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Treatment of subchondral lesions with recombinant human osteogenetic protein 1 (rhOP-1)

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In-vitro studies have shown that recombinant human osteogenetic protein-1 (rhOP-1) or BMP 7 stimulates the differentiation of chondrocytes from progenitors. This is probably the cellular mechanism of the induction of cartilage formation by rhOP-1 in vivo. Therefore we investigated cartilage formation in subchondral lesions treated with rhOP-1 and/or autologous perichondrium.

Material and methods: In the medial femoral condyle of the left knee joint of 15 goats a subchondral lesion of 9 mm diameter was made. The defect was filled with fresh coagulated blood mixed with a) small particles of autologous ear perichondrium, b) rhOP-1 or c) rhOP-1 plus ear perichondrium. RhOP-1 was added either in combination with collagen (OP-1 Device) or without collagen (OP-1 Peptide). The defect was closed with a periosteal flap which was stitched to the cartilage. After implantation times of 1, 2 and 4 months, the material was investigated with histological techniques (metachromasia and hyalinity) and biochemical methods (gel chromatography of proteoglycans).

Results: After 1 and 2 months, there were no obvious differences between control and OP-1 treated defects. However, after 4 months only one out of three control (perichondrium only) defects showed cartilage formation, while all four OP-1 treated defects were completely or partly filled with cartilage, as shown by histological and biochemical analysis.

Conclusion: These results indicate that OP-1 has a cartilage-promoting capacity in large subchondral defects in goats. This suggests that OP-1 may be of clinical relevance in treating large lesions of articular cartilage.

Table. Cartilage score of 5 condylar defects, treated for 4 months without OP-1 (perichondrium only) or with OP-1 with or without perichondrium

Implant	Defect[1]	A[2]	B[3]	Cartilage score[4]	
Perichon. only	86	0.7	0.0	0.60	1.58
	14	3.0	4.0	0.98	
OP-1 device	62	2.0	4.0	3.72	7.25
	38	3.3	6.0	3.53	
OP-1 device	79	2.0	5.0	5.53	7.99
+ perichon.	21	5.7	6.0	2.46	
OP-1 peptide	79	1.2	2.0	2.53	4.23
	21	2.1	6.0	1.70	
OP-1 peptide	78	1.0	2.0	2.34	4.36
+ perichon.	22	4.2	5.0	2.02	

[1] The defect was divided into homogeneous parts; the percentages are indicated.
[2] Biochemical score was assigned a value from 0 to 5 based on gel chromatography.
[3] Histology is based on undecalcified plastic sections on a grading scale of 0 to 6.
[4] Calculated as follows: % x (A+B), e.g. 0.86x(0.7+0.0) = 0.60.

Polyactive to prevent peridural adhesions after spinal surgery—a comparative histomorphometric study

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Following a laminectomy, a 'laminectomy membrane' may develop which may cause low back pain or pseudoradicular pain. The question was studied whether use of Polyactive (PA) as a mechanical barrier may prevent scar formation after spinal surgery, as compared with a free fatty transplant and a control.

Material and methods: Use was made of sheets of Polyactive 60/40 (polyethylene glycol/polybutylene terephtalate, HC Implants, Leiden). 12 beagles were subjected to 3 laminectomies per dog (L2, L4, L6). The dura was covered either with Polyactive or with a free fatty graft, while the third defect served for control purposes. The animals were killed after 4, 12 and 26 weeks and histological sections were made

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of the separate levels. The sections were assessed by optic microscopy and subsequently examined histomorphometrically (IBAS) to determine the amounts of peridural connective tissue and of bone tissue in the defect. Analysis of variance according to Student-Newman-Keuls was carried out ($p<0.005$).

Results: The laminectomies treated with PA displayed a little connective tissue between the sheet and the dura. Dorsally, there was dense connective tissue not continuous with the dura. Histomorphometrical examination revealed significant differences in the amounts of connective tissue: the control group always had more connective tissue than the fatty graft group. After 4 and 12 weeks, there was less connective tissue in the PA than in the control group. After 4 and 26 weeks, there was more connective tissue in the PA group than in the fatty graft group, and more than in the control group after 26 weeks. After 4 weeks, the amount of new bone was smallest in the fatty graft group.

Discussion: Application of Polyactive prevents continuity of connective tissue between the dura mater and the dorsal muscles. Apparently, as the PA disappears, so does this barrier action. In the study reported, it was demonstrated that use of a fatty graft is superior to PA and controls where formation of active tissue is concerned.

An animal experimental model for cryosurgery of bone tumours—peroperative temperature recording and extension of the necrosis

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Cryosurgery is being used in clinical studies as an adjuvant treatment after curettage of benign bone tumours. It increases the surgical margin and reduces the proportion of recurrences. The purpose of the present experiment was to gain insight into the degree of necrosis as related to the temperature at various distances from the cryoprobe.

Method: In the tibias of two goats and four rabbits, a closed cryoprobe was positioned in a mid-diaphyseal drill hole. In the course of three identical cycles of freezing and spontaneous rewarming, the temperatures at different distances were recorded continuously. The animals were sacrificed one week after the operation. The extent of necrosis was determined histologically and related to the peroperative temperatures.

Results: In each separate test animal, the three successive freezing sessions displayed an identical pattern of rapid fall of the temperature and slow rewarming. The temperature showed an exponential fall in the direction of the cryoprobe. Histological examination after one week showed necrosis of cortex and bone marrow, extending in a circular front until the -10° isotherm. Apart from hemorrhage, there was intravascular stasis in the bone marrow. In the rabbits, after one week at the level of the -10° isotherm there was a periosteal reaction with formation of woven bone. Periosteum situated on the necrotic bone was not reactive.

Conclusion: These experiments show that a reproducible freezing injury can be obtained using a closed cryoprobe. Temperatures below -10° C during three freezing cycles induce necrosis of cortex and bone marrow. This cryosurgical model will be used as a basis for further research into the effect of cryosurgery on bone strength.

Incorporation of morselled bone graft under conditions of controlled load bearing

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For a long time now we have successfully been using in our clinic the impacted morselled bone grafting technique, for reconstruction of deficient bone mass round failed hip prostheses. During a simulation animal experiment in which this reconstruction technique was examined with regard to the femur, indications were found that the incorporation behaviour of this type of bone graft is dependent on load bearing (Schreurs et al., Biomaterials 1996). The purpose of the present study was to investigate the role of load bearing in the incorporation process of the impacted morselled bone graft under controlled experimental conditions and to find out if there exist 'stimulatory' degrees of load bearing.

Materials and methods: An animal model was developed for this purpose with use of a new implant, the 'Subcutaneous Pressure Implant (SPI)'. This implant consists of a hollow titanium screw opening out in a cylindrical pressure chamber. A stainless steel piston fits exactly in this screw. The implant is sealed off by a stainless steel screw cap with a coupling for a subcutaneous tube. A defect is drilled in the lateral epicondyle of the distal femur of the goat (depth 3 cm, diameter 6.4 mm) with the aid of a water-colled diamond drill. One centimeter of the defect is filled with impacted bone graft (0.8–1.0 g) following which the SPI is screwed in. A pressure-resistant polyurethane tube is tunneled from the neck region to the SPI and connected. 20 operated goats were subdivided into three groups: with 2 MPa or 4 MPa load bearing, 1 Hz, 1 hour/day and without load bearing (controls). Two goats from each group were killed after 3, 6 and 12 weeks. Specimens were evaluated using quantitative CT and without decalcification processed for histological and histomorphometric analysis (GV = graft volume [%], GR = rest graft [%], MS = mineralizing surface, MAR = mineral apposition rate µm/day). The data were evaluated statistically using two-way analysis of variance.

Results: Three goats dropped out because of complications. The quantitative results are shown in Table 1. Revascularization started after 3 weeks from the edges of the graft, irrespective of the load bearing. Together with the revascularization, a front of resorption developed, following which apposition of bone occurs on the graft remnants. This pro-

cess appeared to be advanced further in the specimens with 2 MPa load bearing after 6 weeks. In the 12-week specimens, the graft after load bearing was transformed into a vital trabecular structure with a higher density in the specimens with 4 MPa load bearing. In the non-load-bearing situation, only a few thin trabeculae were yet visible in the area of the graft. This observation is reflected in the QCT and graft volume results. The percentage of residual graft decreased steadily until 12 weeks. The rate of osteogenesis was similar in the nonload bearing and in the load-bearing specimens.

Table 1

Fu wk	F MPa	QCT mg/cm	GV (%)	G% (%)	MS mm	MAR µm/d
3	0	678	56.5	100	0.43	3.0
3	2	630	53.5	100	0.34	3.4
3	4	607	52.3	100	0.40	3.5
6	0	637	53.5	47.3	0.35	2.4
6	2	545	43.1	57.2[a]	0.34	2.5
6	4	530	49.3	50.6	0.52[a]	3.0
12	0	393	17.8	17.8[a]	0.35	2.3
12	2	343	28.4	4.7	0.32	2.1
12	4	554	43.9	4.7	0.30	2.8

[a] $p < 0.04$

Conclusion: 1) This animal model is suitable for the study of graft incorporation under specific mechanical conditions because of the standard amount of chip graft, the low-traumatic operation technique and the controllable load bearing.

2) Exposure to high load bearing appears to have an adverse effect on the initial vascularization of bone graft, but load bearing does not appear to play a major part in starting up the initial repair reaction.

3) Load bearing is necessary for the ultimate formation of a vital trabecular structure.

Determination of physiological loads for trabecular bone tissue in a femoral head using high-resolution finite element models

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Trabecular bone fractures are initiated by the mechanical load at the level of the trabeculae. Consequently, determination of the physiological trabecular load bearing is essential for better understanding and better prediction of bone fractures in osteoporosis or after bone remodelling, Recently, new techniques were introduced which make it possible to calculate the mechanical load on individual trabeculae, using computer models on the basis of high-resolution finite element models. So far, however, this was only done using experimental fragments loaded in non-physiological ways.

The objective of this study was to determine the physiological load bearing in trabecular bone tissue of the femoral head. To this purpose, a finite element model was developed that can represent the trabecular architecture of a complete proximal femur, so that realistic weight-bearing situations are possible.

Methods: A dog femur was scanned in a micro-CT scanner and reconstructed in a three-dimensional computer model consisting of voxels (3-D pixels) of 70 micrometres. Then, all voxels representing bone tissue were converted to elements in a finite element model resulting in a model with 7.6 million elements. For the material qualities of these elements, an elasticity module of 15 MPa and a transverse contraction coefficient of 0.3 were chosen. Three weight-bearing situations from the walking cycle, including the weight bearing during the stance phase of walking were chosen for the external weight bearing. After solution of the finite elements problem, a volume measuring 100x100x100 voxels from the centre of the head was analysed in greater detail. For all elements in this volume the maximal main tensions and stretches, the Von Mises tension and the elastic energy density were calculated and compared with the mean values that can be calculated using continuum models.

Results: The highest trabecular load bearing was found to occur during the stance phase. However, compared with the other load-bearing situations, the maximal values at this load bearing were relatively small. It was found in all load-bearing situations that the trabecular load bearing may exceed the mean value to a considerable extent. However, for 97% of the bone tissue the local load bearing was less than four times the mean value.

Discussion: This study has demonstrated that it is now possible to create and to solve finite element models the size of a proximal dog femur, which models are so detailed that the load bearing in each individual trabecula can be calculated. The results of this study also show that for physiological load-bearing situations , the maximal trabecular load bearing can greatly exceed the mean value, although peak values are found for only a very small proportion of the bone tissue, and these peak values are lower than values measured for the fatigue strength of trabecular bone tissue.

We conclude that using these models, it is possible to obtain the information about local bone load bearing that is necessary for a better understanding of failure processes in trabecular bone.

High liquid pressure causes bone resorption in an animal model of aseptic loosening

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Failure of cemented total hip prostheses begins with loosening of the prosthesis from the cement mantle. The effective

articular space is then defined as the (pseudo)articular space itself and all communicating spaces round the prosthesis. According to current views, transport of attrition particles, among others from the articulation, might take place via this space along the prosthesis, allowing these particles to reach the bone via (small) defects in the cement mantle. Macrophages, activated by phagocytosis of these particles, would then be responsible for the subsequent bone resorption. However, at histological examination attrition particles could not always be observed in the lytic foci round hip prostheses. It has been demonstrated that a high pressure, of several hundred millimetres Hg, may be present in the articulation of total hip prostheses. Also, a pressure risen to 200 mm Hg could be established in a lytic focus along a cemented femur stem, which pressure fluctuated during passive movements of the artificial joint. Conceivably, such high pressure may exist in the articulation as well as in the entire effective articular space, so that, at the sites of defects/microfractures in the cement, impairment of perfusion and oxygenation might lead to bone necrosis and bone resorption. In order to test the hypothesis that such a pressure may lead to bone resorption, a new experimental animal model was developed.

Material and method: In 12 adult rabbits, a titanium implant was positioned partially on and partially in the proximal metaphysis of the tibia. On the underside of this implant there was an opening toward the cortical bone, which at first could be closed off. The positioning was followed by 5 weeks' rest, during which osteointegration could result in a watertight barrier between the implant and the cortical bone. The implant was subsequently equipped with a top piece which permitted transmission of a fluid pressure via the above-mentioned opening to the bone. This top piece was connected with a system of silicon tube and expander placed subcutaneously. In six rabbits, this system was filled via an external mouth with physiological saline solution, at a pressure that could be raised to 150 mmHg. Twice daily for 2 weeks the pressure was checked through the mouth; if it had fallen, solution was added to restore the original pressure. No pressure was induced in the systems of six other rabbits which served as controls.

Results: Two animals throughout the experiment showed virtually no loss of pressure in the system. It was found that at the level of the opening in the implant a small cavity had developed with signs of cell death in the surrounding cortical bone. In the remaining four animals, loss of pressure occurred after a few days, attributable to occurrence of more extensive resorption of bone reaching the medullary canal. In these specimens, the microscopical image sometimes was greatly similar to the image seen in lytic foci round hip prostheses: large numbers of macrophages with intracellular particles. These particles strongly resembled bone debris. None of the six control animals showed resorption or loss of vitality of the bone underneath the implant.

Conclusion: Our results suggest the possibility that all signs of aseptic loosening attributed to macrophages activated by attrition particles may just as well be caused by a high liquid pressure existing in the effective articular cavity.

Periosteal regeneration of cartilage under the influence of dynamic fluid pressure

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Damaged cartilage has a limited capacity of recovery and, accordingly, leads to a considerable risk of osteoarthritis. There is currently no successful treatment of this problem in young and middle-aged patients with this condition. A 'biological' method for repair of articular surface is therefore needed. Periosteum contains undifferentiated stem cells with the potency of generating cartilage and bone. It may be used to repair articular surfaces affected by osteoarthritis. Regeneration of cartilage from periosteum takes place in three phases: proliferation, differentiation and matrix synthesis with organization. Every phase is regulated separately. Motion (CPM) causes significant changes in periosteal regeneration of cartilage in vivo. CPM leads to cyclic changes of intra-articular pressure. Articular distraction causes stimulation of articular cartilage through fluid pressure accompanied by signs of recovery. This prompted us to study the effect of dynamic fluid pressure on periosteal regeneration of cartilage in vivo.

Method and techniques: Periosteal explants from 72 rabbits (2 months old, New Zealand White) were cultured under dynamic fluid pressure (13_2 kPa, 0.3 Hz). The effect of DNA synthesis during the proliferation phase was determined by measuring the ^{3}H thymidine uptake on days 1, 3 and 5. The proteoglycan synthesis was measured with the aid of ^{35}S from day 6 to day 24. Histomorphometric examination of cartilage was performed after 2, 3, 4 and 6 weeks. Results were analysed with paired t-tests for each rabbit (n=16 per group).

Results: Thymidine uptake (Fig. 1) increased to 250% on days 1 and 3, to become normalized on day 5, indicating stimulation of DNA synthesis in the experimental group. The proteoglycan synthesis and matrix formation increased to levels similar to our standard model but an at accelerated rate (Fig. 2).

Discussion: Regeneration of cartilage from periosteum is a reliable and successful method to repair cartilaginous defects. This model makes possible reproducible studies of the effect of dynamic fluid pressure on periosteal regeneration of cartilage. The DNA synthesis increases significantly while proteoglycan synthesis is accelerated by this stimulus. These findings support published data that demonstrate that movement and variation of pressure stimulate regeneration of cartilage; the findings prompt further investigation of these effects and their mechanisms.

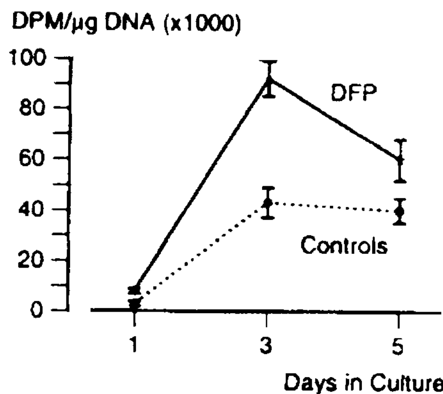

Figure 1. ^{3}H thymidine uptake. Dynamic fluid pressure (DFP) versus control

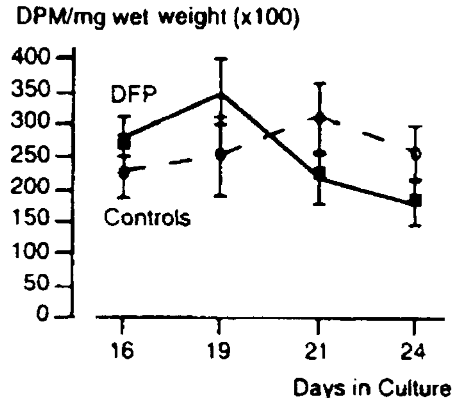

Figure 2. ^{35}S sulphate incorporation DFP versus control, acceleration due to pressure stimulation.

Osteogenic protein-1 (OP-1) induces formation of cartilage in human and goat perichondrium in vitro—histological and biochemical observations

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Our previous in-vitro study showed that recombinant human osteogenic protein-1 (rhOP-1 or BMP-7) stimulates chondrogenesis. This suggests that rhOP-1 might stimulate the regeneration of articular cartilage. For this reason we investigated whether rhOP-1 might stimulate formation of cartilage in perichondrium, since perichondrium is a potential source of cartilage.

Material and method: Ear perichondrium and blood were collected from three goats and from four women subjected to surgical correction of flap ear. The perichondrium was cut up into small pieces and mixed with 0–400 µg/ml rhOP-1 (Stryker Biotech, Natick, Mass. USA) and fresh autologous blood which coagulated immediately afterward. Coagulated blood was used to simulate the natural milieu of wound healing. The blood clots with the perichondrial tissue were cultured in vitro for 3 weeks, and the amount of cartilage formation was assessed biochemically and histologically.

Results: rhOP-1 induced formation of cartilage in human as well as in goat explants. Biochemically, the cultures treated with rhOP-1 showed twice as much production of glycosaminoglycans. Cartilage formation was stimulated maximally by 40–200 µg/ml rhOP-1. Histologically, a metachromatic cartilage matrix with cell nests could be observed only in explants with rhOP-1.

Conclusion: rhOP-1 in vitro stimulates the differentiation of chondrocytes from perichondrium. This might constitute the cellular mechanism of the induction of cartilage formation by rhOP-1 in vivo. Therefore, in orthopedic practice rhOP-1 might be an interesting option for the regeneration of cartilage in defects of articular cartilage.

Generation and visualization of annulus ruptures in the lumbar spine—a pilot study

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Epidemiological data show that people in occupations that expose them to prolonged vibration run more risk of developing low back pain. Our purpose was to relate vibration of the spine to disc herniation. Fresh human cadaver lumbar segments were exposed to prolonged vibration. This vibration serves to simulate vibrations to which people are exposed during certain activities such as truck driving.

Methods: We exposed three fresh human cadaver lumbar segments, aged 25–55 years, to small sagittal flexion/extension movements with a frequency of 6.75 Hz during 235 to 600 minutes. Axial load was set at 200 N. A continuous power-to-time diagram was made of each test series to monitor energy absorption of the disc. MRI was used to compare disc status before and after testing. Finally, tested discs were sectioned to demonstrate annulus ruptures after prolonged vibration.

Results: The fissures were located dorsolaterally and all annulus layers, except the peripheral layer, were ruptured from the inside out. Nucleus material migrated into the annular defect. The annular defect shown by MRI was confirmed by cross-section of the disc in all cases.

Conclusion: We demonstrated that small flexion/extension movements with application of only 200 N axial load can produce annulus ruptures. The progression of this process can be followed with MRI. The outcome of this study suggests that vibration can cause annulus damage prior to disc herniation.

Effects of TGFß2, bFGF and L-ascorbic acid on the in-vitro multiplication of chondrocytes for transplantation purposes

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Use of isolated chondrocytes to reconstruct articular cartilage defects has shown promising results. Autografts are preferable to allografts. Because the amount of articular cartilage in a patient is limited, chondrocytes are to be isolated and multiplied in monolayer culture in vitro. To optimize the multiplication of chondrocytes in vitro, we studied the effects of TGFß-2, bFGF and L-ascorbid acid on the proliferation of chondrocytes in monolayer culture.

During monolayer culture, chondrocytes dedifferentiate and lose their ability to produce hyaline cartilage-specific type II collagen. We studied the potential of chondrocytes to produce hyaline cartilage matrix after different passages in monolayer and we investigated whether this potential was influenced by the addition of TGFß-2, bFGF and L-ascorbic acid.

Methods: Bovine articular chondrocytes were exposed to TGFß-2 (1 ng/ml), bFGF (1 ng/ml) or L-ascorbic acid (25 µg/ml) in addition to 10% FCS, during primary culture, or during the third or tenth passage in monolayer. We designed a scheme for optimal addition of growth factors, based on our earlier experiments. Cells were multiplied during four passages. TGFß-2 was added in the first two passages and L-ascorbic acid in the next two. After each passage, the cells were counted.

To study the potential of chondrocytes to produce hyaline cartilage matrix, the cells, after multiplication in monolayer, were cultured in alginate beads. After 7, 14, 21 and 28 days, immunohistochemical staining for pro-collagen type I (M38) and collagen type II (II-II6B3) was performed on cytospins.

Results: Cells reached the subconfluent phase in approximately eight days, corresponding with a cell multiplication of approximately twice. TGFß-2 significantly increased the proliferation rate of primary chondrocytes but had no effect in the third and tenth passages. bFGF had no effect on proliferation during any of the passages tested. L-ascorbic acid had an inhibitory effect on the proliferation of primary chondrocytes but became a growth stimulator in the third passage.

In control cultures, after four passages a 15.5 times increase in cell number was obtained. Using an optimal addition scheme, the number of chondrocytes increased 99.3 times.

Immunohistochemical analysis showed that freshly isolated chondrocytes, if cultured in alginate, developed a pericellular matrix consisting mainly of collagen type II. Chondrocytes suspended in alginate after one passage in monolayer presented collagen type I as often as collagen type II. After three passages, the chondrocytes produced only collagen type I. No differences in collagen expression with time were found in alginate and no influence of addition of growth factors during monolayer culture was seen.

Conclusions: This study showed that TGFß-2 and ascorbic acid can both stimulate chondrocyte multiplication. The effects of both factors depend on their time in monolayer culture; TGFß-2 stimulated fresh chondrocytes while ascorbid acid stimulated dedifferentiated chondrocytes but inhibited freshly isolated ones. This has important implications for the choice of growth factors when proliferation of chondrocytes needs to be stimulated. By choosing an optimal scheme, we obtained an approximately 100-fold increase in four weeks of the amount of cells originally harvested. Chondrocytes lost their ability to produce collagen type II after three passages; TGFß-2, bFGF or ascorbic acid could not prevent this. In spite of what Bonaventura et al. reported, a culture period in alginate may not be optimal to regain the phenotype of chondrocytes multiplied in monolayer. The potential of our chondrocytes to produce cartilage in vivo needs further investigation.

Spinal operation on an outpatient basis—findings in 2000 cases

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The development of minimally invasive surgical techniques and of new techniques of anesthesia and new drugs now make it possible to perform dorsal operations on an outpatient basis. From July 1989 to December 1992, outpatient dorsal operations were performed in 2000 patients, which number has since grown to over 5000. The objective of the study was to evaluate complications and problems of the outpatient treatment in the first 2000 cases.

Material: Percutaneous nucleotomy in combination with chemonucleolysis or laser vaporization was carried out in 946 cases, microdiscectomy in 712 and laminectomy in 135 cases. There were 72 cases of cervical nucleotomy and 135 miscellaneous other dorsal operations.

Results: Over 90% of the patients and of the referring physicians were satisfied with the fact that the treatment had been carried out on an outpatient basis, in spite of the frequently long distance of the patients' homes. In eight cases, it was decided postoperatively to hospitalize the patient after all; no other specific problems related to the outpatient intervention were encountered. Complications occurred in 21 of the 2000 patients (1.05%). Five patients showed aggravation of the neurological symptoms, two, postoperative thrombosis, six superficial infections. There were no cases of diskitis. One patient developed a reversible anaphylactic reaction, one Quincke's oedema, and one a transient cauda equina syndrome. Virtually all complications were reversible.

Conclusions: A high degree of satisfaction of patients and referring physicians was achieved in various therapeutic groups, consisting mostly of hernias and stenoses with few complications, given an accurate preoperative diagnosis, an extensive postoperative protocol and specialization of the surgeon.

Long-term results of anterior interbody spondylodesis of the lumbar spine by means of the Lübeck implant

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One of the problems that occur after interbody spondylodesis by means of bone grafting is development of pseudarthrosis. Waisbrot in the early eighties designed an implant made of metal, to be used for anterior spondylodesis. This retrospective study shows the long-term results obtained in a group of patients in whom this spondylodesis was performed at that time.

Material: In the Twente Medical Centre 15 patients were subjected to spondylodesis using the Lübeck implant between February 1986 and September 1987. The group of patients consisted of 11 women and 4 men with a mean age of 45 (30–65) years. The level of the operation was L4/L5 in 6 and L5/S1 in 9 cases. 10 patients had previously been subjected to laminectomy at the spondylodesis level, and 3 patients not only at the same level but in addition at a different one. 5 patients had not previously undergone a dorsal operation. The indications for these spondylodeses were spondylolisthesis, radicular syndrome and narrowing of the disk. The follow-up period was 9.6 (8.7–10.3) years. At follow-up examination, standard AP and lateral radiographs were made, as well as in flexion and extension. These follow-up examinations were performed after 1, 4.5 and 9.6 years on average.

Results: Subjective results could be classified by the patients as good, reasonable or poor, using marks from 1 to 10. The classification was as follows: good 2 cases, reasonable 6 cases and poor 7 cases. After an average of 9.6 years, 5 patients gave the results marks of 7 or more and 9 patients marks of 6 or less. 5 patients in due course were able to resume their activities without pain. The other patients were given adjusted occupations or were declared completely unfit. As regards sports, 5 patients could continue their activities at their former level without any problems.

Radiographically, none of the patients after 9.6 years displayed signs of loosening, displacement or pseudoarthrosis.

Conclusion: It is difficult to draw conclusions from this heterogeneous group, but it may cautiously be stated that the results are similar to those of spondylodesis using spongy bone. The radiographs showed no signs of loosening, displacement or pseudarthrosis. However, these findings are not in agreement with the results as assessed subjectively by the patients.

Results of surgical treatment of grade I isthmic spondylolisthesis L5-S1 and mechanical low back pain after earlier discectomy by means of interbody spondylodesis with carbon fibre cages and instrumentation with pedicle screws and VSP plates

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In 1991, carbon fibre cages were introduced which, filled with autologous spongy bone, were placed between vertebral bodies to normalize and maintain disc height and to achieve good fusion.

Method: A multicenter follow-up study was made of 80 patients who had undergone surgical treatment because of symptomatic grade I isthmic spondylolisthesis L5-S1, viz. posterior lumbar interbody fusion with the above-mentioned implants and posterior fixation with pedicled screws and plates. There were 30 women and 50 men, mean age 45 years. None of the patients had been operated before. Mean follow-up period was 22 months. Mean duration of symptoms before operation was decided upon amounted to 56 months.

Results: Solid fusion was achieved in 92%. Clinical improvement was plotted on a 20-point scale, on which the patients scored an average of 11.9 before and of 18.5 after the operation. The screws and plates were removed after one year in 20 patients, because in some clinics, this is done routinely one year postoperatively. It was interesting to note that the radiological assessment of the fusion showed very good correlation with the findings at reoperation.

The proportion of radiographic fusion was compared with that in 13 publications that met the criteria of historical controls for spondylolisthesis. The proportion of fusion was better to a statistically significant extent than that reported in 6 publications, while that in one paper was possibly slightly better and there were no differences from 6 other papers.

Tle clinical results were compared with those in 12 papers in the literature that met the criteria for historical controls for spondylolisthesis. The results were better than those in five other articles, possibly slightly better than that in one article and identical to those in six other papers.

This study included a multicenter follow-up of 32 patients who had been operated at one level because of mechanical low back pain after previous discectomy. The operation was performed in the same way. The percentage of fusion in this group after a follow-up of 21 months was 96%, while the clinical results, plotted on a 20-point scale showed improvement from 9.2 before to 16.9 after operation. The proportion of fusion was about the same as that reported in the literature, while the clinical results were clearly better than those reported in nine of the ten publications that met the criteria for historical controls for failed discectomy.

Conclusion: The findings obtained in this study show that use of carbon fibre cages with pedicled screws and plates is safe and efficacious in the treatment of spondylolisthesis and mechanical symptoms after an earlier discectomy.

Spondylodesis with Isola pedicular instrumentarium—a postoperative study of 49 patients at least one year after operation

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A prospective study to investigate the clinical and radiological results of spondylodesis with Isola fixation was organized in the hospital De Weezenlanden, Zwolle, the Netherlands. Patients with spondylolisthesis, post-laminectomy syndrome, pseudarthrosis and stenosis of the vertebral canal were subjected to posterolateral spondylodesis and pedicular fixation.

Patients and method: All 51 patients, who had undergone the operation more than one year previously (between 22 April 1991 and 4 May 1995) were invited for physical examination and to answer an enquiry. Nearly all patients had been treated preoperatively with a trial corset, which had resulted in good improvement. The patients could indicate the clinical improvement, and the degrees of pain before and after operation using a visual analog scale (VAS). The data were analysed using the chi-square test and the Pearson test.Of all patients, radiographs made one year after the operation and, if possible, two years postoperatively were examined.

Results: Two of the 51 patients had died from extraneous causes and were eliminated from the study. The mean improvement on the VAS was 5.7 (10 = 100% improvement); 74% classified the results as sufficient to excellent. The mean pain score on the VAS (10=great pain) was 8.7 before and 4.8 after the operation. 23/49 patients could resume their occupation or increase their working time, 38/49 patients said they would choose the undergo the operation again in identical circumstances.

The patients with postlaminectomy syndrome showed a significantly poorer result than the patients with spondylolisthesis, but their pain score did not differ significantly. Sex, age and the interval elapsed after operation had no significant influence on the results and the pain score after operation.

17/49 patients still displayed residual neurological signs and symptoms at physical examination, viz. mild sensibility disorders, a positive Lasèque's sign and reflex abnormalities.

46/49 patients showed good fusion; in 3, no fusion had occurred. A total of 8 screws had broken, 7 in the sacrum and one in the 5th lumbar vertebra. Malposition of the fixation material was observed in three patients.

Infection of the osteosynthesis material had developed in 4 patients.

Conclusion: Posterolateral spondylodesis with Isola pedicular instrumentarium can bring relief in many cases. In spite of good preoperative criteria, no good results are obtained in one-quarter of the patients, their pain is just as bad or even worse than before the operation.

Posterior lumbar interbody fusion (PLIF) using a carbon fibre implant

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This study is concerned with 14 patients treated surgically for neurogenic claudication due to degenerative spinal stenosis. Treatment consisted of laminectomy combined with Posterior Lumbar Interbody Fusion (PLIF), with the aid of a carbon fibre cage implant and Isola spondylodesis of the segments involved.

Method: The postoperative clinical conditions were evaluated using the Prolo scale. On this scale, the functional and economic states are scored. Clinical success is determined by the combination of return to the previous job/activities part time/full time, in combination with no/recurrent pains in back/leg. Pain and walking distance were also scored before and after operation using the 'Visal Analogue Scores' with a range of 0 to 10. Fusion was assessed on conventional radiographs.

Results: The clinical scores after an average follow-up of 3.3 years (2–4.5) were excellent in 4, good in 7, fair in 2 and poor in only 1 patient. The mean VAS back pain score improved from 2.2 (0.1–4.5) to 7.8 (3.5–9.9), the mean VAS leg pain score from 2.0 (0.1–8.3) to 7.9 (3.3–9.9) and the mean VAS walking distance score from 1.5 (0.1–3.4) to 7.9 (4.8–9.8). No conclusive assessment of the fusion achieved could be made with conventional diagnostic radiography.

Conclusion: After a mean follow-up of 3.3 years it may be concluded that the results of this PLIF procedure were good in 79%. The pre- and postoperative VAS scores for pain and walking distance show distinct improvement. Our results may be explained by the fact that this PLIF procedure is a construction with optimal stability after adequate decompression.

Chemonucleolysis in isthmic spondylolisthesis with pain in one leg

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The intervetebral disc plays an important part in the root compression in isthmic spondylolisthesis. This takes place mainly at the level of the slipping. Chemonucleolysis currently is an accepted treatment of disc hernias.For this reason this therapy also deserves consideration in spondylolisthesis with unilateral crural pain.

Material and method: 63 patients with first or second degree spondylolisthesis and radicular pain treated with chemonucleolysis between 1981 and 1995 were examined after an average of 4.5 (1–13) years. Mean age before operation was 39 (15–62) years. The crural pain had been present

for an average of 25 (1–180) months. Physical examination revealed signs of radicular irritation in only 23 patients. The lysis was localized at level L5 in 53 patients, at L4 in 9 and at L3 in 1 patient. Supplementary examination (MRI, discography) revealed no abnormalities of the adjacent discs.

Results: Ten patients still had to be subjected to decompression and/or spondylodesis (L4-L5: 4, L5-S1: 6) after the chemonucleolysis. One patient died 2 years after the operation from an extraneous cause. The remaining patients (52) were questioned and examined physically. Radiographic examination of the spine was performed in 47 of them.

Subjectively, 47 patients were satisfied and 5 patients were dissatisfied. According to the Prolo scale, 41 patients had an excellent (29) or good (12) result, 11 patients a fair (10) or poor (1) result. In most patients radiography showed (increased) disc narrowing. In 10 patients, the slipping was found to have increased without clinical effects.

Conclusion: Chemonucleolysis is a possible treatment of patients with spondylolisthesis and unilateral crural pain provided a discogenic root compression can be demonstrated, preferably by MRI. Three-quarters of the patients are satisfied with the results of the treatment. This equals the results of surgical treatment. There appears to be no reason to worry about the consequences of developing segmental instability.

Repetition of chemonucleolysis safe and efficacious

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There is still no certainty about the permissibility of repeated chemonucleolysis in recurrence of nucleus pulposus hernia. It is especially because of possible sensitivity reactions that there is considerable reluctance to repeat application of this therapeutic technique. This study describes the results and complications in patients subjected to repeated chemonucleolysis.

Material: Chemonucleolysis was carried out 1690 times in Martini Hospital (location Van Swieten) of Groningen, during the period 1980 to July 1996. 85 patients (5%) were subjected to a repeated chemonucleolysis: 81 patients were treated for the second time, three for the third time and one, a woman, for the fourth time.

The group comprised 68 men with a mean age of 38 (18-72) years and 17 women with a mean age of 43 (19-58) years at the time of the first injection. 9 patients during the first chemonucleolysis session were injected at more than one level. In 65 patients, the chemonucleolysis was repeated at the same level because of recurrent nucleus pulposus hernia (42 times level L5/S1, 21 times level L4/L5 and 2 level L3-L4). It should be mentioned that in 8 patients, the contralateral side was involved.

The mean follow-up after the first chemonucleolysis was 117 (34–203) months, that after the second 64 (2–156) monthsand that after the third 42 (19–68) months. The mean interval between the first and second chemonucleolysis at the same level was 53 (2–127) months.

The procedure was carried out under general anesthesia; for 3 preoperative days the patients were treated with 200 mg of an antihistaminic three times daily. During the procedure the patients received prophylactic treatment with an infusion containing corticosteroids. Before the injection of chymopapain, level and rupture were determined by means of discography.

Results: Of the group of 65 patients (76%), who were subjected to another chemonucleolysis at the same level, 2 patients had to be subjected to surgical decompression later on. Surgical intervention was performed in a total of 5/85 patients. Of this remaining group of 63 patients again injected at the same level, 49 gave the results marks of 7 or higher on a scale of 1-10.

55 patients considered themselves almost or completely free of pain. 44 patients reported the ability to resume to their former occupations. As regards athletic activity after chemonucleolysis, 46% reported having reached their former level again.

Finally, as regards the complications that occurred in the group of 85 patients after repeated chemonucleolysis, a type I sensitivity reaction was observed in 5 patients. No reactions of type 2 or 3 were seen.

Conclusion: Our experience with repeated chemonucleolysis in 85 patients appears highly satisfactory. Provided adequate precautionary measures are taken, the risk of complications and especially the risk of sensitivity reactions appears to be very low.

Lumbar columnotomies without internal fixation in Bekhterev's disease

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Objective of the study was to evaluate the results with regard to the long-term preservation of the correction obtained at operation and to the prevention of complications without using internal fixation in lumbar columnotomies, as compared with literature data on lumbar columnotomies with use of internal fixation.

Material and method: 8 patients were treated in the AMC from 1991 through 1994, with a dorsal closed wedge vertebral osteotomy with partial corporectomy at a lumbar level without using internal fixation. The patients were males suffering from Bekhterev's disease, with an average age at operation of 47 (35–55) years and with an average angle of thoracic kyphosis of 88 (54–105) degrees. All patients were operated by the same surgeon.

The patient lying prone on the table was fitted with a plaster scale which was replaced after one week by a corset with reinforcing pipe for the duration of six months, followed by two months in a corset without pipe. The patients were mo-

bilized in the corset after approximately two weeks.

Results: Mean duration of follow-up was 32 (20–54) months. Mean postoperative correction was 41 (28–53) degrees, with an average of 3.6 (-12 to 4) degrees of loss of correction at follow-up. Mean duration of operation was 147 (110–165) min and the peroperative blood loss averaged 1090 (200–2355) ml.

The correction achieved was sufficient in all patients to allow looking forward, and their posture had improved. The patients were satisfied with the result. No fatal complications were seen, but four patients developed a transient complication such as delirium or transient functional nerve disorder.

Conclusion: The results of lumbar columnotomy without use of internal fixation are similar to those reported in the literature with internal fixation.

Primary tumors of the spinal column

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In the period 1980-1995, 51 patients with a primary tumor of the spine were treated in Leiden University Hospital. 29 patients had a benign lesion (mean age 18.5 years: 14 osteoid osteoma, 6 aneurysmal bone cyst, 4 giant cell tumor, 2 osteoblastoma, 2 eosinophilic granuloma, 1 osteochondroma) and 22 had a malignant lesion (mean age 43.5 years: 10 chordoma, 4 chondrosarcoma, 4 Ewing sarcoma, 2 osteosarcoma, 1 haemangio-endothelioma and 1 malignant fibrous histiocytoma).

Material: Symptoms at presentation: local and/or radicular pain. Neurological defects: 19 (6 cases of paraparesis). Surgical treatment of benign lesions consisted of curettage (23), thermocoagulation (1), embolization (1), injection of depomedrol (2); follow-up 2 years and 10 months.

Of the group with malignant tumours (follow-up 4 years and 11 months), 6 patients were treated with ample resection. 15 patients underwent intralesional resection, 1 patient was treated palliatively. Reasons for incomplete resection were: technically impossible (7); preoperative diagnosis incorrect (1) and 2/8 decompression for acute paraparesis, 7/8 referred to Leiden University Hospital after primary operation elsewhere. Chemotherapy and/or radiotherapy in 19/22 patients.

Results: The survival of patients with a benign tumor was 100%, with local recurrences in 3 patients (giant-cell tumour 2; aneurysmal bone cyst 1).

7/22 patients with a malignant tumor had died (3 chordoma, 1 chondrosarcoma, 1 Ewing, 1 osteosarcoma and 1 malignant fibrous histiocytoma). Survival after ample resection 100% (4 chordoma, 2 chondrosarcoma), while at the latest outpatient follow-up examination these patients showed no recurrences or metastases. Of the other 9 patients with incomplete resection 3 developed a recurrence and two a metastasis.

Conclusion: Benign tumors: prognosis favorable, interval between start of symptoms and diagnosis long (20 months), morbidity high in giant-cell tumor and aneurysmal bone cyst.

Malignant tumors: 1) ample resection, if technically possible, gives the best chance of survival; 2) preoperative staging (not performed in 4/6 deceased, surgically treated patients) positive influence on prognosis; 3) long survival after incomplete resection possible owing to chemo- and radiotherapy (e.g. 2 patients with Ewing sarcoma, follow-up 9 and 16 years, respectively); and 4) referral to a tertiary centre is advisable, in part in view of possible incorrect diagnosis.

Giant-cell tumors of the spinal column: complete curative resection

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The results of intralesional operations are poor. It was therefore decided to resect these tumors completely, as much as possible en bloc.

Patients: 10 tumors were resected since 1986. 8 of these (in seven patients) are the subject of this paper. 7 tumors were localized between T2 and L2; 3 were recurrences after curettage or partial excision. There was 1 sacral tumour. The patients were 3 men and 4 women (5 tumors); average age 29 (25–35) years. Grading of the biopsy sample did not affect the surgical technique because the value of grading in the treatment of the individual patient has never been proved.

Surgical technique: En-bloc resection after mobilization of the dura posteriorly (Fidler 1994). There was theoretical microscopical contamination in 6 of the 7 thoracolumbar tumors, but no macroscopical tumor spill. The sacral tumor was removed intralesionally with multiple frozen sections to check the resection surfaces.

Complications: Major bleeding: 3. Late: fracture of the bone chip and reoperation: 1.

Results: All patients remained neurologically intact or were improved (apart from the unavoidable severance of root nerves). No local recurrences. Multiple lung metastases in one patient, at present clearing up spontaneously.

Conclusion: Complete resection, preferably en bloc, of a giant-cell tumour is locally curative. There are no indications for partial resection or curettage.

Clinical evaluation of peroperative neuromonitoring system in surgery of the lumbosacral spine

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The insertion of pedicular screws entails the danger of incorrect placement and damage to nearby root nerves. It is possible to guard against perforation of the pedicular wall by measuring the resistance in the environment of the pedicle combined with electrical stimulation (motor evoked potentials—MEP). The method was developed with use of recording of the liminal current for an MEP during stimulation by the pedicular screw.

Method: Eight EMG electrodes were attached to four muscle groups in both legs, and the EMG signs were processed with filters. Minor responses can be made audible through analogous signal processing.

Results: The system was used to monitor 18 patients in whom 92 pedicular screws were inserted in the tract between Th12 and S2. During the dynamic moments of the operation, spontaneous muscle activities were recorded. Subsequently, sensor wires and pedicular screws were stimulated and the liminal currents for the evocation of MEPs were recorded.

Conclusion: The method described proved useful for the monitoring of the insertion of pedicular screws. None of the patients postoperatively exhibited disorders of nervous function due to incorrect placement of pedicular screws. At present, a measuring method is being developed which records the impedance, also. The equipment is easy to operate and requires no special physiological expertise.

Reduction of homologous blood transfusions during dorsal spondylodesis operations

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A retrospective analysis of 44 patients operated on for dorsal spondylodesis of the spine proved that all patients had received homologous blood transfusions during the perioperative period. In the study presented here, 31 patients were subjected to dorsal spondylodesis operations, according to a protocol including four transfusion-saving techniques. Objective of the study was to reduce blood loss and homologous blood transfusions during the perioperative period.

Method:

1. Preoperative autologous blood donation.
2. Peroperative autotransfusion with use of a cell saver
3. Controlled hypotension.
4. Hypervolemic hemodilution.

Results: The blood loss was found to be greatly reduced in comparison with the retrospective analysis. More than three-quarters of the patients are now operated without donor blood or plasma. There were no complications.

Conclusion: This method proved very effective for reduction of blood loss and transfusion requirements.

Patterns of disc degeneration after fractures of the thoracolumbar spine

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Damage to intervertebral discs may play a crucial part in the stability of a fractured vertebra, during the acute phase as well as in the long run. However, patterns of damage and repair are very poorly understood because of the difficulty of visualization using traditional imaging techniques.

Method: This study was carried out to investigate patterns of degeneration of discs around a fractured vertebra. The material consisted of 35 patients who had been treated in our hospital between January 1991 and December 1993 for a compression type fracture (Dennis groups 1 and 2) of the thoraco-lumbar spine (T10–L4). The minimal follow-up was 2 years. 13 of the patients had been treated conservatively and 22 surgically with posterior fixation with AO fixateur interne as well as posterior spondylodesis. Clinical evaluation was performed according to the criteria of Denis. Patients treated conservatively had a significantly higher pain score (p=0.007). After conventional radiological examination, MRIs were made (T1, TSE, T2).

Results: The MRIs were examined by an orthopedic surgeon and a radiologist for alterations in the various parts of the disc. Using these data, we developed a 6-point classification system for posttraumatic discs. The inter- and intraobserver variations were good (Cohen's Kappa 0.77 and 0.79). The disc classification had an independent predictive value for the ultimate progression of kyphosis. These findings confirm the importance of the disc for the long-term clinical and radiological stability after a compression type fracture. Our classification system appears reliable and reproducible for further investigation into the role of intervertebral discs in the prognosis of thoracolumbar fractures.

Comparison of surgical and conservative treatment of thoracolumbar burst fractures

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No consensus has yet been reached concerning the treatment of thoracolumbar burst fractures. Various criteria such as the percentage of stenosis of the vertebral canal and the local kyphosis are described in the literature as indications for the surgical treatment irrespective of the neurological status.

Method: In our hospital a total of 125 patients with thoracolumbar burst fractures were treated between January 1981 and September 1990. Of these, 104 were available for follow-up study. 28 patients had been treated surgically (19 Harrington osteosynthesis, 25 dorsal stabilization with os-

teosynthesis while 3 patients were treated with just a decompression and a laminectomy). The group consisted of 77 men and 27 women with an average age at the time of the accident of 35 years. Duration of follow-up: 40 (12–108) months.

Results: Of the 41 patients with neurological signs of functional impairment, 63% showed neurological improvement, with slight preference for the group treated conservatively. The patients treated conservatively showed an increase of the kyphosis angle by 5.5 degrees and a reduction of the proportion of stenosis of the vertebral canal by 21%. The patients treated surgically showed a decrease of the kyphosis angle by 2.9 degrees and a reduction of the percentage of vertebral canal stenosis by 56%. However, we could demonstrate no correlation between the reduction of the stenosis, the increase or decrease of the local kyphosis and the neurological improvement or abatement of pain. Both the patients treated conservatively and those treated surgically reported the same mild degree of pain. The capacity to work, and the period of absenteeism were not affected by the method of treatment.

Conclusion: The conservative treatment of thoracolumbar burst fractures is a good option, even in patients with symptoms of loss of nervous function.

Results of surgical treatment of burst fractures of the thoracolumbar spinal column

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A compressive axial load may bring about a burst fracture of the thoracolumbar spinal column. According to the Denis classification of vertebral fractures, the anterior and middle column are affected with retropulsion of bone fragments into the spinal canal. Neurological damage occurs in half the cases. The treatment is still controversial. Conservative treatment is sometimes recommended. The current tendency is more toward operation. It should be aimed at (in)direct decompression of the spinal canal, restoration of the spinal shape and rigid fixation, so as to allow rapid mobilization and better nursing. The present study was performed to compare three possible methods of surgical treatment.

Material: 75 patients with thoracolumbar burst fractures were treated in the AMC in the period 1983 through 1993. Complete follow-up was known of 64 patients. The diagnosis of burst fracture was made, and the degree of spinal stenosis determined by means of conventional radiographs and CT scan. Anterior decompression and single-rod stabilization (I), anterior decompression and stabilization in combination with posterior stabilization (II) or posterior repositioning and stabilization with AO fixateur interne (III) were the methods of treatment used in 28%, 43% and 29% of the cases, respectively.

The groups were comparable with regard to age, sex, causative accident and presence of additional injuries. Neurological injury existed in 42% of all cases. Mean duration of follow-up was 7 years.

Results: Bone healing occurred in all vertebral fractures. Loss of reposition by more than 5 degrees and failure of material occurred significantly more often in groups I and III than in group II. However, at late follow-up there was no difference between the groups with regard to pain. In all cases but one the neurological condition improved.

Conclusion: A combined anterior and posterior approach corrected the kyphosis best, without difference in ultimate clinical results, however. Incomplete decompression of the spinal canal by posterior distraction and short-segment stabilization with AO internal fixation is to be preferred in the surgical treatment of thoracolumbar burst fractures, since it is a less elaborate procedure than the anterior and posterior approaches.

Anterior interbody spondylodesis with the Brantigan Anterior Lumbar Interbody Fusion cage—a multicenter study of results in 66 patients

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The traditional anterior interbody spondylodesis with use of two tricortical iliac crest grafts entails a large number of graft-related complications: Pseudarthrosis (5–44%), resorption and collapse, dislocation of the grafts, donor site pain (25%). We, also, encountered these problems, so we looked for an alternative and found it in the Carbon Fibre Brantigan ALIF (Anterior Lumbar Interbody Fusion) cage by Acromed Cleveland, Rotterdam.

Material: A total of 77 levels were fused in 38 women and 28 men. All patients had a follow-up of 12 months or more. 27 patients had never had a back operation before, 25 had had one and 14 two or more back operations. For each patient, 39 items were scored pre- and postoperatively and analysed statistically.

Results: A pseudarthrosis had probably developed in two patients. Judging by pain and function, the spondylodesis may be regarded as a success in 54 patients. Clinical success was even obtained in 79% of the patients who had previously had two or more operations.

Conclusion: The Brantigan ALIF cage gives substantially better results than the previously used tricortical graft. In particular, the number of graft-related problems is minimal. Stability is achieved immediately after operation, which also makes the after-treatment much simpler and less uncomfortable to the patient.

Lumbar interbody spondylodesis with hydroxyl apatite implants

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The purpose of ventral interbody spondylodesis in symptomatic disc degeneration of the lumbar spinal column is to obtain solid arthrodesis and adequate interbody distraction. The long-term results of hydroxyl apatite (HA) constructions were studied prospectively.

Material: 14 patients were subjected to lumbar interbody spondylodesis with use of autologous iliac crest grafts reinforced with HA blocks (Ceros 80, Mathys Company, Bettlach, Switzerland). A control group consisted of 12 patients who had earlier been subjected to lumbar interbody spondylodesis using just autologous iliac crest grafts. All operations were performed by the same surgeon. After a follow-up of at least 10 years for both groups, the interbody height was measured and the loss of distraction evaluated on radiographs.

Results: Both groups were similar with regard to sex, age, spondylodesis level and preoperative diagnosis. The loss of interbody distraction was significantly larger in the HA group ($p=0.0003$); it was caused largely by disintegration and migration of HA blocks.

Conclusion: Use of HA implants at lumbar interbody spondylodesis increases the frequency of complications compared with operations using only iliac crest autografts. The loss of intervertebral height brought about by distraction is significantly larger. We recommend using only iliac crest grafts for ventral lumbar interbody spondylodesis.