosis alone (49 patients) or on fine-needle aspiration cytology as well (24 patients). The frequency of amputation was 15 percent in the primary series and 48 percent in the secondary series.

Results: Local operations with a radical or wide margin preceded by incisional biopsy resulted in a significantly higher frequency of local recurrence than such operations based on clinical diagnosis alone; operations preceded by fine-needle biopsy showed a similar tendency. Sixteen of 25 marginal local operations resulted in local recurrence. When local surgery was based on clinical diagnosis alone, it did not unintentionally result in a marginal margin more often than when it was preceded by biopsy (8/46 and 11/42, respectively). Local recurrence entailed a significantly increased risk of tumor-related death.

Independent unfavorable prognostic factors concerning the risk of tumor-related death were increasing histologic malignancy grade, increasing age, and ablative surgery compared with local surgery (radical and wide margins). The four-grade scale of histologic malignancy was found to be of value for estimating the prognosis. Thus, a tumor-related death occurred in 0, 29, 47, and 67 percent of the patients with tumors of malignancy grades I, II, III, and IV, respectively. In terms of both metastasis and tumor-related death, the difference was significant between grades II and III, as well as between grades III and IV. None of the 4 patients with a grade I tumor had metastasis or a tumor-related death. Eighty-seven percent of the tumors were of grade III or IV (31 and 56 percent, respectively).

A long-term follow-up is essential in prognostic studies. Eleven of 28 local recurrences occurred more than 2 years after operation and 13 patients developed metastases after more than 5 years, 2 of them more than 10 years.

Conclusion: The present study gives support to the use of the following surgical principle applied at our department for more than 30 years: to omit biopsy when the history, the physical examination, and various radiographic studies all agree on the diagnosis of malignancy and the location of the the tumor allows its complete removal without significant loss of function. By doing so, good local control with well-preserved function can often be obtained; and local adjunctive treatment, such as irradiation as an alternative to extended surgery, can be restricted to patients operated on intentionally or unintentionally with an inadequate surgical margin.

Centralization of soft tissue sarcoma

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Soft tissue sarcomas are rare; the annual in incidence in Sweden is around 15 per million inhabitants. Treatment requires a cooperation between the orthopedic surgeon, the cytologist, the radiologist, the pathologist, the radiotherapist, and the oncologist. Therefore, treatment of these patients must be centralized. The patient should be referred to the tumor center before surgery for several reasons.

1. Clinical, cytologic, and radiologic data are sufficient for the choice of an appropriate surgical procedure in the majority of the patients. By such primary surgery the margin necessary for a low local recurrence risk can be kept less than that required after an open biopsy.

2. A biopsy performed by an inexperienced surgeon may sample only necrotic tumor tissue or reactive tissue peripheral to the tumor. A misplaced biopsy sometimes makes limb-sparing surgery impossible; the inclusion of the biopsy tract in the operative specimen requires amputation. Diagnosis by a marginal, shelling out excision makes radiologic staging impossible. The planning of definitive surgery, especially in deep-seated tumors, then become hazardous.

3. When biopsy is considered necessary, it is best performed at the tumor center for correct location and procurement of fresh tumor tissue for specialized studies, e.g., electron microscopy, immunohistochemistry, DNA determination, and chromosome analysis.

The majority of soft-tissue lesions are benign; the proportion benign/malignant is about 200–300/1. Thus, every patient with a soft-tissue lesion cannot be referred to the tumor center. Based on epidemiologic data on benign and malignant soft tissue tumors, the following guidelines were given in 1983 in our region, southern Sweden, with 1.4 million inhabitants:

Refer before surgery patients with soft tissue tumors that fit any of these criteria:

1) larger than 5 cm
2) deep-seated
3) otherwise suspected of malignancy

We have analyzed the outcome of this policy for the years 1983 through 1986. All patients who had a soft tissue sarcoma in the extremities diagnosed during this period, irrespective of whether treated at the tumor center in Lund or not, were identified by the regional tumor registry. Patients with metastases diagnosed before surgery were excluded.

Soft tissue sarcoma in the extremities, southern region, Sweden. Referral pattern 1983–86. N 80

Depth	Not referred	After surgery	Before surgery	Total
Superficial	4	16	12	32
Deep	1	5	42	48

Thus, nine tenths of all the patients with soft tissue sarcomas were referred to the tumor center in Lund, three forths of them before surgery. Nine tenths of the patients with deep-seated tumors were referred before surgery. For every sarcoma patient, 10 patients with benign tumors, suspected of malignancy, were referred. This is the cost to be paid to catch the majority of the sarcoma patients before surgery.

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The role of rotation plasty for malignant tumors of the femur and tibia

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For malignant tumors of the femur or tibia, rotation plasty is a surgical alternative to amputation especially in patients who are still growing. The functional results are excellent, and the

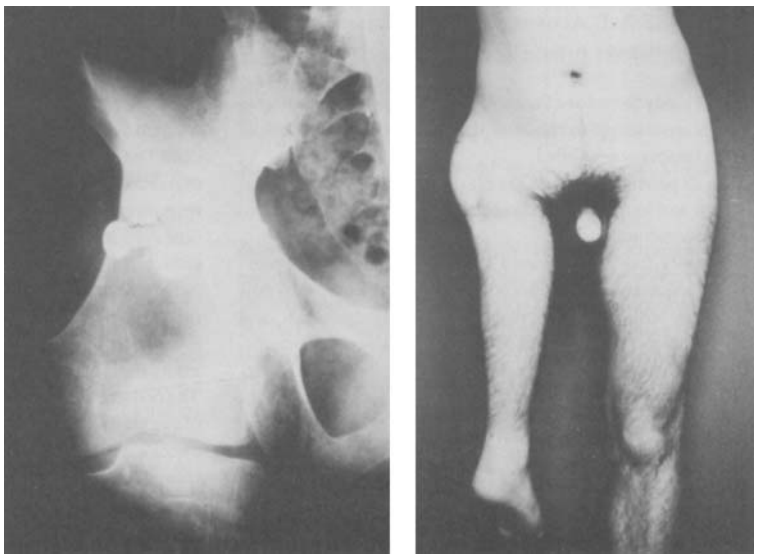

Figure 1. Hip-rotation plasty type B I.

psychological problems due to the rotated limb are amazingly few and minor. Therefore, in world centers rotation plasty is discussed when planning the local treatment of a malignant tumor of the femur or tibia.

Since 1980, I have performed 42 rotation plasties, 17 by the technique first described by Salzer and Kotz for distal femur lesions, three by my modification for malignant tumors in the proximal or proximomedial part of the tibia and 22 by my technique of hip rotation plasty for malignant tumors in the middle or proximal part of the femur.

Nineteen patients had Ewing's sarcoma, 17 patients had osteosarcoma, 3 patients had chondrosarcoma, 2 patients had malignant fibrous histiocytoma, and 1 patient had fibrosarcoma. Out of 42 patients, 22 had vascular resection followed by end-to-end anastomosis during surgery.

The follow-up time is more than 5 years in 4 patients, more than 4 years in 10 patients, and more than 2 years in 12 patients.

Three patients had superficial wound complications, and 1 patient had a deep infection. One patient developed a compartment syndrome and still has a peroneal palsy. One patient had to be amputated owing to vascular complications. To date, there has been one local recurrence in all the patients. One patient (with chondrosarcoma) developed a solitary pulmonary metastasis that was resected. Two patients died of their malignant disease.

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Role of vascular resection and reconstruction in rotation plasty

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In this study the role of vascular resection and popliteofemoral reconstruction in rotation plasty for primary malignant bone tumors was studied.

In 29 patients with rotation plasty, 13 had vascular preservation and looping of the vessels and 16 vascular resections and reconstructions,

Twenty-five patients were studied by means of Doppler-flow measurement and phlebography. All the Doppler-flow measurements showed normal arterial hemodynamics; and all the phlebograms exhibited normal open venous systems, except 1 case of loop obliteration and extensive collateral circulation after vascular preservation. Two local recurrences were found in the preservation group, and none in the resection group so far. For malignant bone tumors of the femur with tumor extension into the popliteal fossa, rotation plasty is a more feasible procedure if the vascular structures are resected together with the specimen and vascular reconstruction is performed.

Massive half-joint allografts in bone sarcomas and semimalignant tumors: Studies of incorporation and regeneration of the grafts

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Introduction: The fate of massive long bone allografts consisting of both metaphyseal bone and joint surface was studied experimentally, and in patients treated for bone tumors.

Materials and methods: In dogs the distal end of the femur was replaced by an allograft stored at – 70 °C. A plate was used in fixation. The graft incorporation was studied radiographically, histologically, and biochemically. In man the grafts were obtained from young individuals after accidental deaths. The temperature of the bone bank was – 70 °C. After resection of the long-bone end affected by tumor, the osteoarticular allograft was fixed using an AO plate. Autogenous bone chips were laid on the osteosynthesis site. Reconstruction of the ligaments was performed using the host's own ligaments. Altogether, 16 patients have been treated. The mean follow-up time is 6 (1–15) years.

Results: In dogs, consolidation of the graft to host bone occurred within 3 months. Ingrowth of new bone into the intertrabecular spaces of the old, dead allograft bone was evident within 6 months. On the articular surface, generally, fibrocartilage formation was seen. The high concentrations of organic matrix components in the early phases after transplantation indicated a reparative healing process. In man, graft incorporation began with the onset of weak metabolic activity early after transplantation as indicated by bone scans. The union of the osteosynthesis site occurred uneventfully, but slowly within 18 months. Graft biopsies showed histologically slight new bone formation within dead graft bone. Radiographically, signs of slight joint cartilage degeneration were observed 3 years after transplantation. According to the classification of Mankin et al. (1983), the long-term result was good in 69 percent. The most common complications were fatigue fracture, transient peroneal palsy, and infection. A significant mitotic response of the host lymphocytes to the graft antigenicity was observed in only 1 patient. No patient showed evidence of clinical rejection.

Conclusions: Massive osteoarticular allografts incorporate well, but slowly, to the host bone; but late arthrotic changes seem to develop within 3 years. The metabolic activity in grafts starts early and continues at a moderate level for years. The cell-mediated immunity tests suggest a low antigenicity of the grafts. The joint function is generally good. If complications, especially infection, can be avoided, the method is recommendable for limb salvage in patients with malignant bone tumors.

Functional evaluation of reconstruction after resection of primary malignant bone tumors about the pelvis and extremities

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Introduction: This is a review of our experience with 25 patients with primary malignant bone tumors of the pelvis and extremities, treated by local resection and reconstruction, mostly by implantation of an endoprosthesis.

Patients and methods: Between 1978 and 1987, 10 females and 15 males were treated. Their average age at the time of operation was 40 (10–76) years. Osteosarcoma accounted for 17 patients, chondrosarcoma for 4, and malignant fibrous histiocytoma for 4 patients. Of the primary malignant tumors, 2 patients had a stage IIA, 22 a IIB, and 1 a stage III lesion. The localization of the tumor was the humerus in 2 patients, pelvis in 1, proximal femur in 5, distal femur in 16, and proximal fibula in 1 patient. Wide en bloc resection was the most frequent procedure in these tumors. All the osteosarcoma and MFH cases received preoperative and postoperative chemotherapy according to the Rosen protocols. For reconstruction a custom-made endoprosthesis was used in 24 patients. For knee replacement either a spherocentric (Howmedica) or an Endo (Link) prosthesis was used. A bicentric cup was preferred for the hip region. The follow-up period for primary malignant tumors varied from 0 to 8 years.

Results: At follow-up, 2 patients with a primary malignant bone tumor had developed a local recurrence. One of these had died and 1 is alive with disease after disarticulation of the hip. Two other patients developed lung metastases. One additional patient required an interthoracoscapular amputation because of too small margins. Twenty patients with a primary malignant bone tumor were continuously free of disease at follow-up. Mechanical failure requiring revision of a prosthesis occurred in 5 patients.

According to the revised Enneking Functional Evaluation System, the results in these tumors were excellent in 1, good in 5, fair in 17 , and poor in 2 cases.

DNA content in soft tissue tumors

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Flow cytometric (Ortho Cytofluorograph 50/H) DNA ploidy analysis was performed on postoperative, fresh tumor tissue from 102 soft tissue tumors (44 benign tumors and 58 sarcomas of which 49 were primary and 9 recurrent) during August 1984 through December 1987. Aneuploidy was defined according to Hiddemann et al. (1984).

Table 1. Correlation between malignancy grade and ploidy

	Euploid	Aneuploid
Benign tumor	44	0
Sarcoma Grades I–II	5	2
Sarcoma Grade III	13	3
Sarcoma Grade IV	6	29

Table 2. Correlation between ploidy and progressive disease in 49 primary sarcomas. Follow-up time: 3–40 months. 10 out of the 49 patients developed meastasis or died of tumor.

	Metastasis	Death of tumor
Euploid		
Grade III (12)	1	0
Grade IV (4)	0	0
Aneuploid		
Grade III (3)	0	1
Grade IV (24)	3	5

Ploidy was correlated with benignity and malignancy and further to histologic malignancy grade in the sarcomas (four-grade scale, Grades I–II low-grade malignant and Grades III–IV high-grade malignant) (table 1) and to prognosis (metastasis and death of tumor) (table 2).

Conclusions: The majority (14/15) of Grade II sarcomas, considered to be high-grade malignant, were euploid. The majority (29/35) of Grade IV sarcomas were aneuploid. Of the 10 patients with progressive disease, 9 had Grade IV sarcoma and 9 had an aneuploid tumor.

Further studies will show if DNA ploidy determination, together with known prognostic factors, may further separate patients with high-grade malignant sarcomas into different prognostic groups.

Bone reconstruction following resection of bone tumors

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Introduction: During recent years surgical treatment of bone tumors has changed from primary amputation towards limb salvage operations. Progress in the fields of diagnostic imaging and oncology are prerequisites for this development, and this study is a review of our experience during the last 3 years. The necessary allografts were obtained through our bone bank, which was established 2 years ago.

Patients and methods: Sixty-one bone tumors were removed, 39 benign (mean age 31) and 22 malignant (mean age 33). The defects after surgery were reconstructed in the fol-

lowing ways: Excochleation and autologous bone grafting were used in 19 cases, and in 3 of these allogenic bone was added. In 4 cases the defects after curettage of a giant cell tumor were filled with bone cement. Proximal femur (3 cases): a proximal femur allograft and a long stem total hip prosthesis (2) and a Kotz modular tumor prosthesis (1). Distal femur (5 cases): a hemijoint allograft (4) and a 1/4 joint allograft (1). The knee ligaments were reconstructed using the patients' own ligaments and ligaments on the allograft. Proximal humerus (4 cases): humeral hemijoint allograft (3) and proximal femur allograft (1), all fixed with an interlocking nail. Shaft of long bones (3 cases): tibia segments fixed with interlocking nail (2) and femoral segment (1) fixed with plate. Pelvis (3 cases): removal of the anterior part of the pelvis including the inferior part of the acetabulum without any reconstruction (1), removal of most of the hemipelvis with the hip joint and fusion of femur to the rest of ilium (1), and hemipelvectomy for recurrent osteosarcoma (1). Spine (5 cases): The defects were filled with autologous bone (1), bone cement (1), or Dick device (2), later replacement of the vertebral body with allograft (1) or autograft (2) through an anterior approach.

Results: Two patients were dead at follow-up, both from distant metastasis. The defects treated with autologous bone graft have all healed, and the limb function is good. One shaft allograft became infected during a secondary autologous bone grafting procedure: the bone healed, but a fistula persists. Nineteen allograft-host bone junctions were created, nine of which are radiographically completely healed. Two junctions could not be assessed because of the patients' deaths. The other junctions were radiographically stable, but due to a short observation time, they were not completely consolidated.

Conclusion: Resection of bone tumors and reconstruction using autologous bone is an excellent method. Both segmental and articular allografts have given good primary results. The experience obtained encourages us to continue using these methods.

Bone bank for deep-frozen osteoarticular allografts: A 2-year experience

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Introduction: Our hospital has a close cooperation with the Norwegian State Cancer Hospital, and we are doing most of the orthopedic surgery needed in the treatment of bone sarcomas. To be able to do more limb-conserving surgery for the bone tumor patients, we established a bone bank to supply us with allografts for shaft and joint replacements. The bones are procured from organ donors of heart, kidneys, liver, and pancreas. The bones are removed with ordinary sterile technique in an operation theater, and the defects are replaced by wooden material. The bones are cultured individually and thereafter washed in a 0.01 percent solution of chlorhexidine. The cartilage is impregnated with a 10 percent solution of dimethylsulfoxide for 30 min. After procurement the bones are packed triply in sterile wrappings and cooled to 4 °C for the next 6 hours. Thereafter, they are transferred to a storage freezer with a temperature of – 70 °C. Before use the selected bone is thawed in a solution of 100µg/ml Neomycin and 10 µg/ml Bacitracin. A precise record of the bones is kept in a PC, allowing us to have an up-to-date survey of the contents of the bank at any given time. The donor blood type and tissue type are recorded, but these parameters are not taken into consideration when choosing a graft. To avoid transferring infections, the donors are screened clinically and serologically for possible transmittable diseases. No bone is procured from donors after prolonged bed rest, recent infections, steroid therapy, or malignant disease.

Subjects: We have removed 52 bone pieces from 8 donors with a mean age of 26 years. The primary cultures were positive in 8 cases, yielding the following microbes: 2 *Staphylococcus epidermidis*, 2 diptheroids, 1 *Serratia*, 1 *Acinetobacter*, 1 *Toluropsis candida*, and 1 gram-positive aerobic dust bacterium. Two of these bone pieces have been used for transplantation without any infectious complication. Two proximal tibial parts were used to replace vertebral bodies; one proximal femur was used to replace a humerus; and 10 bones were used to replace the same bone or part of a joint. No infections have occurred after the primary operations. One infection occurred at a secondary bone-grafting procedure 6 months after the primary operation. So far, no other transmittable diseases have occurred in the recipients. The outcome of a joint replacement with an allograft is probably related to the congruency between the allograft and the recipient joint. To be able to choose the most fitting graft, we have, on the last procurements, measured some dimensions of the grafts; and we have compared these measurements with the corresponding ones taken from the preoperative radiographs of the recipients, correcting for the magnification. In the future, we probably will have a computer to judge from both the measurements and the joint contour which graft is most suitable.

Conclusion: The patients with bone tumors have benefitted from the bone allografts. The low complication rate and good functional results have encouraged us to continue using material from the bank in the future, possibly with some refinements to improve joint congruency.

Extraskeletal myxoid chondrosarcoma

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Extraskeletal myxoid chondrosarcoma is a distinct entity among soft tissue tumors. It is relatively rare, only 70 cases have been reported previously, and it has been considered as a relatively benign category of soft tissue sarcomas. We report

6 cases of extraskeletal myxoid chondrosarcoma including tumors with features of high-grade malignancy.

Three of the patients were women and 3 men; the mean age was 46 (26–68) years. In 2 cases the tumor was located in the inguinal region, in 1 female patient in the breast, in 1 patient in the palm of the hand, and in 2 patients in the forefoot between the metatarsal bones. In all the patients the tumor was treated operatively 2–12 months after the patient had first become aware of its existence. Two patients had additional radiotherapy. The tumor recurred in 5 of the 6 patients. Three patients died of massive pulmonary metastasis 3 to 16 months after the operation; 1 patient had local recurrence 3 years after primary surgery and died 5 years after a second operation of pulmonary metastasis. One patient was treated with radical wide resection for a fast growing grade II tumor, and he had also postoperative radiation. He has survived more than 5 years without recurrence.

Extraskeletal myxoid chondrosarcoma might recur after many years, and these patients should be carefully followed up. Primary operative treatment should follow the same guidelines that are given for other soft tissue sarcomas. It is probably advisable to treat the high-grade tumors with adjuvant radiotherapy and chemotherapy.

Antibiotics in orthopedics

Antibiotic treatment in experimental septic arthritis

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Thirty-eight rabbits with verified septic arthritis of the knee were treated with cloxacillin combined with probenecid for 7 or 21 days, respectively. The knees were punctured after 2, 3, and 4 days for bacterial culturings. The animals were killed weekly up to 5 weeks after the inoculation, and the joints were evaluated according to the primary infection model (1).

Following 4 days of treatment, all the joints were sterile. At killing, the joints were inflamed and distended, with thin purulent fluid with a leukocyte content of 10^6–10^{12}/μL. Minor marginal erosion was visible after 3 weeks. The histologic specimens revealed a progressive joint destruction at a significantly slower rate than untreated cases (1). After 3 weeks, the tidemark was broken in all the cases. The loss of glycosaminoglycans was evident after 1 week and progressed to a severe depletion after 3 weeks.

It is concluded that antibiotics may sterilize the infected joint, but are insufficient as the only therapy.

Reference

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Continuous intraarticular infusion with implantable miniosmotic pumps

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The role of leukotriene B_4 (LTB_4) in synovial inflammation was studied by means of local intraarticular deposition of 15-hydroxy-eicosatetraenoic acid (15-HETE, an endogenous selective 5-lipoxygenase inhibitor) during induction of carragheenan-induced arthritis in dogs. Discontinuous administration of the enzyme inhibitor was considered insufficient because of rapid transsynovial escape of injected drugs. We therefore developed a method of continuous intraarticular infusion using the implantable ALZET® miniosmotic pump: In 9 young dogs, aged 12–14 weeks, bilateral catheterization of the knees was performed. A thin polyvinyl catheter with a flanged metal cannula was impacted in an oblique drill hole through the lateral femoral condyle, the catheter emerging subcutaneously behind the lateral recess of the suprapatellar pouch. An ALZET® miniosmotic pump filled with isotonic saline was connected to the catheter and implanted subcutaneously on femur. After 14 days, the right pump was exchanged with a pump loaded with 15-HETE. The catheter function was verified after 4 weeks by radiography, arthrography performed through the catheter, and dissection. All the dogs tolerated the operation well. No joints were infected. No joint reaction to the implanted catheters was observed. Fifteen catheters worked without complications. Leakage at the junction between the catheter and the cannula occurred in two instances, whereas one separated in this junction, although the catheter remained in place in the bone canal and secreted correctly into the joint. Thus, it seems possible to maintain continuous intraarticular infusion of drugs or metabolites at a constant rate for weeks to months using the implantable ALZET® osmotic pump. The model is attractive in experimental joint research.

15-Hydroxyl-eicosatetraenoic acid (15-HETE) inhibits carragheenan-induced experimental arthritis and reduces synovial fluid leukotriene B4 (LTB4)

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Leukotriene-B_4 (LTB_4) is a highly potent chemotactic and chemokinetic agent found in synovial fluid from patients with rheumatoid arthritis, spondyloarthritis, and gout. However, the significance of LTB_4 in arthritis is unknown. 15-Hydroxy-eicosatetraenoic acid (15-HETE) specifically inhibits the formation and chemotactic effect of LTB_4. The purpose of the present study was to determine whether 15-HETE might modulate the clinical and pathophysiologic manifestations of carrageenan-induced arthritis in dogs. 15-HETE was synthesized by soybean lipoxygenase and purified by HPLC. Bilateral arthritis of the knee was induced in 7 dogs by instillation of carrageenan every 3rd day for 2 weeks. One joint received infusion of 15-HETE using an implanted ALZET® miniosmotic pump with a fine catheter to the joint space. In addition, 15-HETE was injected discontinuously with each carrageenan provocation. The reference joint was injected with isotonic saline via these two routes. After 14 days, the severity of arthritis was assessed by joint pressure, volume of effusate, ^{99m}Tc-DPD scintimetry, and measurement of regional blood flow using radioactive microspheres. Synovial fluid LTB_4 and PGE_2 were determined using RP-HPLC and RIA. The severity of arthritis was reduced as judged by clinical symptoms, joint pressure, and volume of effusate; and the LTB_4 and PGE_2 levels were lower in treated joints. However, no differences could be discerned regarding synovial blood flow, bone blood flow, or delayed regional ^{99m}Tc-DPD uptake. These results indicate that LTB_4 may be involved in the development of arthritis and that 15-HETE may regulate inflammation by interfering with LTB_4 formation.

Bone density changes in experimental arthritis determined by quantitative computed tomography

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Introduction: In a series of studies on bone-implant interface in experimentally induced osteopenia, we have adopted the use of QCT bone density measurements for noninvasive evaluation of the bone bed at the site of implantation of porous-coated implants.

Materials and methods: Quantitative CT of the knee, obtained with the EMI 7070 scanner, was performed in 12 mature dogs with chronic carrageenan-induced unilateral arthritis scheduled to undergo implantation of porous-coated implants. Six dogs were selected for a longitudinal QCT study starting immediately before induction of arthritis. At two consecutive levels, 2 mm apart, CT images were recorded starting 10 mm proximal to the distal limit of the femoral epiphysis.

Results: In the arthropathic bone a significant decrease in bone density with time was found at all the scanning levels, averaging 16 percent in the medial and 6 percent in the lateral condyle. In contrast, a significant increase (3 percent medially and 14 percent laterally) was found on the control side. After 3 months of arthritis, the CT values were 22 percent lower in the arthropathic bone as compared with the control side ($P < 0.001$). Reproducibility tests showed an average coefficient of variation of 3.7 percent.

Discussion: The increment in bone density on the control side as compared with the reduction on the arthritic side is in agreement with Wolff's theorem that bone adapts to functional demands by remodeling. However, age-related bone changes cannot be ruled out. CT scans documented the suitability of the carrageenan-induced arthritis for studies on porous-coated implant fixation in osteopenic bone.

In vivo release of gentamicin from PMMA beads: Quantitative determination of gentamicin

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Gentamicin polymethylmethacrylate (PMMA) beads are currently used, with excellent results, in the treatment of osteomyelitis and infected endoprostheses. Each bead contains 4.5 mg of gentamicin sulfate.

In a clinical prospective study, we quantitatively assessed the amount of gentamicin that had left the body during the treatment period by renal excretion and secretion in wound drains, and we measured the residual gentamicin concentration in beads after use. The data were gathered from 8 patients who had 90–240 beads implanted for 9–16 days. Indications for treatment were infected hip (6 patients), knee arthroplasty (1 patient), and osteomyelitis of the femur (1 patient). In 5 patients the gentamicin content in the seroma around the beads at the end of the treatment period was analyzed as well. Following implantation of the PMMA beads, wound drains were left for up to 3 days, no suction being applied to the bead-compartment drains.

Gentamicin was extracted from the beads by dissolving the polymer in chloroform. Gentamicin concentrations were determined with EMIT and HPLC (1).

Results:

1. Total renal excretion of gentamicin varied from 60.3 g (90 beads, femur) to 302.3 g (240 beads, total hip revision), and was correlated with the number of beads implanted ($r = 0.95$).
2. Early gentamicin loss through wound drains varied greatly

from 14.3 g to 118.7 g, and was not correlated with the number of beads ($r = 0.3$). The maximal concentrations ranged from 6 µg/mL (180 beads) to 462 µg/mL (210 beads).

3. The gentamicin content and concentration in the local seroma at the end of the treatment period were relatively low, ranging from 1.6 to 6.9 g and 12.5 to 37.2 µg/mL.
4. The gentamicin residuum in the sampled beads varied from 1.87 to 3.52 mg per bead. In a large sample of 30 beads, only 35 percent of the initial load of gentamicin had diffused out of the beads.
5. The percentage composition of the six major components of the gentamicin mixture, analyzed by the HPLC, was identical in used and unused beads.

Conclusion: The number of gentamicin PMMA beads administered is directly correlated with the amount of eluted, biologically effective gentamicin. Gentamicin concentrations in wound drains do not represent true tissue concentrations. Wound drainage should be restricted to prevent substantial losses of gentamicin. There is no preferential elution from the beads of one or more of the gentamicin components.

Reference

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The use of prophylactic antibiotics in hip surgery in orthopedic departments in Denmark

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The use of antibiotics is one of the possible methods to prevent deep infections following total hip replacement (THR) and hip fracture operation (HFO). A questionnaire dealing with the use of prophylactic antibiotics in THR and HFO was sent to 30 orthopedic departments in Denmark in November 1986. Twenty-eight departments answered the questionnaire. For THR, all but two departments routinely used systemic antibiotics. These two departments used systemic antibiotics only for risk groups. Local application of antibiotics was in three departments used in all THRs; but in 21 departments, this was reserved for risk groups. The risk groups mentioned most frequently were previous hip surgery (19 departments) and corticosteroid therapy and/or rheumatoid arthritis (6 departments). Seven departments used systemic antibiotics in all HFOs; in one department, local antibiotics were used as well. Thirteen departments used systemic antibiotics only for risk groups, and seven departments never used antibiotics in HFO. The risk groups most frequently mentioned were prolonged operation time (four departments) and implantation of the Moore prosthesis (four departments). For systemic prophylaxis in THR and in HFO, most departments used an isoxazolylpenicillin-penicillin (two thirds of the departments) or a cephalosporin. The local antibiotics were (except for one department) administered as gentamicin-containing bone cement. There was considerable variation in the dosage regimens used. The treatment period ranged from a single dose to a 6-day treatment period; half of the departments used a treatment period of 24 hours or shorter

Antibiotic treatment and prophylaxis

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Introduction: Antibiotics are used widely in orthopedic practice, both in the treatment and in the prevention of infection, and can be administered both systemically or locally. However, the effectiveness of antibiotics is in part dependent on the structure of bone and its blood supply.

Blood supply of bone: Bone is a relatively vascular structure that is supplied by independent blood systems. The main supply of a tubular bone, such as the tibia, is the nutrient artery, which traverses the cortical bone, ascending and descending within the haversian systems. The flow of cortical bone is centrifugal in direction. Water-soluble solutes leave the capillaries within the haversian systems through transcapillary clefts by the process of passive free diffusion, the rate of flux being dependent on the size of the molecule. Once the solutes have left the capillaries, they cross a definable fluid space, which has been estimated to be about 10 percent of the available volume. Within this fluid space are the bone cells that constitute an active membrane regulating bone exchange. Pathogenic organisms must use the same route as the solutes or, indeed, antibiotics to enter bone; and once they have left the capillaries, they lie within the fluid spaces acting on the bone cells and affecting the collagen and hydroxyapatite structure. In the presence of infection, the fluid spaces change, accompanied by an increase in the blood flow through the bone with an increase in new bone turnover.

Prophylaxis: Prophylactic antibiotics are primarily used in total joint replacement, but are now becoming widely used in all the branches of orthopaedic surgery, particularly where metal is inserted. Ericson et al. (1973) clearly demonstrated the effectiveness of antibiotics in preventing infection following total joint replacement. Based upon the pioneering work of Polk and Lopez Mayor (1969) in general surgery, we have used and reported the regime of high dose, short-course antibiotics in total joint replacement. Recent clinical trials have shown that a three-dose regime of a cephalosporin is able to achieve an infection rate of less than 2 percent. Alternative methods of delivering antibiotic to patients undergoing joint replacement include the addition of antibiotics to bone cement as introduced by Buchholz (1970). The method of delivery of antibiotic by this route has caused much speculation and research. Suffice to say, this method has been reported as clinically effective, and it appears that the antibiotic probably diffuses from the surface layers of the cement structure early in the process. A recent prospective trial from our

own centre demonstrates the benefit of this method and confirms the findings of others.

Treatment: Clearly, the methods of antibiotic delivery are the same when applied to patients requiring antibiotics for therapy. The differences appear to be that the bone is more vascular in the early stages of fracture healing or after infection. At the same time, the bone turnover is increased. In a similar manner, as in prophylaxis, antibiotics can be given systemically or locally in bone cement. Indeed, intravenous antibiotics are frequently administered to patients with open fractures and are continued for variable lengths of time. At the same time, antibiotic in cement beads, as introduced by Wahlig and colleagues (1978), has proven effective in the management of infection in bone.

Summary: Antibiotics can be administered systemically or locally in the management of infection in bone. Systemic antibiotics depend on the presence of an adequate blood supply to reach the bone. Locally applied antibiotics are best given in the bone cement, so that they can provide a limited, but effective concentration of antibiotic to the surrounding tissues.

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Antibiotics and bone metabolism

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In livestock, feed antibiotics are used as a growth-promoting agent. Although the degree of growth promotion may vary or be totally absent, the percentage increase has averaged 4–8 percent. The mode of action is, however, still under debate. One possible explanation could be that the antibiotics treat subclinical infections.

In humans and in animal experiments, antimicrobial drugs have been found to cause reduced body growth and bone growth. Tetracyclines administered to premature infants have been shown to cause a 40 percent depression of normal skeletal growth as measured by the inhibition of fibular growth. In several animal studies, these effects have been confirmed. Tetracyclines reduce not only the amount of bone produced, but the bone that is produced has a lower mechanical strength and a lower content of calcium than normal bone. Further, skin wounds in rats heal with less strength under tetracycline medication. Because collagen is the main structural substance both in bone and in skin, these findings have been attempted to be explained by effect on the collagen metabolism (e.g., on cross-linking, on collagenase).

Osteocalcin is the most abundant noncollagen protein and a specific product of the osteoblast. Its function is not definitely settled, but seems to be involved in mineralization. Osteocalcin has been shown in rat experiments to be reduced by 50 percent by oxytetracycline, and to a lesser extent by doxycycline, fusidic acid, lincomycin, but not by cloxacillin.

The topical use of antibiotic powders on bone grafts has been shown to reduce osteogenesis, both with chloramphenicol powder or methicillin powder and with Polybactrin spray. The extremely high local concentration around each particle of antibiotic could damage any cell close to it either by its pharmacologic activity or by osmosis.

The quinolones, the new promising group of antibiotics, have been reported to cause arthropathy in growing animals, and they should therefore not be used in children or in pregnant women or nursing women.

In conclusion, however, the literature gives rather few indications that antibiotics have any profound negative effects on bone metabolism.

The pharmacokinetics of gentamicin after total hip replacement with respectively low- and high-viscosity gentamicin bone cement mixed with and without vacuum

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Introduction: Low-viscosity bone cement is thought to give better fixation of prosthetic components by increased intrusion into cancellous bone. The necessity of improved fixation is greater in revisions, especially for infection. It has been shown that vacuum mixing of the cement improves its mechanical properties. We investigated the pharmacokinetics of gentamicin released after primary total hip replacement with a new low-viscosity versus a high-viscosity bone cement, both containing gentamicin, mixed with and without a vacuum.

Patients and methods: Two series of patients were operated on with total hip replacement for arthrosis. In series A there were 47 and in Series B 24 patients. In both series the patients were randomly allocated to operation with low- or high-viscosity bone cement. In series A the cements were conventionally hand mixed, and in Series B the cements were mixed in a vacuum (150 mbar). The amount of cement implanted was calculated, and the concentration of gentamicin in the serum, urine, and wound secretion was measured by the agar diffusion test using *Bacillus subtilus* ATCC 6633. The lower sensitivity level was 0.05 µg/ml.

Results: The concentration of gentamicin in wound secretion was constantly about three times higher with low-viscosity cement; in Series A the mean value for the second day was 18.9 µg/ml compared with 5.6 µg/ml. The concentration in serum and the recovery of gentamicin from urine was also about 3–4 times higher in the low-viscosity groups. The aver-

age amount of implanted low-viscosity bone cement per patient was only slightly larger: in series A 104 g compared with 98 g. The results in Series B were similar.

Discussion: In an in vitro investigation, it was found that the release of gentamicin from low-viscosity cement was only half of that from high-viscosity cement, and the concentration in the cement had to be doubled to result in the same concentration in the elution fluid. The very high concentrations of gentamicin in the wound secretion could only be explained by better intrusion of the cement into the bone and a greater surface of the cement body, as the amount of implanted cement was only slightly larger. This makes the low viscosity cement a better choice, especially in revisions for deep infection, because gentamicin in very high concentrations is effective also against bacteria resistent to levels attained by parenteral treatment. Vacuum mixing is preferable because it improves the mechanical properties of the cement and does not affect the release of gentamicin.

Antibiotic prophylaxis in orthopedic surgery — ecologic consequences and toxic drug effects

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Introduction: Prophylaxis against postoperative infections in orthopedic surgery can be effected by hygienic measures and peroperative antibiotic administration. Because antibiotics are given to big populations in this connection, the side effects must be highly considered and should be kept to a minimum.

Patients and methods: One study was performed in collaboration with the Departments of Orthopedics in the University Hospitals in Lund and Malmö. In a placebo-controlled double-blind study comparing cefuroxime for 24 hours and cefuroxime + 6 days of subsequent oral cefadroxil, 56 and 65 patients, respectively, were evaluative. As a secondary objective, a study of a postoperative superinfection was performed. In this study, urinary tract infections (UTI) that occurred postoperatively were noted in a total of 15 of the patients (14 percent). Some of the patients had bladder catheters. Cultures and susceptibility tests were performed.

In another material comprising 789 courses of antibiotic prophylaxis in a retrospective analysis, 378 patients received peroperative dicloxacillin during an initial period in hip arthroplasty, and 411 patients got cloxacillin during a later period. This material was analyzed as to the drug effect on renal function. A repeated chemical laboratory and clinical investigation was initiated after a case of severe renal failure had occurred.

Results: The first study showed that peroperative antibiotic prophylaxis in fixation of trochanteric fractures with a plate and a sliding nail could be reduced in time without an increase of postoperative deep infections. In 9 and 15 percent, UTIs were noted during the first 5 postoperative weeks in the patients receiving long and short prophylaxis, respectively. Of 20 isolated strains, only six were sensitive to cefuroxime, only 1 of 7 in the group having 1 week of antibiotic prophylaxis was sensitive to cefuroxime. Isolated resistant strains were *Streptococcus faecalis* in 4 cases, *Pseudomonas aeruginosa* in 2, and *Proteus morganii* and *Enterobacter cloacae* in 1 of each. Five *E. coli* and 1 *Klebsiella* strain were intermediately sensitive. Five *Proteus morganii* strains and 1 *Enterobacter* were fully susceptible. The observations show that a selection of strains with reduced susceptibility against the used prophylactic agent can occur, particularly after a prolonged prophylaxis. Clinically significant UTIs with fever were the results.

In the other material, 16 patients (4 percent) receiving dicloxacillin had an increase of serum creatinine from normal values (some had a lowered renal clearance, estimated by a nomogram, in the preoperative period) to at least 100 percent increase. In 2 of these patients, dialysis was performed and considered in 4 more patients. An S-creatinine increase of > 45 μmol was seen in 12 percent of the patients. A correlation with preoperative antiphlogistic treatment was noted with an increase to an average value of 123 μmol ($P = 0.015$ compared with patients without antiphlogistic drugs) 1 week after operation.

Conclusion: The choice of prophylactic antibiotic and its duration must be carefully done with the aim to avoid ecologic consequences and toxic side effects.

Reference

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Resistance pattern of coagulase-negative staphylococci in staff and total hip patients

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Introduction: During the last few years, coagulase-negative staphylococci (CNS), mainly *S. epidermidis*, have been the bacteria most frequently found in prosthetic joint infections. The operating team, the patient, and the ward staff are possible sources of these infections.

Patients and methods: Swab cultures from the anterior nares were obtained from 24 orthopedic surgeons, 54 operating theater staff, 48 staff from orthopedic wards, and 97 patients before a total hip replacement, and in 79 of them also 2 weeks after the operation.

Results: CNS were found in almost all the cultures. In patients, methicillin resistance increased from 3 to 25 percent. Multiresistance was found in 11 patients before surgery, and 8 of them had been hospitalized during the previous 9 months. Gentamicin resistance was found postoperatively only in 14 patients, and 10 of them had prostheses inserted with gentamicin cement.

Resistance to methicillin was significantly more common in ward staff than in theater staff, and occurred in 1/24 surgeons, 6/24 theater staff, and in 16/54 ward staff. Among them gentamicin-resistant CNS were not found.

Conclusion: The low number of methicillin-resistant CNS in surgeons and theater staff supports a continued use of short-term antibiotic prophylaxis with beta-lactamas-resistant penicillins. Preoperative hospitalization should be minimized.

The bactericidal activity of methicillin and dicloxacillin for Staphylococcus aureus in surgical wound fluid

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The purpose of the present in vitro study was to compare methicillin and dicloxacillin with regard to bactericidal activity in surgical wound fluid collected from nonantibiotic-treated patients following hip fracture operations. A colony-counting technique was used. The test bacteria were four strains of *Staphylococcus aureus*. The tested concentrations of the antibiotics were 2, 4, 8, 16, and 64 µg/ml, which for both antibiotics corresponded to 2–64 times the minimal inhibitory concentration (MIC). Colony countings were performed 2, 4, 8, 12, 24, and 48 hours after the inoculation. Each strain was tested twice, but in wound fluid from different patients. There was found considerable medium- (= patient) dependent differences in the time-killing curves, but there were small differences between the two antibiotics and the five concentrations. Expressed as the reduction after 24 hours' incubation in percent of the inoculum, the mean killing effect was 99.4 percent for methicillin and 99.5 percent for dicloxacillin. A slight increase in the killing effect with an increase in concentration was found, which was for methicillin from 98.9 to 99.7 percent and for dicloxacillin from 99.4 to 99.7 percent. However, the observed differences between the two antibiotics and the five concentrations were small and are without clinical significance. It is concluded for both antibiotics that a wound-fluid concentration at 2 x MIC (= 2 µg/ml) is sufficient for preventing infection with *Staphylococcus aureus* in hip surgery. An increase in wound-fluid concentration above that is not followed by an equivalent increase in prophylactic effect against infection with *S. aureus*.

The effect of antibiotics on the prevention of infection after experimental open fractures

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An experimental model of a contaminated open fracture has been used to assess the effect of antibiotics in preventing post-traumatic osteitis, with particular reference to the effect of delay in giving the first dose of antibiotic.

Osteitis developed in 91 percent of the animals in the control group (no antibiotic). The osteitis rate fell to 30 percent if a single injection of cephradine was given 1 hour before inoculation with bacteria ($P < 0.005$). If antibiotic administration was delayed until after inoculation, the osteitis rate was 50 percent, which was still less ($P < 0.005$) than the control group. This antibiotic effect persisted even if the initial dose of antibiotic was delayed for 4 hours after bacterial inoculation.

This experimental study supports the use of appropriate systemic antibiotics in the management of open fractures in man, even if administration is delayed up to 4 hours after injury.

Sports injuries

An epidemiologic and traumatologic study of injuries in handball

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A double prospective study of injuries in handball was performed.

Subjects: I. In a handball club (C), all the injuries were examined once a week and registered: 105 injuries in 221 players. Injury incidence: 8.0 per 1,000 playing hours. II. A registration of all hospital-treated (H) injuries in the municipality of Århus: 824 injuries (341 males, 483 females) out of 4,154 sports injuries in a population of 253,753 persons with 5,980 registered handball players (3,010 males and 2,880 females).

Results: In C, 24 percent were finger injuries and 33 percent ankle injuries versus 44 percent and 18 percent in H. In H, females had the majority of finger injuries (66 percent), ankle injuries (58 percent), and knee injuries (70 percent).

Injury mechanisms are seen in Table 1. There were 58 percent due to stumbling, 60 percent from jumping, and 72 percent were ball-contact injuries injured females. Totally, 31 percent incurred from shooting from a distance, 13 percent from struggling on the line, and 28 percent from running. During the preceding year, 32 percent had an injury of the same type and location.

Table 1. Injury mechanism in handball

	Ball con-	Stumb-ling	Fall	Opponent player	Other	Intrinsic injuries
Club:	18%	16%	9%	22%	12%	23%
Hospital:	31%	20%	6%	25%	11%	7%

In C, 45 percent were treated at hospitals and 15 percent in general practice. When extrapolating to the municipality of Århus, we found about 2,200 handball injuries, approximately 1,200 of which required medical treatment. Twenty percent of the injured players in C were absent from their sport for more than 1 month, and 42 percent of them still had complaints after 6 months of observation.

Conclusion: Handball is shown to give a high injury incidence and a great load on public medical service. The high risk of reinjuries and long-lasting sequelae shows that better treatment and rehabilitation are desirable.

Epidemiology and traumatology of injuries in four ball games

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Introduction: To identify and analyze risk factors of injuries incurred in sports, a prospective investigation was performed in a Danish athletic club. Four team sports were studied during a single season.

Subjects and methods: Six hundred players were followed in soccer (S) 123, handball (H) 221, basketball (B) 120, and in volleyball (V) 136. At weekly visits to the clubs, the injuries were examined by the authors, and records of absence from activity were kept by the trainers. Only an injury that caused the player to miss at least one game or practice session was recorded. The records were obtained at the end of the season, and a follow-up was done 6 months after the season.

Results: Totally, 303 injuries were recorded (S 109, H 105, B 56, V 33). The incidence of injury per 1,000 practice hours was S 3.6, H 2.2, B 2.2, V 2.1 and injuries per 1,000 game hours S 14.3, H 11.4, B 9.3, V 5.7. Ankle sprain was the most common injury (34 percent), and was found equally in all the games. Finger sprains (20 percent) were mainly seen in basketball. The majority of the knee injuries (13 percent) occurred in soccer. Strains (11 percent) were also most common in soccer. Overuse injuries (13 percent) were equally seen in all the games. Fifty-nine percent of the injuries were contact injuries. The finger sprains were caused by ball contact in handball (18 percent), basketball (38 percent), and volleyball (30 percent). Half of the ankle sprains and 35 percent of the knee injuries occurred during contact with opponent players. Tackling caused most injuries in soccer (40 percent), whereas injuries during shooting were more common in the three other games. The risk of reinjury was the same in the four games (35 percent). Forty-eight percent of the injuries were treated by the players themselves. Absence from the sport for more than 4 weeks after the injury was found in soccer (35 percent), handball (20 percent), basketball (9 percent), and volleyball (3 percent). At follow-up, 35 percent of the injured players had complaints.

Conclusion: Ball games are responsible for many injuries, with the highest incidence in soccer and handball.

Injuries in badminton

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Introduction: Badminton is one of the most popular sports in Denmark, with more than 170,000 players in 650 clubs and numerous players outside the clubs. The aim of this study was to determine the frequency of badminton injuries and to describe the etiology and epidemiology of these injuries.

Patients and methods: During 1986, 4,154 patients with sports injuries were treated at Århus County Hospital and Århus Municipal Hospital. Only patients living in the city of Århus entered the study, and they were registered on a standard questionnaire. The mean age was 22 (7–72) years, and 2,749 were men.

Results and discussion: Totally, 208 badminton injuries occurred in 201 patients (132 men), with a mean age of 20 (7–57) years; they constituted 5 percent of all the sports injuries in Århus. Joints and ligaments were injured in 60 percent of the patients, and most frequently the injury was in the ankle or in the knee. Ligamentous injuries were more frequent among patients under 30 years of age ($P<0.01$). Overuse injuries occurred in 30 percent of the patients, and this type of injury was more frequent among patients over 30 years of age ($P<0.01$). Most of the injuries were mild ones, but 7 percent of the patients were hospitalized, and 26 percent received further treatment in the outpatient clinic; 7 percent were treated by their own general practitioner.

The present study indicates that badminton injuries occur to a relatively older age group than sports injuries as such. Although badminton injuries occur with a relatively low frequency, the type of injury is often severe and demands a long period of treatment.

Running injuries in long-distance runners

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Introduction: Participants in long distance races are known to strain the musculoskeletal system causing running-related injuries. The aim of this study was to determine the injury frequency at the Århus Marathon in 1986 and to relate the risk to training condition.

Subjects and methods: Totally, 924 participants were given a questionnaire, and 90 percent (n 831) answered it. The sex ratio (F/M) was 0.13, and the mean age was 35 (11-77 years). The runners had trained 47.5 ±24.6 km (x ±SD) per week and with a pace of 10.8 ±2.9 km/h.

Results and discussion: In all, 161 runners had 193 injuries in relation to the race (19 percent); 89 had an injury that prevented them from sports activities for more than 1 week. Only 21 of them sought medical care — 5 at a general practitioner or a specialist in sports medicine and 15 at a physiotherapist. The injuries were blisters (27 percent) and overuse injuries of the leg (68 percent), especially of the knee and lower leg. The injured runners were significantly younger ($P < 0.05$), had trained significantly shorter distances, and at a lower pace ($P < 0.05$). Ninety three of the injured had previous running-related injuries ($P < 0.05$).

Conclusion: The present study showed the risk of injury to runners participating in a long distance race to be rather high, although the severity of the injuries was mild in 53 percent. The injury risk was related to training, earlier injury, and age. Attempts should be made to treat and retrain runners after injury and to urge runners to train sufficiently before participating in a long distance race.

Exercise-induced knee joint laxity in distance runners

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Introduction: The objective of this study was to evaluate the effect of exercise on knee joint laxity. If exercise-induced laxity is physiologic, this quality should perhaps be incorporated into a ligament replacement material.

Patients and methods: Twenty recreational distance runners (11 men and 9 women, mean age 41 [24–50] years) were tested before and immediately after 30 minutes of running. Using a computerized goniometer-type instrument (Acufex KSS), knee flexion, axial tibial rotation and anteroposterior tibial displacement were recorded simultaneously while the runners were subjected to tests of static and dynamic knee joint laxity.

Results: At 20° of knee flexion, 14–16° postexercise increases in mean total anteroposterior laxity were found (displacement forces of 50, 100, 150, and 200 N). The increase was less at 90° of flexion (8° at 50 N of applied force, 0 at 200 N). At the examination 30 minutes after exercise, laxity at 30° of knee flexion was still increased; however, laxity at 90° of knee flexion had decreased to preexercise levels or below. Anterior tibial displacement, recorded while the seated subjects performed knee extension from 90 to 0 ° with weights (10 percent of body weight) attached to the foot, showed increased postexercise laxity. At 30° of knee flexion, a mean increase of 18 percent over preexercise levels was found.

Conclusion: Repetitive physiologic stresses produce significant ligamentous laxity in normal knee joints.

Low shock absorbency in the soccer shoe — a possible risk factor in overuse injuries

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Shock absorption is a simple way to reduce the body load and can be used in the prevention and treatment of overuse injuries, which comprise one third of the injuries in soccer.

The purpose of this study was to investigate 1) the shock absorbency of the soccer shoe compared with other sports shoes and 2) whether it was possible to increase the shock absorption in gait and running.

Methods: In the shoe drop test, a soccer shoe had the lowest SA and a running shoe the highest. Impact forces at heel strike were measured on an AMTI(R) force platform. Fourteen legs were tested in 7 persons (9 normal heel pads and 5 with low shock absorbency) in gait analysis (2.0 m/s) and in human drop tests. Tests were performed barefoot in the two different shoes ±the distal 2 cm of the heel counter.

Results: The running shoe provided 2.2 times greater SA than the soccer shoe in gait and 1.3 times greater SA in simulated running. Heel support increased the SA in both shoes significantly; the mean increase was 6.8 percent in the soccer shoe and 10.7 percent in the running shoes.

Conclusions: The SA in the running shoes was significantly better than in the soccer shoes. An improvement of the SA in the soccer shoe is a necessity. The heel counter had a significant effect on the shock absorbency at heel strike in both shoes. This should be considered when choosing, constructing, or testing shoes where an optimal shock absorbency is desired, as in persons with or at risk of heel strike-dependent overuse injuries.

Ankle injuries in athletes

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Introduction: The aim of the present study was to correlate the type of ankle injury with activity, age, sex, type of accident, and type of sport.

Patients and methods: During 1986, 4,920 patients with sports injuries attended the emergency rooms of Århus County Hospital and Århus Municipal Hospital. Ankle injuries occurred in 941 of these patients. The sex ratio (F/M) was 0.41, and the mean age was 22 (2–65) years.

Results and discussion: Eighty-four percent of the patients were aged 10–30 years. The most common type of injury was lesions of the ligaments, occurring in about 75 percent of all the patients, followed by lesion of the bones, skin, tendons, and muscles. Fifty-eight percent needed no further treatment; 35 percent received further treatment or were followed up by the orthopedic outpatient clinics, and 1.5 percent were kept in the hospital. Twenty-one percent of the injuries occurred during free-time athletic competition — 62 percent in clubs and 11 percent in schools.

Conclusions: The present study showed a high frequency of ankle injuries in connection with sports, especially in younger persons. One third of the patients had to be treated further or followed up by the orthopedic outpatient clinics.

Knee problems in former high-level soccer players

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Introduction: Soccer players have a high injury rate as compared with many other athletes. Totally, 25–40 percent of all the soccer injuries are located in the knee joint. The aim of this study was to determine the incidence and amount of knee problems in high-level soccer players 15–20 years after the termination of their active career, i.e., if there are any long-standing knee problems.

Subjects and methods: Sixty-six former high-level soccer players born between 1936 and 1944 were randomly chosen from team lists submitted to the Gothenburg Soccer Association during the years 1961–65. As controls, 33 persons of the same age group were randomly chosen from the male population of Gothenburg. The soccer players and controls were interviewed and underwent a careful clinical knee joint examination, in many cases including an objective measuring of the laxity of the anterior cruciate ligament (ACL)

Results: Three of 66 soccer players reported knee problems interfering with activities of daily living. During physical exercise, 25 percent reported some degree of knee problems. The corresponding figures for the controls were 9 and 18 percent, respectively. The rate of physical activity at the time of the investigation was still high in the soccer group and much higher than in the controls.

Half (33) of the soccer players had sustained 41 knee injuries during their active period. Twenty-three were meniscus tears, 14 were ligament injuries (7 MCL, 4 LCL, 3 ACL), and four others. The controls had two knee injuries — one meniscus tear and one injury to the joint capsule.

Clinical and objective examination of the stability of the knee joint showed an increased laxity of the ACL in 75, 55, and 42 percent of injured soccer players, uninjured players, and controls, respectively. Corresponding figures for increased laxity of medially stabilizing structures were 36, 21, and 21 percent. We found no or very little increased laxity in the LCL and PCL in all the groups.

The Lysholm Knee Scoring Scale was 92 for injured soccer players, 94 for uninjured players, and 96 for controls.

Conclusion: Half of the soccer players had sustained knee injuries during their active period. The soccer players had an increased joint laxity as compared with a control group. Few players had any knee symptoms 15–20 years after termination of their active careers, and they maintain a high standard of physical exercise.

Soccer injuries

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Introduction and subjects: In a 1-year period, 1,530 cases of soccer injuries (37 percent of all sports injuries) were treated at the two casualty wards in Århus. The mean age of the injured was 22 years.

Results: The women accounted for 8 percent of all the injuries. Thirty-seven percent occurred on the weekends, and 54 percent were connected with tournament matches. Accident mechanisms involving contact with other players accounted for 46 percent of the accidents. The 1,530 accidents caused 1,620 lesions. The head and neck were injured in 6 percent of the cases — all men. The back, chest, and pelvis were injured in only 2 percent, the upper extremities in 24 percent (hand 16 percent), and the lower extremities in 67 percent (knee 18 percent, ankle 25 percent, foot 18 percent) of the cases. Contusions accounted for 31 percent, skin wounds for 7 percent, and distorsions plus luxations for 45 percent of the lesions. Fractures constituted 15 percent of all the lesions (among 241 cases there were only 11 women). Half of the fractures were located in the upper extremities and 45 percent in the lower extremities. Most of the patients (61 percent) were treated and finished up at the casualty ward. Only 3 percent were hospitalized immediately, but 24 percent were seen in the outpatient clinic. Many of these were later hospitalized with tears of the ligaments and the menisci of the knee.

Conclusion: Soccer injuries contributed a large part of all sports injuries. In the present study, mainly men were injured. The hand, knee, ankle, and foot were the predominant sites of injury.

Injuries and risk factors in alpine skiing

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Introduction: Although the injury risk in alpine skiing has

decreased, the number of skiing injuries is increasing due to more skiers on the slopes. The growing popularity of alpine skiing makes it therefore important to identify risk factors while skiing to generate data for preventive measures.

Subjects and methods: The skiing injuries in four Norwegian ski resorts were recorded during the winter season of 1985/86. The registration was carried out by the local physician, and the number of injured skiers totaled 328. A control population of 316 uninjured skiers were randomly selected from lift lines in the same skiing areas throughout the season.

Results: The most common injury sites were the knee (24 percent), shoulder (15 percent), and head (14 percent). Only 6 percent of the skiers suffered a lower leg fracture, but the frequency of this fracture was almost six times higher in children under 10 years of age than in adult skiers. Beginners had an injury risk four times the average, whereas skiers taking formal skiing instruction during the current season were underrepresented among the injured skiers. Tested bindings were more common among uninjured skiers, and such bindings were also more apt to release during the accident than bindings not tested.

Conclusions: Inferior skiing ability is the most important risk factor in skiing. Thus, skiers should take instructions to shorten their number of beginner days on the slopes. They should also self-release test their bindings every day for safer skiing.

Sports-related injuries: A prospective study from a Danish community

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Introduction: Sports-related injuries are an important problem worthy of major preventive efforts in terms of magnitude and cost. The present study concerns macrotraumas requiring medical care. Its purpose is to report epidemiologic data, such as frequency, type of lesions, and the mechanism of accident.

Patients and methods: During 1986, all the sports-related accidents to patients living in the municipality of Århus attending one or two hospital emergency rooms were registered in detail. Århus municipality has 253,753 inhabitants. The analysis includes 4,154 cases.

Preliminary results: Male predominance was observed, 2,749 males (66 percent) and 1,405 females (33 percent). The highest incidence of injuries occurred in the 15–19-year age group (58/1,000 inhabitants) and secondly in the 10–14-year age group (52/1000 inhabitants). The mean age was 22 (7–72) years. Sport areas represented 67 percent of all the places of accidents including 11 percent in school. There were 1,889 (45 percent) injuries among competitive-level participants and 1,941 (47 percent) injuries among noncompetitive-level participants. The highest number of injuries occurred in football (1,530 or 37 percent), followed by handball (824 or 20 percent) and basketball (278 or 7 percent). Horseback riding gave rise to 105 (4 percent) of the injuries. A fall was the cause of injury in 1,522 (37 percent) of the cases, whereas a kick was the cause of injury in 1,396 (34 percent). In 703 (17 percent) of the cases the patients were struck by a ball. The location of the injury (percent) was ankle/foot 36, hand/fingers 26, knee 13, and head 7. The most common types of injuries were sprains and strains (2,743 or 52 percent), which were most frequently occurred in the ankle (816 or 20 percent). Fractures comprised 584 cases (14 percent), mostly of the upper limb (328 or 8 percent). The hospital admission rate was 3 percent. Ambulatory care was provided in 34 percent.

Sports injuries in a large urban population: Incidence and epidemiologic aspects

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Most studies reporting on sports injuries have been investigations of specific sports events and levels. This study aims at outlining the features of sports injuries regardless of type, severity, or treatment during 1 year among the adult population of the Greater Helsinki area (pop. 600,000). The study was carried out in cooperation with the Central Statistical Office, which in 1980 performed an extensive survey aimed at outlining the incidence and features of acute accidents occurring in Finland. The actual data from this study concerning sports injuries in the Greater Helsinki area was further analyzed.

During the period of investigation, an estimated 40,380 acute sports-related injuries occurred, the calculated incidence of sports injuries in the area thus being 670 ± 121/10,000 inhabitants. Sports injuries were found mainly among young people. Surprisingly low was, the occurrence of injuries among women of 20–24 years of age.

The majority of injuries were found to be of mild character; however, 9 percent were classified as severe, and on the basis of the information obtained from this study, some 4,000 patients attended a casualty department in the area because of an injury sustained in sports, thus placing a considerable burden on these agencies. Distorsion (65 percent) was the most common type of injury, and most of the injuries could be treated with basic knowledge of acute musculoskeletal injuries.

Although the majority of injuries found in this study were trivial, and in only about half of the cases medical treatment was needed in the acute stage, at follow-up 2 years after the injury, 11 percent of the patients complained of some sequelae from their initial trauma. In the majority of cases the initial trauma had been a sprain of ligamentous structures of either the knee or ankle joint. Thus, in addition to proper diagnosis and treatment of these injuries, a rehabilitation program is of paramount importance before the injured persons return to sports activities.

Detection of jumper's knee (patellar tendinitis) with ultrasound

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Introduction: Jumper's knee (patellar or quadriceps tendinitis) commonly occurs in athletes whose major activity includes repetitious jumping. Blazina's classification is based on anamnestic data. Radiographic findings are inconstant and nonspecific. Ultrasound was used to investigate the structure of the patellar tendon in healthy athletes and in those with the clinical picture of jumper's knee.

Patients and methods: Twenty-five first division volleyball players (8 women, 17 men) were investigated before and after vigorous exercises including jumping. Fourteen athletes had complaints compatible with the clinical syndrome of jumper's knee: 3 at the upper pole of the patella, 10 at the lower pole, and 1 near the insertion at the tibial tuberosity. Three had bilateral complaints. All 14 complained after the training, and the symptoms disappeared within 24 hours (Blazina stage 1). On the ultrasonogram the thickness of the tendon was determined. Hypoechogenic areas, calcifications, and lack of homogeneity were looked for. A real time sector scanner (Toshiba F.L.A. 38-B, 7.5 MHz probe) with a water pad transducer was used.

Results: The changes found in the tendons of the players with the clinical syndrome of jumper's knee were overall thickening, hypoechogenic swollen areas, and heterogeneity of the tendon structure with or without calcifications. Because of these changes, the border between tendon and tendon sheath was sometimes poorly defined.

Hypoechogenic areas and thickening of the tendon correlated well with the clinical diagnosis. An observer, who was not aware of the clinical picture, could diagnose jumper's knee because of thickening of the tendon and hypoechogenic areas in 8 of 10 players with pain at the lower pole of the patella. No changes were found in the players without complaints.

Conclusion: Ultrasonography of the patellar tendon is helpful in diagnosing jumper's knee. The most specific findings in clinically evident tendinitis are hypoechogenic swelling and thickening of the tendon.

Knee sprain complexity

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Introduction: The combination of injuries to different structures of the knee should be of importance for the outcome of a knee sprain.

Methods: Ninety-three knees were examined. Patellar dislocation was excluded if isolated, but included if combined with ligamentous injuries. Minor depression of the tibial plateau (less than 5 mm) was included if combined with ligamentous injuries. The injuries were not graded according to severity, nor was the exact site of rupture considered. The injuries were diagnosed by exploration in 76 cases and by arthroscopy in 17 cases. The injuries were recorded as anterior cruciate, posterior cruciate, medial ligaments, lateral ligaments, intraarticular fracture, medial meniscus rupture, medial meniscus avulsion, lateral meniscus rupture, lateral meniscus avulsion, and dislocation of the patella. The combinations were analyzed.

Results: With this method, 24 different combinations of injuries were found in 93 knees.

Discussion: Probably there were even more combinations in this group of patients because arthroscopy cannot expose all the extraarticular injuries. If the severity and the exact location of injury is considered, the number of combinations will be even greater.

Conclusion: The great number of combinations indicates that when comparing different treatments, we are seldom comparing the same combination of injuries. This must be a problem when we compare, for example, operative versus conservative treatment.

Accidents

Routine computerized accident registration in a casualty department

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Introduction and method: Since 1983, all the case sheets from our casualty department have been processed by a computerized "on-line" system. There were two intentions, one was to process the data and case sheets concerning approximately 20,000 contacts a year, and the other was to apply a coding system developed by NOMESCO (Nordic Medical Statistic Committee) as a routine. All the data are dictated/coded by the doctor treating the patient immediately after treatment. The parameters registered are personal data, anamnesis and clinical examination, diagnosis, time of accident and arrival, cause of contact, place of accident, mechanism of accident, treatment, mode of termination, and it is noted if the accident is a traffic or occupational accident.

Results: In the period 1983–86, there were 79,505 contacts; 89 percent of the contacts were caused by a fresh accident. Nearly one third of the accidents happened at home, 20 percent during work, 14 percent in traffic areas, and 8 percent occurred during sports activities. Ten percent of the contacts had to be hospitalized. It was possible to describe the cause of contact in 99.6 percent of the cases and the place of accident in 93.2 percent.

Discussion: The intentions have been fulfilled. The system functions well as a descriptive accident data base —registering basic epidemiologic data — and as an administrative

tool. The system has been introduced without the need of more manpower. As a local system, changes are rather easy to perform and analysis can be made without charge. In-depth analysis of the factors causing accidents cannot be performed directly, but demands further analysis. For a further improvement, it is recommended that modules regarding involved products and home, traffic, occupational, and sports accidents (totally, 73 percent of the accidents) are developed and are made mandatory.

Chest injuries sustained in severe traffic accidents by seat-belt users

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In Finland during the period 1972–1985, 4,045 severe traffic accidents occurred where one or more of the drivers or passengers sustained an injury leading to a fatal outcome within 30 days. Of the victims who had been wearing a seat belt, 207 had fatal and 73 severe chest injuries.

The four leading causes of fatal outcome resulting from chest injuries were ruptures of the aorta (37 percent), ruptures of the heat (28 percent) and bilateral lung contusions (31 percent) or lacerations (16 percent). Seat-belt wearers with heart ruptures had more often concomitant rib fractures, lung injuries, and sternum fractures than was the case with the victims who had sustained ruptures of the aorta.

The victim's location in the car was associated with the side of rib fractures, drivers having more right-sided and right-front passengers more left-sided rib fractures.

Eighty-seven percent of the victims had in addition to their chest injury other concomitant injuries. Liver injuries (40 percent) and spleen ruptures (27 percent) were found to be the most common associated abdominal injuries.

It seems that the severity of chest injuries that lead to fatal outcome in seat-belt wearers is extremely high, since seat-belt wearing saves life in more moderate accidents. The Y-type harness seat belt probably provides far more protection regarding chest injuries and should be further investigated.

Comprehensive analysis of traffic accidents and injuries in Gothenburg

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Introduction: A hospital-based registration of traffic accidents and injuries was introduced in Gothenburg in 1978 by the Traffic Injury Register (TIR). One purpose was to compensate for deficiencies in official traffic accident statistics, based on police reports. Another purpose was to study the mechanisms of injuries in traffic accidents. The aim of this presentation is to illustrate how data reported from police and hospitals can complement each other in a comprehensive analysis of causes and consequences of traffic accidents.

Materials and methods: The accident circumstance described in the police reports are documented and analyzed with a computer program (TRAFO), which has been used by the traffic planning department (TPD) of the town planning council in Gothenburg since 1971. The medical consequences described in the hospital records are documented by the TIR and reported to the TPD. The number of killed, seriously and slightly injured, and the time spent in the hospital are the primary measures of the accident outcome. Complementary information about the accident circumstances, the injuries, and their sequelae is added from inquiries and medical examinations. In-depth, at-the-scene analyses of the accident sites and the vehicles are made by a technical team in specific cases. From 1979, the hospital data have been used by the TPD as a complement to the police reports. From 1983, the accident data in the TRAFO-system can also be linked with the hospital data of the TIR. A comprehensive analysis has been made of the data from these two sources for about 2,000 accidents and casualties registered in 1983 in order to describe the accident outcome for different types of accidents on different parts of the road network.

Results: About 10,000 casualties have been reported from the TIR since 1979. This has increased the number of accidents known by the TPD by about 70 percent. The increase is greater for unprotected road users and as high as 285 percent for bicyclists. As a consequence, the priorities of traffic safety investments in the city have changed, and more money is now allocated for these categories. Pedestrian casualties are the most expensive. In 1983, they constituted 15 percent of all the traffic casualties, but consumed 30 percent of the time spent in the hospital of all traffic casualties. Pedestrians hit by cars often sustain severe leg and knee injuries. Studies on such injuries and biomechanical studies have led to proposals how to reduce the aggressiveness of the car front. The protective effect of bicycle helmets has been verified. A major part of the neck injuries are sustained by car occupants. Neck injuries are seldom life threatening, but they cause serious permanent impairment in about 10 percent.

Conclusions: Clarifying the causes of accidents is a prerequisite for accident prevention, and the understanding of the mechanisms and consequences of impact trauma is essential not only for diagnosis and treatment of injuries, but also for effective injury prevention.

Progress in development of home accident surveillance system (HASS)

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Introduction: The corner stone in accident prevention is the

development and use of well-functioning information systems (1). Many systems are based on data collected at a health center facility, which may serve as a basis for epidemiologic research into the causes and consequences. If data from health-care systems shall prove useful in accident prevention, they have to adopt elements essential to the sectors of society responsible for running accident-prevention programs.

Materials and methods: We describe a HASS based on an 18-month registration period. The registration was prospective and was made ad hoc, and included interviews with the victims. It included 7,182 registrations of product-involved accidents in the home.

Results: The information system was constructed with three levels of information — from an overview level based on 40 head groups of products to a detailed one-case sample.

The original HASS system was based on numerical registration of products involved (2), but we introduced a measure of severity in our system. By using the number of registrations combined with a severity measure, it is possible to point out "problem areas."

The relative risk by the use of specific products would be very interesting to know for priority-setting prevention purposes, but that type of data are hard to catch through this information system. However, by using an indirect measure of population at risk, we were able to demonstrate variation in risk by using specific products, such as saws and drills.

This type of information system will need further development in the 1990s, and will place orthopedic surgeons in an important spot when it comes to prophylactic measures. Development of the information system call for coordination between the Nordic countries (3).

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Children in traffic accidents — injuries and sequelae

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Introduction: This study has been performed in order to analyze the risk groups, the injuries, the time of hospital care, and the sequelae of children injured in traffic accidents in urban traffic.

Subjects and methods: A study was made on children injured in traffic accidents and treated at the emergency hospitals in Gothenburg during 1983 and 1984. During these years, 4,116 traffic accident casualties were registered. Of the injured, 1,027 (25 percent) were children below 16 years of age. The type of accident, the protective equipment, the injuries and their severities, and the time of hospital care were documented by the Traffic Injury Register. The severity of the injuries was classified according to the AIS-system. A "seriously" injured person is defined as a hospital inpatient and a "slightly" injured person as a hospital outpatient. A clinical follow-up was performed on those children who were not free of symptoms 2 years after the accident.

Results: Two children (0.2 percent) died, 338 (33 percent) were seriously injured, and 687 (67 percent) were slightly injured. The time of hospitalization was less than a week in 95 percent of the injured children. The highest frequency of injured children was noted in the age groups 4–6 and 13–15 years. Sixty-nine percent were boys. Totally, 740 (72 percent) of the injured were bicyclists, 117 (12 percent) moped riders, 94 (9 percent) pedestrians, and 70 (7 percent) car occupants. In total, 1,590 injuries were registered. Of those, 43 percent were located in the head, 26 percent in the upper extremities including the shoulder, and 25 percent in the lower extremities including the pelvis. Eighty-six nonminor (AIS > 2) injuries were registered. Of those, 13 percent were located in the head, 33 percent in the upper extremities, and 50 percent in the lower extremities. Sixty-two (72 percent) of the nonminor injuries were noted in pedestrians and bicyclists. At the clinical follow-up, 113 (11 percent) children had sequelae of varying degrees, frequently in the older children. The highest number of sequelae were found after injuries to the head and lower extremities. Twenty-one (19 percent) of the children had undiagnosed injuries at the follow-up.

Conclusions: The proportion of children among injured road users in Gothenburg was the same as the proportion of children in the population. A major part of the injured were bicyclists. Head injuries were the most frequent injuries. Life-threatening injuries were infrequent, and they were mostly noted in pedestrians hit by cars and in car occupants. Late sequelae were noted in 11 percent of the total number of injured children, but major sequelae were infrequent. The traffic safety for children can be improved by the use of bicycle helmets and mandatory use of child seats and seat belts in cars.

Prevention of leg injuries in car-pedestrian collisions

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Introduction: Pedestrians hit by cars most often sustain inju-

ries to the lower extremities. It is believed that these injuries can be reduced in number and severity if the car exterior is modified and adapted to the tolerance level of the human body. The aim of this presentation is to illustrate how the type and severity of leg injuries in such collisions are correlated with the shape and mechanical properties of the vehicle front, and to suggest what measures could be taken to protect against these injuries.

Subjects and methods: Experimental and clinical studies were made on leg impacts in adults. In the experimental part, impact tests were made with a simulated car front with human leg specimens. The configuration and the mechanical properties of the front were varied. Collisions were made with the bumper impacting at various levels between the knee and the midtibia. Two test series simulating 60 collisions in all were carried out with the simulated front. The impact speed was between 16 and 32 km per hour. Thirty-five impact tests were also performed with a compliant bumper system for pedestrian protection, developed by the National Highway Traffic Safety Administration (NHTSA), U.S. Department of Transportation. In the clinical part, a retrospective study was made of 34 adult pedestrians injured by cars and treated as inpatients at an orthopedic department. Medical records, police reports, and technical investigations were used to analyze the accidents and to correlate the injuries with the shape of the car front. Clinical follow-ups and interviews were carried out 1-3 years after the accidents. The injury mechanisms were studied for injuries to the different parts of the lower extremity. Special attention was paid to knee and lower leg injuries, the walking impairment, and the bumper level of the car.

Results and discussion: In the experimental and clinical studies, a bumper impact at or just below the knee level was found to correlate with a great risk of serious knee injuries. Some of these might also have been caused by a protruding hood edge. The pedestrian-adapted car front from NHTSA, with the compliant bumper, also resulted in serious knee injuries if the bumper struck at the knee level. In the clinical study, blows from bumpers mounted at or above 40 cm from the ground seem to have caused severe knee injuries and greater walking impairment 1-3 years after the accident more often than those mounted at lower levels. In the experimental study, serious injuries to the lower leg and knee could be avoided in most cases if the bumper was compliant and energy-absorbing, and if it struck at the midtibia level.

Based on these studies, an impact protection zone was recommended for the car front. It should consist preferably of two main parts:

1. A lower leg impact zone, which can be deformed plastically at least 10 cm by a force less than 1 kN. The vertex of this part should be approximately 35 cm above the ground, and the zone should extend downwards for at least another 10 cm.

2. A hood-edge impact zone, which should be designed to take into account the pelvic injury tolerance in adults and the head and chest injury tolerance in children.

Implant research

Effects of interface bonding on stress shielding in cementless THA

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Introduction: Coatings, such as porous metals or hydroxyl apatite (HA), allow for firm bonding of hip prostheses to bone, contrarily to "press-fit" designs, but could cause stress shielding and resorption of bone. For that reason, some hip stems are only coated in part, on the assumption that this reduces the degree of stress shielding. The purpose of this project was to investigate the validity of this assumption.

Methods: A standard 2-D FEM model of the proximal femoral THA configuration was used to analyze the load-transfer mechanism for uncoated "press-fit", fully (HA) coated, and partly coated stems. In all cases, bone and interface stresses were determined. Using adaptive bone-remodeling theory in a time-dependent computer simulation (1), the possible amounts of bone loss due to stress shielding were estimated.

Results: With the fully coated (bonded) prosthesis, complete proximal cortical resorption may occur. In the case of the partly coated stem, stress shielding along the proximal one third of the stem does not differ significantly from the fully coated case. The "press-fit" stem causes bone stresses beyond normal due to its sliding/tapering mechanism. The same mechanism is responsible for elevated compression and some relative motion at the implant/bone interface.

Conclusion: Interface stability and normal bone stresses require contradictory interface-bonding characteristics. More subtle biomechanical criteria than used to date must be developed for coating locations in order to reduce their adverse side effects.

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Development of cemented hip-stem shapes for optimal load transfer

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Introduction: In this paper a new method is introduced whereby a specific, desired interface stress distribution around THA structures is taken as a basis for determining the associated optimal shape of the prosthesis.

Methods: The method of analysis is based on Numerical Shape Optimization (NSO), in which the FEM is applied iteratively. The shape of the prosthesis is described by n "design variables," adapted in the course of the iterative procedure

until the optimal configuration is reached. The NSO method was applied first in a simplified model and later in a more realistic 2-D FEM model of the cemented femoral hip stem. The procedure was repeated for several parametric variations, such as load, bone modulus, stem material, cement modulus, and stem length.

Results: In all the procedures, a typical cigar-shaped contour for the optimal stem was obtained. Depending on the structural parameters and the applied load, stress-peak reductions of 60–85 percent relative to those in conventional stem shapes could be reached in the proximal and distal cement and cement/bone interfaces.

The parametric analysis indicated the following: 1) The best stem length of the optimized design is about 120 mm. 2) CoCr-alloy as a stem material enables more stress reduction compared with titanium. 3) The proximal stem profile is rather susceptible to the bone and cement moduli, but not to the actual applied load.

Conclusions: The NSO method is an extremely powerful tool for prosthetic design generation for the purpose of obtaining optimal load transfer and minimal chances of loosening. The results of the present investigation indicate that contemporary cemented hip stems can be significantly improved in this respect.

Stimulation of osteopenic bone ingrowth into porous-coated implants by hydroxyapatite coating

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Introduction: Retrieval studies of porous-coated implants have demonstrated a lack of bone ingrowth in high percentages, particularly in the knee joint. The reason might be a lack of initial mechanical stability, as well as osteopenia. To evaluate the effect of various coatings on ingrowth of osteopenic bone, we developed an experimental model in dog knees.

Materials and methods: Unilateral osteopenia of the knee was induced in 12 mature dogs by weekly intraarticular injections of carragheenan into the right knee for 12 weeks. The bone density of the implantation site was assessed by CT scans prior to surgery. Titanium plasma spray-coated cylinders were inserted bilaterally in both femoral condyles in 6 dogs. Hydroxyapatite-coated plugs were implanted in another 6 dogs. Press fit was used in the lateral condyles, whereas a 1-mm gap surrounded the implant in the medial condyles. The animals were killed after 4 weeks. A histologic and biomechanical evaluation was performed to assess bone ingrowth and fixation of the implants.

Results: CT scanning showed a 20 percent reduction of bone density in the arthritic bone ($P < 0.001$). In the press-fit group, the anchorage of titanium plasma spray implants in osteopenic bone was significantly reduced compared with normal bone. The hydroxyapatite coating was found to enhance the fixation of the implant in both normal and osteopenic bone ($P < 0.01$).

Conclusion: The most significant finding of the present study was the capability of hydroxyapatite coating to enhance the ingrowth of osteopenic bone in the presence of an initial gap between the bone and implant. Thus, the benefit of hydroxyapatite coating eliminated the negative influence of osteopenic bone.

Hydroxylapatite coatings for total hip implants

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Hydroxylapatite coatings of titanium implants offer attractive biological perspectives for biological implant fixation. In a dog implant study using a hydroxylapatite-coated prosthesis in the right hip with a noncoated titanium implant as a control in the left hip, mechanical, radiographic, scintigraphic, and histologic evaluations of implants were made up to 2 years' follow-up. Noncoated prostheses were loose with radiolucent lines on radiographs. Bone scintigraphy revealed microinstability; and histologically, the prostheses were surrounded by fibrous tissue. In contrast, the apatite-coated implants were rigidly fixed from the third week on with good bone formation on the implant surface. On radiographs, beginning at 3 weeks, the bone interface was smooth with an increase in bone density towards the implant. Bone scintigraphy showed a very even distribution of technetium uptake over the entire area of hydroxylapatite coating. In the histology, bone bonding occurred from the third week on both with mature osteocytes and with young osteoblasts. Bony defects up to 3-mm distance filled with bone within 6 weeks from both surrounding bone and the bone plate on the implant surface. There was an increase in size and density of bone trabeculae towards the implant surface.

The results with hydroxylapatite-coated prostheses were far superior based on their good bioactive and osteoconductive properties. The mechanism of bone bonding between implant coating and bone causes the prosthesis to not only withstand high compressive loads, but also tensile and shear forces. This significantly increases physiologic load transfer through the implant, adding towards an increased life expectancy.

Conclusion: Hydroxylapatite coatings permit an implant fixation superior to current cementless implant fixation techniques. As an outcome of the study, a human total hip prosthesis was developed with hydroxylapatite coating for chemical fixation to bone, which has been in clinical use since 1986.

Early results are very satisfying, especially the absence of "midthigh" pain is striking. Radiographs show good preservation of bone stock without radiolucent lines, but with an increase in density of the bone around the implants, similar to the results of the experimental study.

Osseointegration of titanium implants in arthrosis and rheumatoid arthritis

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A total of 23 screw-shaped implants of pure titanium were inserted 5–10 mm below the joint line in 5 patients with rheumatoid arthritis and 6 with arthrosis of the knee. The observation times ranged from 5 weeks to 24 months.

A histologic analysis was done of the bone adjacent to the implants. It was shown that a direct bone-implant contact (osseointegration) was established after 5 months in all the cases but 1. The amount of bone surrounding the screws varied greatly from patients with osteopenia to patients with good bone quality.

Thus, the joint disease as such does not preclude osseointegration. Osteopenia appears to be a risk factor, both for the development of osseointegration and for its maintenance.

The reaction of bone to implants of polyacetal (Delrin)

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Implants of Delrin and Delrin-titanium mosaic were inserted into rabbits. In the mosaic implants, the titanium served as an internal control during the histologic analysis.

The implants were removed with the surrounding tissue, embedded in epoxy resin, and sectioned with the Delrin in situ.

Not all the implants showed a direct contact between bone and titanium, but the ones that did showed a tissue reaction similar to the bulk implant. The reaction to Delrin was typically a thin membrane containing numerous foreign body giant cells However, in spite of this reaction, there were also small areas with a direct bone-Delrin contact. No cellular necrosis was seen.

Thus, Delrin causes an untoward reaction in the tissue. The observation of a direct bone-Delrin contact suggests that this bony reaction may be an unspecific response to a number of implants.

The reaction of bone to bone cement

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In an attempt to evaluate the basic bony response to polymerized bone cement, cement plugs were covered by a thin layer of pure titanium, which was then removed in certain areas, producing a mosaic surface.

These implants were inserted into the rabbit tibia, as were implants of bone cement without the titanium coat. At killing the implants and surrounding tissue were removed. The specimens were embedded in epoxy resin. During the embedding procedure the cement was dissolved, leaving an empty implant bed with or without a covering film of titanium.

The histologic studies showed a direct bone-implant contact with both titanium and bone cement. Even the pure cement plugs were invested in bone. Foreign body giant cells were rarely seen at the interface.

The basic response of bone-to-bone cement thus seems to be the direct bone-cement contact. The membrane often seen around cemented implants in bone is probably caused by a number of factors, and paradoxically even by the cement itself, which may injure the tissue chemically and thermally.

Preliminary experimental results of titanium press-fit resurfacing of the femoral head

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Introduction: Cemented double cups have shown unacceptably high failure rates. We have therefore designed a new cementless double cup for the hip joint. A similar prosthesis has been tried out on a cat model.

Material and methods: Ten cats, weighing 2.9–4.9 kg, underwent a surface replacement procedure in the right hip. The acetabular component was made from UHMW polyethylene, and had a cylindric and threaded outer surface. The femoral component was made from commercially pure titanium. The internal surface was cylindric and threaded. The whole titanium surface was oxidized. The acetabulum and femoral head were prepared by using special reamers. The prosthetic components were screwed into position. Unrestricted postoperative weight bearing was allowed. The animals were killed after 1.5, 3, 4.5, and 6 months, respectively; and later on, it is anticipated, every 6 months. The femoral components with the adjacent bone were removed and prepared for sectioning in the undecalcified state. The cut slices were examined under a light microscope.

Results and discussion: All the cats were fully weight

bearing from a few days after the operation. One cat dislocated its hip 3–4 weeks postoperatively, and it was killed at 1.5 months. All the other cats functioned well without a limp throughout the observation period. No radiographic or macroscopic signs of loosening were seen in the removed components. Histologic examination revealed contact between bone and metal in all the specimens. At 1.5 months, the contact was limited to some of the outer edges of the threads. At 3, 4.5, and 6 months, there was an increasing bone filling in the threads. At 6 months, several areas had a direct bone-metal contact. Although none of these specimens fulfilled the definition of osseointegration, the increasing bone-metal contact during conditions of weight bearing seems promising.

In vitro depressive biological effects of metal ions on human bone cells and animal whole bone

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Introduction: In recent years, several new prostheses based on noncemented fixation have been designed. With an uncemented prosthesis, a long-term linkage of metal ions due to corrosion could be anticipated. The amounts of ions liberated to the adjacent bone in vivo is poorly investigated; for nickel, 20.6±36.4 µg/g dry tissue weight has been found (1). Evaluation is most often based on the appearance of these ions in the urine or the blood (3, 4).

Materials and methods: We have used two in vitro systems to evaluate the effects of chromium ($CrCl_3$ and Na_2CrO_4), nickel ($NiCl_2$), cobalt ($CoCl_2$), aluminum ($AlCl_3$), and iron ($FeCl_2$). Human bone cells were cultured from fresh cancellous bone chips, and determination of alkaline phosphatase activity per µg DNA and incorporation of tritiated thymidine were performed. Mice calvaries were cultured as paired halves for 2 days and used for evaluating effect on the release of previously incorporated calcium-45 and alkaline phosphatase activity per µg DNA.

Results and discussion: The results from the human and the animal model corresponded well. Chromium in the 3-valent form (2.25–56.3 x 10^{-5} M) had little effect on all the parameters determined in both systems, only in the upper part of the concentration range could an effect be recorded. The 6-valent form of chromium (0.53–21.4 x 10^{-6}M) had a depressing action on especially calcium-45 release, but also alkaline phosphatase activity and thymidine incorporation were reduced. Nickel and cobalt (5.25–63 x 10^{-5}) inhibited calcium-45 release, alkaline phosphatase activity, and thymidine incorporation in the same pattern, although the effect of cobalt almost always surpassed that of nickel. Aluminum (1.04–6.2 x 10^{-4}M) did not depress any of the parameters, whereas iron (1.26–7.5 x 10^{-4} M) reduced thymidine incorporation slightly.

These results indicate a possible depressive effect on bone turnover by metal ions, because both bone resorption expressed by calcium release and bone formation expressed through the alkaline phosphatase (2) activity are affected.

A reduced bone turnover by ions leaking over long periods of time might be important for the fate of an implant by causing a diminished remodeling capacity.

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Histology of a mechanically defined bone-cement interface

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Introduction: The histologic picture of the bone-cement interface after artificial joint implantation ranges from wide zones of fibrous tissue with macrophages and foreign body giant cells to intimate contact between the cement and living bone (1). The mechanical definition of these interfaces rests, however, with the sole fact that the arthroplasties were"clinically successful." Recently, roentgen stereophotogrammetric analysis (RSA) has been used to measure motion of knee implants(2). We report a case of unicompartmental knee arthroplasty that was followed from the primary arthroplasty to the revision for osteonecrosis of the contralateral compartment.

Material and methods: The patient was a 71-year-old woman, who had been operated on for lateral gonarthrosis in 1981. The arthroplasty was totally successful. The tibial component showed a normal degree of initial migration and remained stable after 3 years. There was a translation away from the tibial eminence, a rotation"toe-out" and a slight lateral tilt of the tibial component. In 1986, aches and pain on weight bearing rapidly developed in the medial part of the same knee. Scintimetry and later radiography revealed the typical signs of osteonecrosis in the medial femoral condyle and discrete radiolucent lines around the prosthesis. At the revision operation to a tricompartmental arthroplasty, the tibial component was resected en bloc with the underlying bone to save the interface. After fixation the cement was dissolved and the specimen was embedded in PMMA to allow cutting and staining.

Results: The entire interface consisted of soft tissue. Between the tibial eminence and the cement, there was fibrous tissue with blood vessels and foreign body giant cells. By contrast, the interface underneath the cement was made up of highly differentiated fibrocartilage. At points, there was direct contact between bone and cement. This part contained no blood vessels and no giant cells. A layer of osteoid tissue was found to have intervened between the bone and the soft tissue.

Conclusions: This case shows that a soft-tissue interface,

i.e., a radiolucent line, can contain different kinds of tissue. The central fibrous tissue had filled into the void left by the migrating prosthesis. The fibrocartilage underneath the prosthesis with immediate contact between bone and cement probably indicates interface conditions that permit long-term prosthetic survival. This is also suggested by the migratory pattern.

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Heat generation during orthopedic surgery

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Introduction: Roentgen stereophotogrammetric analysis of tibial components in knee prostheses has shown micromotion that did not correlate with, for example, alignment, cortical bone support, or other "relevant" parameters.

It has been suggested that temperatures generated when cutting the subchondral bone could be a factor that is significant for the micromotion.

Method: A clinical study was done with 29 temperature measurements during knee-prosthesis surgery for gonarthrosis. Thermocouples were inserted in the bone and in the saw blade. Twenty-six measurements were done during the cutting procedure. In 8 cases, attempts to cool the saw blade with water were done as in the usual clinical situation with a syringe. Eighteen measurements were made during the cement curing process. Laboratory cutting tests were conducted on ox bone to evaluate different saw blade designs (Sandvik AB).

Results: The maximum temperature in the saw blade was between 44 °C and > 100 °C (mean 68 °C); and in the bone 1 and 2 mm under the cutting surface, the mean maximum temperature was 47 °C and 41 °C. Attempts to cool the cutting process had a minimal effect. The cement curing process in knee arthroplasty caused a mean maximum temperature of 37 °C at the bone-cement interface.

The laboratory cutting test did not show any differences in temperature elevation with different saw blade design using the usual clinical cutting machines.

Conclusions: Bone-cutting procedures, as tested during knee arthroplasty, give rise to significant temperatures. This heat generation may be one factor responsible for micromotion. Alterations in saw blade design does not appear to be able to control the temperature elevation, and further development will have to be made before this factor is controlled.

Varia

Bone dynamics of vascularized fibular graft

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Introduction: Several studies have dealt with the clinical use of autogenous cortical bone and allograft reconstruction. However, resorption of bone and fractures of the graft are possible complications.

It is plausible that vascularized bone grafts, by virtue of more rapid healing and hypertrophy, may better tolerate mechanical loading and thus reduce the incidence of resorption and stress fractures.

Although several clinical studies have discussed the union of vascularized grafts and resistance to infection, there are no studies dealing with the bone dynamics of vascularized grafts, by this is meant the incidence of stress fractures and ability of the graft to undergo hypertrophy

Patients and methods: Sixty-two consecutive patients who underwent a vascularized fibular transfer for reconstruction of a skeletal defect at the Mayo Clinic between 1979 and 1985 were retrospectively studied. All the patients had an evaluation of the radiographs taken at operation, 6 weeks, 3, 6, 9, 12, 18, and 24 months (when available) postoperatively and at the last follow-up. The diameter of the graft was measured on these serial radiographs. The mode of hypertrophy (periosteal, endosteal) was recorded. Bone scans within the first postoperative week were obtained to evaluate the patency of the microsurgical anastomosis.

Results: Hypertrophy. Endosteal hypertrophy was significantly ($P = 0.03$) more common in patients with a positive bone scan. Hypertrophy was observed in 38 percent of the patients overall and in the lower extremity reconstructions in 48 percent at 12 months and in 80 percent at 24 months. Hypertrophy appears to relate to age and imposed stress loading.

Stress fractures. We found an incidence of 25 percent stress fractures, all occurring in the lower extremity. These fractures became evident 8 (3–21) months after reconstruction, and only one fracture occurred more than 9 months after surgery.

We believe that the vascularized fibular graft should be protected in the first year against fatigue fractures, and mechanical loading should then be gradually increased to enhance remodeling and hypertrophy of the graft.

Partial weight-bearing ambulations: The unloading effect of various assistive device and gait patterns

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Introduction: In the prevention and follow-up care of many orthopedic conditions, prescriptions like nonweight bearing, touch-down ambulation, marked step, and various percentages of weight bearing of the affected lower extremity are frequent. In clinical practice, it is impossible to visually estimate the amount of unloading, and there are no simple ways to control the weight bearing prescribed. The aim of this study was to quantify the maximum unloading effect of the most usual walking aids used in combination with various walking patterns when both feet alternately touch the ground.

Subjects: Twenty-four healthy subjects were instructed to unload a pretended affected leg as much as possible with combinations of walking aids (canes, crutches, trestles, and walker) and walking patterns (aid on contralateral/ipsilateral side, three- and four-point gait).

The maximum vertical floor reaction force (percent body weight) of each leg, free walking speed (cm/s), duration of single-stance phase (percent gait cycle) of each leg and stride length/lower extremity length were recorded at a gait laboratory.

Results and discussion. There was no significant difference in maximum vertical force, 64 percent, between using a cane in the contralateral and in the ipsilateral hand. For unloading of the hip, a cane in the opposite hand was more effective due to the long lever arm to the hip joint. Three-point gait with crutches was the only combination to achieve a maximum vertical force of 17 percent body weight, equivalent to the weight of the leg. This type of unloading known as"marked step" is considered less stressful to the hip than nonweight bearing, where the foot is kept off the ground. Three-point gait irrespective of walking aid had a greater unloading effect than one walking aid or four-point gait. The crutch had a significantly greater unloading effect than the cane irrespective of walking pattern. There was no significant difference between three-point gait with crutches and trestles. Four-point gait was considered unsuitable for the the purpose of unloading. In spite of great exertion, a short walking distance and the slowest walking speed of all combinations maximum vertical force was 70 percent body weight on each leg. Maximum unloading during walking necessitated a very slow walking speed, 41 cm/s with one walking aid, 36 cm/s in three-point gait, and even slower in four-point gait. Walking speed with canes or crutches was faster than with trestles and walker.

Conclusion: In planning a surgical treatment requiring postoperative partial weight bearing, the surgeon should take into consideration that maximum unloading during walking requires three-point gait, crutches, very slow walking speed, arm strength, and a way to control weight bearing.

The importance of atmospheric pressure and joint capsule in the stability of the hip – a biomechanical study

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Introduction: Muscle force, joint capsule, geometry, and atmospheric pressure are stabilizing factors in a joint. Our purpose was to clarify the role of atmospheric pressure in relation to the capsule in stabilizing the hip joint and the importance of this mechanism in hip joint disease and diagnostics.

Methods: Six cadaver hips with an intact joint capsule and including a sufficient part of the pelvis and the proximal part of the femur were prepared and mounted in a constructed test rig. Joint distraction, traction force along and rotation ("flexion") around the axis of the neck of the femur, as well as intracapsular pressure and volume of intracapsularly infused saline, were simultaneously monitored. Three hips were used to study the relationship between rotation and intracapsular pressure/volume, the remaining three to study the role of atmospheric pressure in relation to the capsule in stabilizing the joint. Theoretical calculations were performed for comparison with the experimental data.

Results: Two actual recordings illustrate the results.

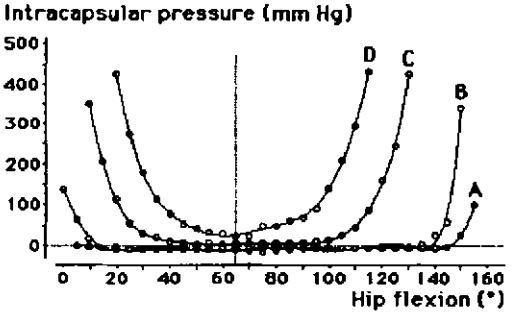

Figure 1. The intracapsular pressure in relation to hip flexion and intracapsular volume of infused saline. A = 0 ml, B = 8 ml, C = 24 ml, D = 36 ml.

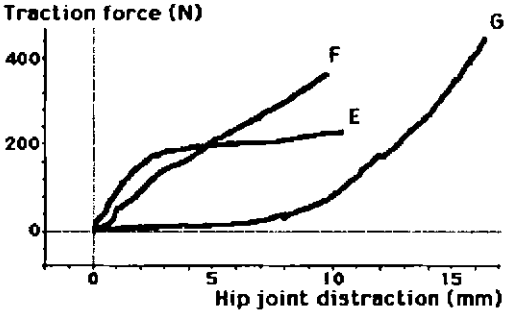

Figure 2. The traction force needed to dislocate the joint. E = joint capsule intact, hip in medium flexion. F = joint capsule opened via small longitudinal incision to neutralize atmospheric pressure, hip in full extension. G = joint capsule opened, hip in medium flexion.

There was an excellent correlation between the theoretical calculations and the experimental data.

Conclusions: 1) In the normal joint, there is no increase in intracapsular pressure within the normal range of rotation ("flexion") around the axis of the neck of the femur. 2) Intracapsular fluid (e.g., blood, pus, synovial edema and/or free

synovial fluid) decreases the pressureless range of motion, a cause of pain and subsequently flexion contracture. 3) Within the normal range of rotation, stability is primarily maintained by atmospheric pressure. The joint capsule is tightened only in extreme flexion or extension and contributes to stability only in these positions. 4) The traction force needed to dislocate the adult joint is approximately 200 N, in a child less, proportional to the square of the diameter of the femoral head. 5) Intracapsular fluid makes the joint potentially unstable, a prerequisite for unfavorable mechanical cartilage load. 6) Arthrography or arthroscopy should be performed with the hip in flexion to obtain optimal, easy, and harmless distraction of the joint by fluid infusion.

The prediction of amputation wound healing: The role of transcutaneous oxygen tension assessment

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Introduction: Selection of amputation level is traditionally based on clinical criteria and measurements of the skin perfusion pressure (SPP) and the segmental blood pressure (SBP). The use of transcutaneous oxygen tension measurements ($TcPO_2$) is a valuable supplement in predicting the chances for wound healing following below-knee (BK) amputation. The aim of the present study was to correlate the $TcPO_2$ with SPP, the SBP, and the clinical outcome in patients with foot ulcers.

Patients and methods: Twenty-two patients with ulcers were evaluated with $TcPO_2$, SPP, and SBP measurements. Based on SPP and clinical observations, 13 patients (average age 71 [44–88] years) were selected for conservative treatment. Primary amputation was performed in 9 patients (average age 69 [60–86] years).

Results and discussion: Primary healing was observed in 3 patients in the conservatively treated group, and 10 of these had an amputation – 9 BK and 1 through-knee. The average time for conservative treatment was 4 (1–24) months. In the primarily amputated group, there were 5 BK amputations, 2 had a toe amputation, and 1 had a Syme's amputation. There was no correlation between SPP measured BK and $TcPO_2$ measured at the ankle, or between $TcPO_2$ and SBP measured at the ankle and at the base of the first toe. The average SPP in conservatively treated patients was 69 (50–100) mmHg and in the primarily amputated group (50–90) mmHg. There was no difference in the average ankle $TcPO_2$ in the two groups. Five patients with primary healing of their ulcers or amputation wound on the foot had an average $TcPO_2$ on 26 mmHg. As expected from the high levels of SPP, all the BK amputations healed without complications.

Conclusions: SPP values above 50 mmHg gave primary healing in all BK amputations, but were of no value for evaluating the chances for healing of ulcers on the foot. Below-knee amputation was required in three fourths of the patients with $TcPO_2 < 30$ mmHg measured at the ankle. No correlation between SPP, SBP, and $TcPO_2$ could be demonstrated.

Rheumatoid arthritis: Cellular localization of gold following chrysotherapy

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Introduction: Many patients suffering from rheumatoid arthritis (RA) have successfully been treated with gold. In order to visualize gold deposits within the synovial membrane from patients previously exposed to gold, tissue specimens were processed according to a histochemical technique, autometallography, based on physical development (1).

Materials and methods: Twenty-six patients were included. Synovial biopsies were fixed in 96% alcohol, embedded in paraffin, sliced (3 µm), and placed on glass slides prior to drying. Sections were then placed under UV light for a minimum of 1 hour before they were exposed to physical development at 26 °C in a dark box for 1 hour. Counterstaining was performed using hematoxylin and eosin. Light microscopic analysis was performed.

Results and discussion: The finding of gold deposits within the cytoplasm of *macrophages* and *synoviocytes* is consistent with previous studies (2, 3), but gold staining of synovial *fibroblasts* has not previously been reported. No gold deposits were seen in *lymphocytes* or *plasma cells*.

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The clinical use of plastic plates for osteosynthesis in human fractures

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Introduction: After a fractured bone has passed the phase of union, the remodeling of the bone begins, the periosteal and endosteal callus being resorbed according to Wolff's law. In this later stage the stress-protecting effect of rigid metal plates has an adverse effect on cortical bone and gives rise to osteopenia with reduced strength of the plated bone. From many experiments, it is clear that the most important single factor that determines the degree of stress protection is the stiffness of the plate relative to that of the bone.

Patients and methods: We have used semirigid plates made of polyethersulfone reinforced with carbon fibers for internal fixation of bone-shaft fractures in men. Two humeral, 10 forearm, and five lower leg fractures were fixed with 21 carbon fiber-reinforced polysulfone (CFRPS) plates using stainless steel screws. The indication for osteosynthesis was malposition of the fracture after failed manipulative reduction. The mean time for bony union was 12 weeks; the mean time for plate removal was 8 months.

Results: There were no infections. All the fractures showed bony union between 6 and 18 weeks after operation (mean 12 weeks). Full consolidation was seen between 12 and 36 weeks. Plate removal was carried out at a mean of 8 months postoperatively. Microscopically, all the capsules surrounding the plates showed a normal aspect. Except for some mild foreign-body reaction around some particles of carbon fiber, no adverse reactions were seen. Upon retesting the plate, no alteration of mechanical data of the plates could be detected.

Conclusion: The results of this study support the concept that semirigid fixation for diaphyseal fractures is not only desirable theoretically, but also works in practice.

The predictive value of fracture, disease, and radiographic examination for fragility fractures in women and men

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Introduction: The aim of this study was to examine the predictive value of previous fracture, disease, and fall incidents with regard to future fragility fractures.

Subjects and methods: In all, 1,076 women and 654 men were included from 1972 through 1976. All of them were interviewed with regard to previous fracture and disease; all the radiographs from 1975 through 1985 were recorded.

Results: Totally, 258 women and 61 men had one or more fragility fractures. In *women* aged 50–69 years, there had been significantly more previous fractures of vertebrae and of the hip (trochanteric) in patients who later sustained a fragility fracture. Fragility fracture patients above 70 years of age were more frequently examined because of falling accidents compared with the nonfracture group. In the fracture group before the age of 70, a history of rheumatoid arthritis was more frequently seen; after that age, cerebral disorder was more common. Patients with trochanteric hip fracture and vertebral fracture in the age group 50–69 years had a greater risk of further fractures, but not after aged 70 years. In men the fragility fractures could be predicted by earlier gastric resection, cerebral infarction, or previous fractures of vertebrae or the hip. The fracture patients had more radiographic examinations due to trauma.

Conclusion: In both women and men before the age of 70, fracture of a vertebra or a hip seems to be a predictor of future fragility fractures. The difference in number of trauma-induced examinations also indicated that after the age of 70 years, trauma prevention may be the most important intervention factor.

The predictive value of forearm bone mineral content measurements in women and men

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Introduction: Most studies of bone mineral content are cross-sectional. We have followed men and women for 11 years and examined the predictive value of forearm BMC measurements.

Subjects: Totally, 1,076 women and 654 men in Malmö had their forearm bone mineral content measured with single-photon absorptiometry from 1970 through 1976. Also, the weight, the force of the hand, and the fertile period in women were recorded. All the fractures that occurred after the BMC measurement from 1975 through 1985 (11 years) were recorded. Fractures of the vertebrae, the proximal end of the femur, the proximal end of the humerus, the distal end of the forearm, the rami of the pelvis, and tibial condyle compression fractures were classified as fragility fractures. The risk ratio was calculated, and stepwise logistic regression analysis was applied. We also estimated the difference in BMC measurement between fracture and nonfracture patients for various types of fractures that occurred.

Results: Totally, 555 fractures occurred in 309 women and 165 fractures in 111 men. In all, 169 women had one fragility fracture, 89 had two or more, and in men the numbers were respectively 46 and 15. The BMC was significantly lower in women and in men before the age of 70 who later on suffered a fragility fracture. After aged 70, bone mass was not a predictor. When calculating the risk ratio per 1,000 women/men years in the various decentiles/quintiles of BMC, the same observation was found, i.e., hardly any difference in risk ratio comparing the lowest BMC with the highest in patients above 70. With stepwise logistic regression, only two variables remained independent: in women, age and BMC; and in men, BMC and hand force. Fracture of the distal end of the forearm had the least BMC deviation from the nonfracture group; again after aged 70, deviation was observed only for fracture of the vertebrae. The body weight at the time of BMC measurement was significantly lower in women with a fragility fracture after the age of 80; and for men in general, except in the age group 70–80 years. Hand force differed in women in the 6th and 8th decades and in men in the 4th and 6th decades. The fertile period was significantly shorter in women in the fracture group.

Conclusion: Bone mineral measurement of the distal end of the forearm has a predictive value before the age of 70 years with regard to the risk of future fractures in men and women. Later in life, possibly the tendency to fall becomes more important.

On the stabilization of the human hip joint I: A kinematic study

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Introduction: The stabilization of the hip joint has been studied in the frontal plane. The importance of the abductor muscles is clear. The hip joint is a spherical joint, with 3 degrees of freedom of movement. In a kinematic definition, stabilization means reduction of the freedom of movement. Spruit (1965) used this principle in a kinematic study. He emphasized the importance of the fan shape of the gluteus medius muscle. The aim of this investigation was to study the role of the adductor muscles for the stabilization of the hip joint, using the principle of reduction of freedom of movement.

Materials and methods: A displacement model was used. Coordinates from the abductor and adductor muscles were measured on a human cadaver. The freedom of movement is reduced to 1°under the condition of isometric length of two muscle bundles. The length changes of several adductor muscles were calculated in the femur track, under the condition of isometric length of the ventral and dorsal bundles of the gluteus medius muscle. The length changes in the gluteus medius muscle were calculated in two tracks, under the condition of two isometric muscle fans in the adductor muscles.

Results and conclusions: According to the length changes, the hip joint can be stabilized in an area around the zero position by the combined contraction of the lateral and a medial muscle fan. On the basis of the anatomic geometry, the adductor muscles are, together with the abductor muscles, important stabilizers of the hip joint. Whether these muscles actually are used as stabilizers needs further study.

On the stabilization of the human hip joint II: An electromyographic study

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Introduction: In a previous study the question arose whether the adductor muscles actually are used as stabilizers of the hip joint. Electromyography is a method to record time-related muscle activity. Simultaneous activity of abductor and adductor muscles is, according to our kinematic study, interpreted as stabilizing activity.

Material and methods: Surface electrodes were used to record the activity of the adductor and abductor muscles of 10 healthy subjects during normal level walking. The heel strike and toe off, recorded electrically, were used as kinematic parameters. Fifty walking cycles were analyzed.

Results and conclusions: Simultaneous activity of abductor and adductor muscles occurred at the heel strike in most subjects. This means that during heel strike the adductor muscles, in addition to the abductor muscles, are used as stabilizers of the hip joint. A consequence is that by calculating the forces in the hip joint during normal level walking, forces generated in the adductor muscles must be taken into consideration.

The value of radiographs in determining the degree of fracture healing

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Introduction: Although it is known that radiographs cannot give absolute certainty about the degree of consolidation of a fracture, in most cases, considerable value is attached to radiographs in determining the time when a fracture can be treated without external support. Animal experiments were performed in an effort to establish which value should be attached to a radiograph in estimating fracture consolidation.

Materials and methods: Thirty-six 6-month-old male rabbits were submitted to an osteotomy halfway up the radius, performed with the aid of a rotary saw. The animals were killed 4, 6, and 8 weeks after the osteotomy. The forelegs were dissected out, and the radius was separated from the ulna. Radiographs of the radius were made in two directions with a mammographic unit. The bone fragments to be used in determining tensile strength (TS) were stored at –45 °C. The breaking force (BF) of the radii was determined using the Instron device. In addition to the BF, the TS of the radii was determined. In all the cases, both radiographs of the osteotomy were examined. The radiograph on which healing seemed least good was used as a criterion of healing. This was done by five different independent evaluators, who arranged the radiographs after a given duration of treatment in diminishing order of healing; the evaluators were unaware of the results of TS measurements. Per rabbit, the scores recorded by all the evaluators for the right and for the left radius were summed. This total score was compared with the sum of the TS of both radii. The data were summed per rabbit in order to obtain random pairs of results. Spearman's two-tailed rank correlation test was performed to establish whether the results were independent.

Results and discussion: Of 36 rabbits, 2 died and 3 developed an infection. The BF and TS obtained in the remaining 31 rabbits are listed in Table 1. Both increased in the course of fracture healing. The correlation between radiographic interpretation and corresponding TS with *P*-value is shown in Table 2. This table shows that a positive correlation between the two groups of data is found only after 4 weeks, but even this is insufficiently close to attach predictive values to radiographic assessment.

In my opinion it is quite possible to deduce from a sequence of radiographs of a fracture whether fracture healing and cal-

Table 1. Mean values of BF (in kg) and TS (in kg)/cm^2) after 4, 6 and 8 weeks (coefficient of variation is 20–50%)

Weeks	4	6	8
Number	11	9	11
BF	17.8	31.2	42.8
TS	86	148	205

Table 2. Results of a correlation study according to Spearman concering TS and interpretations of radiographs

Weeks	Number	Correlation coefficient	P-value
4	11	0.62	0.05
6	9	0.35	> 0.10
8	11	0.29	> 0.10

lus development take place in the normal way. It is impossible, however, to assess the degree of fracture consolidation from one radiograph. One radiograph gives a false impression of the degree of consolidation and the continuity of the shaft at the fracture site. Morphologic changes in fracture callus can be radiographically demonstrated, but this does not apply to the degree of consolidation (if defined as strength of the fracture callus).

Comparison of noninfusion and microcapillary infusion technique for pressure recording

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Introduction: The purpose of this study was to compare two techniques for measuring intramuscular pressures at rest and during exercise.

Subjects and Methods: Pressure in the anterior tibial muscle was monitored in asymptomatic legs of 3 women and 11 men, with a mean age of 30 (17–56) years. A dual-pressure recording system was employed for all comparisons. The subjects were allowed to exercise with submaximal constant exercise during 10 minutes. Slit (noninfusion technique) and Myopress (microcapillary infusion technique) catheters were introduced parallel to each other and 10 to 15 mm apart at the same depth into the muscle.

Results: Pressures at rest were not significantly different between the methods. Muscle relaxation pressure recorded with the slit catheter was significantly higher at the start and after 10 minutes of exercise. Signs of decreased dynamic properties of the noninfusion method were 1) muscle relaxation pressure that depended on contraction frequency and 2) different values between the recorded muscle relaxation pressure during exercise and intramuscular pressure at rest after exercise. The dynamic properties of the Slit catheter were improved when a microcapillary infusion was employed. Two of the slit catheters and none of the Myopress catheters occluded.

Discussion: Diagnosis of chronic compartment syndromes may be difficult using a technique that has low dynamic properties, giving erroneously high recordings of muscle relaxation pressure. Although both techniques are suitable for measuring pressure at rest, the microcapillary infusion technique is better for recording pressure during exercise.

Anabolic steroid nandrolone decanoate therapy in postmenopausal osteoporotic women

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Introduction: Postmenopausal osteoporosis and the subsequent development of fractures are a major health hazard in elderly women. Nandrolone decanoate (ND), an anabolic steroid, has been suggested to restore forearm mineral density in osteoporotic women (1), and we examined, in a double-blind controlled study, the effect on ND (Deca-Durabolin®) on bone mass and bone metabolism.

Subjects and methods: Thirty-nine postmenopausal women (aged 55–75 years) with at least one osteoporotic fracture (Colles' or vertebral) were allocated to 1 years' treatment with ND, 50 mg i.m. every 3 weeks or placebo injections. In addition, all the subjects received a daily supplementation of 500 mg calcium. Thirty-six women completed the study. Bone mineral content (BMC) was measured at two forearm sites with single photon absorptiometry: BMC1, uncorrected for fat, and BMC2, corrected for fat. Bone mineral density of the spine (BMD) was measured by dual photon absorptiometry. Bone turnover measurements were whole body retention (WBR) of ^{99m}Tc-diphosphonate (2), plasma bone Gla protein, serum alkaline phosphatase, and serum phosphate. All the variables were measured every 3 months (five examinations) except WBR, which was measured initially and at 1 year.

Results: Bone mass. BMC1 increased 7 percent ($P < 0.001$) in the ND group and was unchanged in the placebo group. When BMC1 was corrected for fat (BMC2), the difference between the active group and the placebo group was 3 percent ($P < 0.01$). There were no significant differences in the change of BMD between the two groups, although there was a tendency towards a gain in the ND group.

Bone metabolism. WBR and the biochemical estimates of bone turnover were not significantly changed by the ND therapy.

Conclusion: We conclude that treatment with nandrolone

decanoate does increase the bone mineral content. This is not due to a direct increase in bone formation. The mechanism may theoretically be a combination of decreased bone resorption and increased muscle mass.

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Microbubble formation and caisson disease patterns

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Introduction: Patterns of caisson disease osteonecrosis differ between tunnellers and divers (1).

Method: (A) Intraosseous needles were placed in the lower tibia and connected to pressure transducers and a chart recorder. *B)* Whole blood in a closed chamber was scanned ultrasonically to detect microbubbles while the pressure was altered.

Results: (A) Tibial IOP was pulsatile (mean 11 mmHg) while supine. An arterial tourniquet or elevating the foot lowered IOP. A venous tourniquet, lowering the foot, and weight bearing raised IOP. During brisk walking, IOP fluctuated from −30 mmHg to +115 mmHg. *(B)* Lowering the pressure on whole blood produced showers of microbubbles. The bubbles persisted at low pressures, but slowly cleared when the pressure was raised.

Conclusions: (A) IOP fluctuates and bears a simple hydrodynamic relationship to perfusion, drainage, and physical load. Bone is not rigid, but behaves in vivo as a slightly flexible perfused sponge within a relatively constrained cortical membrane. *(B)* Negative pressure applied to blood encourages the formation of persistent microbubbles. Decompression microbubbles are selectively trapped in the cancellous bone. Walking causes a fluctuating IOP: during the brief negative pressure phase, further microbubble formation occurs within osseous blood. This accounts for the different patterns of osteonecrosis seen years later: the "weightless" diver experiences a generalized pattern of caisson disease, and the weight-bearing tunneller has 12 times the incidence of necrosis of the femoral head.

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Personal computers in orthopedics

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Only a few years ago, the personal computer was mainly useful for the orthopedic surgeon as a word processor, whereas research data processing and statistical analysis required professional assistance. Recent developments in hardware costs and capacity, such as expanded memory and graphical presentation, as well as in user-friendly software, has brought us to a point where advanced computer technology has been made available for the nonprofessional user. The following applications are presently in use at our department: (1) Word processing, (2) Research data bases: storing, searching, and sorting data. (3) Statistical analysis and graphical presentation of research data. (4) On-line communication with medical references data bases: Medline, Biosis, Cancer, Orthobase. (5) Medical illustrations: CAD, picture scanning. (6) Desk top publishing: books, theses, manuals. (7) Production of *Acta Orthopaedica Scandinavica:* text editing, checking references, keeping track of manuscripts. (8) Administration of and communication in national multicenter research projects: The Swedish Multicenter Knee Project and The Swedish Multicenter Hip Project. (9) Stock inventory of medical equipment and implants. (10) Patient waiting lists with on-line statistics and graphical presentation.

Future aspects: (1) Comprehensive desk top production of *Acta Orthopaedica Scandinavica.* (2) Picture analysis and stereophotogrammetry. (3) Computer communication.