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PROCEEDINGS OF THE NORDISK ORTOPEDISK FÖRENINGS 33d ASSEMBLY IN GOTHENBURG JUNE 1966

The meeting of the Scandinavian Orthopaedic Association was held in Gothenburg under the Presidency of C. Hirsch

METAL AS MATERIAL FOR OSTEOSYNTHESIS

SOME ASPECTS OF OSTEOSYNTHETIC MATERIALS AS A FOREIGN BODY

by *Hans Emnéus* (Lund, Sweden)

Osteosynthesis presupposes a foreign body and this afternoon's topic concerns metallic osteosynthesis material.

Osteosynthesis material is constructed according to the principles of carpentry. In recent years biomechanical principles have to some extent been followed. 50 years' experience have taught us that the above principles are efficacious and that certain advantages over closed fracture treatment are to be gained. The most essential feature for us has always been and is now a stable osteosynthesis. Here however I shall be dealing in the first place with the biological activity of the foreign body, not with the secondary effects of the osteosynthesis. There will be a certain limiting approach therefore, regarding what we on the whole consider to be the foreign body reaction. It is therefore understandable that the mechanical or physical factor, which is so fundamental both of the osteosynthesis and to the secondary effects of the osteosynthesis, will temporarily move into the background in favour of the chemical properties of the foreign body and the appearance and behaviour of the surrounding tissue. I will now divide the biological activity of the foreign body into two parts: 1. The solubility of the foreign body in body fluids, and 2. The effect of the dissolved substances on the tissues. (Histology is involved in both 1. and 2.). I shall first turn to the chemistry or electrochemistry of the foreign body. All metals are to some extent dissolved by the body's electrolytes. The electrolyte environment in the human body is composite, but from the present point of view, that of metallic foreign bodies, all anions except the chloride ion can in fact be ignored. Apart from the electrolytes pH and pO_2 are also important. From animal experiments it has been found that single isolated implants of high alloyed stainless steels cobalt-chrome-molybdenum alloys and titanium remain relatively the same in tissue. In carefully regulated experimental conditions certain differences between these 3 metals and the tissue reaction can be observed. In this experimental research no great differences could be determined in the histological picture. I and my colleagues could see that different coloured pigments both phagosytized and non-phagocytized were present around the different metals. In the analysis in which

we used X-ray spectrography we found iron around the steel implants, cobalt around the vitallium implants and titanium around the titanium implants. In America research was carried out using another technique, the tissue was ashed and analysed and the same result was found. No special investigations have been made abroad experimentally, in which consideration has been given to the properties of the foreign body, treating it in ways which recall surgical procedure. Admittedly *Laing* has investigated screws treated by a special screwdriver, that is, he has demonstrated the transfer of tool metal to the screws. *Stenram* and I found that there was an increase in tissue reaction and pigmentation in the tissue when stainless steel wire was twisted to cerclage compared with the insertion of an untreated wire. Furthermore we discovered that identical steel inserts and two different types of cobalt alloy, welded together, produced a greater tissue reaction and pigmentation than if an isolated piece of metal was placed in the tissue. In parenthesis it may be said that isolated vitallium implants thoroughly surface-treated result in hardly any tissue pigmentation.

As I stated just now, a single piece of well polished stainless steel remains markedly inactive and indissoluble in the tissues. It is known that stainless steel however is passive, thanks to a thin layer of chrome oxide. This passive layer is perhaps 50 or some 100 Å (Ångström = 0.0000001 mm) thick. If this layer is damaged corrosion will arise. In addition, in order to be completely passive, the environment of the stainless steel surface must have a certain oxygen content. If the surface of the stainless steel is damaged, *i.e.*, is hammered or in some way changed purely mechanically, the stainless properties can be lost. In cerclage, for example, the wire is twisted. A pull is exerted on the wire which changes the wire's properties and can produce local surface damage where the chloride ions can attack and corrosion arises (pitting corrosion).

If two pieces of stainless steel are joined together, *e.g.*, screw and plate with a crevise the oxygen content in the crevise may become too low and the passive layer cannot maintain its passivity owing to lack of oxygen and then too there is a break-through by the chloride ions and the result is a corrosion(crevise corrosion). Vitallium probably has the same properties. On the whole it can be said that there is a passive layer of vitallium consisting of chrome oxide. It is thinner, but vittalium has, as it were, robuster qualities. If there should be a break-through of the passive layer, cobalt is not at all so active as the iron beneath the passive layer.

Ferguson and *Laing* have stated, although I am not certain whether experimental evidence for this exists, that vitallium is affected by crevise corrosion, but it ought to be very rare.

Finally there is titanium. This element has quite specific properties. Titanium is extremely passive in a chloride environment and this is due to the fact the titanium surface oxidises very rapidly and forms a thin oxide layer of titanium oxide. The chloride ions at pH 7 can't penetrate this oxide. Chemically titanium has probably none of the weaknesses possessed by steel. Surgical cold working has, as far is known, no great significance for its corrosion stability.

In clinical conditions it is not to be expected that, for example, stainless steel will behave as ideally as a single stainless steel rod, thoroughly surface-treated, behaves in an animal body. We must expect the design of nail and plate and of screw and plate to produce corrosion in stainless steel in a chloride environment. The surface injuries which we produce with our chisels, the malformation of the screw head

effected when we turn the screw, the twisting of the stainless steel wire when we carry out cerclage, all this increases the biological activity of the stainless steel, *i.e.*, the solubility of the stainless steel in the body fluid increases. It is probable that the same condition exists with vitallium, but to a much lower degree.

I shall leave the electrochemical process now and say a few words about the products which arise when the metals dissolve. When stainless steel is dissolved by corrosion, ionised iron, ionised chrome, ionised nickel and perhaps molybden are formed at the anode. At the cathode hydrogen possibly is formed, rapidly oxidised to H_2O. When vitallium dissolves, cobalt, chrome and molybdenum are ionised. When titanium is dissolved, this cannot be precisely explained in electrochemical terms. Truly ionised titanium scarcely occurs in the body.

It is probable that it is not the quantity of heavy ions which is significant in itself, but it is the toxicity of the ion. One can expect that chrome and nickel are considerably more toxic than, for example, ionised iron. We have evidence of this from experimental research by *Verne* and *Menegaux & Odiette*. Undoubtedly chrome is very poisonous to the tissue and probably nickel also. Iron is toxic, but far less. Theoretically then we may expect that a small quantity of chrome, cobalt or nickel is itself equally as or more harmful than a large quantity of iron. Vitallium consists of chrome and cobalt, stainless steel of chrome, nickel and iron. Naturally I cannot prove it, but it would not surprise me if it were to be found that a human being can tolerate iron in large quantity, but very little chrome. It is not known whether Cr^{+3} or Cr^{+5} is worse, but this will emerge gradually.

How then do the tissues look around the osteosynthesis material? In animal experiments the tissue reaction around implants of high quality, stainless steel, cobalt-chrome alloys, vitallium and titanium is very slight. This applies both to the reaction of bone tissue and soft tissue. Some fibrosis is always seen, and often moderate amounts of monocytic elements, isolated giant cells and isolated phagocytes filled with small quantities of phagocytised metal pigment. Clinically quite a different picture is sometimes found. Of course, slight reaction is often seen exactly as in experimental research, for example, slight fibrosity, moderate amount of monocytic elements, isolated giant cells, and almost always a small quantity of phagocytes filled with iron pigment.

Sometimes however purulent dissolution and proliferation of leucocytes, monocytes and phagocytes containing iron pigment are seen. One often sees around stainless steel tissues of deep rust colour, penetrated intensively by iron pigment and also other pigment, great quantities of non-phagocytised rust, and considerable fibrosity. An astonishing high amount of iron pigment is sometimes seen around vitallium.

Occasionally even Turnbull-negative pigment is seen, *i.e.*, pigment which is not iron but perhaps Cr, Ni or Co. By analogy *Stenram* and I have shown that Turnbull negative pigment with a probability bordering on certainty is precisely C-, Ni- and Cr-pigment. What is important however is that these tissue changes around the foreign body with this abundance of pigment do not at all imply that discomfort of any kind has been clinically observed to result from the foreign body. The patient perhaps may never have given a thought to the fact that he carries a nail or screw in his body. There may never be any reaction at all from skin and muscles, no radiological signs of loosening on the part of screw or plate. Nevertheless considerable pigment may be present. Naturally no purulent dissolution is then present.

In other cases we have seen very severe reaction, which expresses itself in the form

of an aseptic inflammation and almost osteomyelitic changes which then heal quickly, as soon as the osteosynthesis material is removed. What I wish to say is that in individual cases, we have seen an inflammatory process surrounding osteosynthesis material inserted by us, a process which does not show any bacterial infection and in which everything clinically indicates a chemical irritation. In these cases we often discover an abundance of metal pigment in the tissue, but we can expect to find equally as much metal pigment in the tissue of another patient who has not had the slightest purulent reaction.

This means that we cannot in fact rely on a purely histological diagnosis to obtain indications concerning electrochemical irritation. We know certainly that a dissolution of the foreign body has occurred in the tissue, but we also seem to have determined that this dissolution of the foreign body does not affect different individuals in the same way. Certain individuals do not tolerate a biologically active foreign body in their organism. Here the question occurs whether the toxicity previously mentioned is significant. Some humans could well be sensitive to, for example, chrome and thus react more intensely even to slight corrosion of the inserted foreign body.

It was always my idea and dream that the histological picture could be evaluated by some analytical method and that one could say that there is chemical irritation here. I advanced along various paths and during this search I merely found that there was always a defensible proportion of the heavy elements in the tissue. The elements found in the foreign body were present in the surrounding tissues. It is thus shown that chemical solution will always occur. In clinical experiments I also found cobalt and chrome around vitallium applications. Sometimes I found large quantities of titanium around titanium applications, but no answer was produced to the question whether there was any chemical irritation in the individual case.

The whole material may be summarised as follows: considerable metal may be present in the tissue, but no chemical irritation can be demonstrated clinically. If however there is an obvious suspicion clinically of chemical irritation, then an abundance of phagocytic and non-phagocytic metal pigment ought to be present, *i.e.*, toxic pigment. A consistent feature of all the experimental research and of the clinical comparisons is that a *solitary application* of a metal, whichever one of the three, produces quite slight pigmentation of tissue and very rarely any chemical irritation. Combined osteosynthesis material consisting of a number of structures produces constant tissue pigmentation and one suspects chemical irritation considerably more often. There is no doubt that stainless steel is more irritating chemically than vitallium, but it must be realised that stainless steel can rust considerably without affecting the tissue. Vitallium rusts rarely but we must nevertheless be prepared for chemical irritation from time to time. Titanium seems to provoke very slight tissue reaction. With titanium applications an abundant quantity of black pigment is sometimes found in the tissue but the body has quite a good tolerance level of this pigment. Very thin foreign body capsules lie around the titanium applications and the above is possibly due to the fact that titanium does not occur in ion form in the tissue, but is oxidised rapidly and that titanium oxide has a good tolerance level.

I can give no other summary of the present-day situation than that vitallium is excellent as osteosynthesis material. Stainless steel has its limitations and therefore when Moore-prostheses are involved, then one ought perhaps to reject steel. Titanium

probably is on an equal par with vitallium in Moore-prostheses. At this point I will only say that titanium holds its place by the side of steel. Dr. *Gudmundsson* is shortly to give an account of our clinical research into titanium.

DISCUSSION:

E. Sandaa (Sandviken, Norway)

A Lambott's plate with screws was removed 23 years after application for femoral fracture in a girl of 17.

The plate was found reduced to a thickness of ½ mm, the screws were also grossly corroded. The foreign bodies were surrounded by a thin-walled sacculus containing a homogeneous mass consisting, *inter alia,* of a rather high concentration of the metals constituting the plate and screws, and in the same proportions. (Plate and screws: Major element: Fe, minor elements (0.5 to 0.02 pct..): Mn. Si, Cu, Ag, Ni, Co.) The mass also contained P, Ca and Mg proportional to bone, the percentage of P higher, of Ca smaller than that of Fe. There was very marked pitting destruction of bone under and around the plate, the bone being partly necrotic. It was found that approximately half the weight of the plate had been resorbed during the years, one fourth retained in the sacculus.

The local toxic effect and possible toxicity of resorbed metals are briefly discussed.—The alloy used in this case now is obsolete, but even osteosynthesis material of modern allows should be removed from young and middle aged persons.

MICROANGIOGRAFISKA OCH HISTOLOGISKA OBSERVATIONTR VID KOMPRESSIONSOSTEOSYNTHES

by *S. Olerud & G. Danckwardt-Lilliestrom* (Uppsala, Sweden)

FINAL REPORT ON THE CLINICAL TESTING OF TITANIUM

by *Hans Emnéus & Gudmundur Gudmundsson* (Lund, Sweden)

As stated in our preliminary review 1964, Titanium seems equally suitable for use for hip prosthesis af Vitallium and this impression has been confirmed by our extended survey. Since 1961 150 Moore plastics have been performed with Titanium prosthesis strictly alternating with Vitallium.

During the period January 1962 until October 1964 a series of 88 McMurray osteotomies were carried out by the Tupman method.

Table 1

	Arthrosis def.	Necrosis cap. fem. / Pseudarthrosis colli	
Steel	46	8	54
Titanium	30	4	34
Total	76	12	88

For most purposes Titanium seems quite comparable to other osteosynthesis materials in current use. After one has become accustomed to its special qualities, one can work very well with it. In comparison with steel its mechanical strength under exacting conditions appears to be somewhat inferior.

Since this series was started 11 of the Tupman plates have broken:

Table 2

	Inserted	Broken	
Steel	54	5 (6)	9.3 % (11.1 %)
Titanium	34	6	17.6 %
Total	88	11	12.5 %

The tissue is sometimes blackened by the Titanium applications. It is extremely interesting that Titanium osteosynthesis material adheres to the tissue and that in spite of abundant manifestation in both phagocytic and non-phagocytic form it does not cause any tissue reaction.

INTRAMEDULLARY TRANSFIXION: AN EXPERIMENTAL OSTEOSYNTHESIS

by *Børge R. Hansen* (Copenhagen, Denmark)

Efficient stabilization and adaption are fundamental in the operative treatment of fractures. These factors were basic to the design and construction of an experimental osteosynthesis: the intramedullary transfixion.

Two stainless steel wires, bent and threaded in extremities, were placed crosswise over a transverse osteotomy on the femur and tightened with nuts. This resulted in a compressive force over the osteotomy.

In a series of pilot experiments on dogs operative techniques were elaborated. External immobilization was not effective so the transfixion was supplemented with a plate fixed with two screws. In this way bone healing progressed without external or intramedullary callus formation.

AN ENGINEER'S VIEW OF ORTHOPAEDIC NAILS AND SCREWS

by *B. Jakobsson* (Göteborg, Sweden)

The sight of an orthopaedic surgeon inserting a nail or a screw into an intact or broken bone is an eye-opener for a mechanical engineer. He is confronted with problems he had never thought of before. It is obvious that such foreign bodies must be made of suitable material, *i.e.*, it must tolerate the environments in the body, it must be strong enough to stand the stress and strain to which it is subjected, and it must have sufficient fatigue strength. At the same time it should have no injurious effect on the body tissues but rather promote healing and regeneration. As far as the actual material is concerned, much progress has been made and further research is in progress. This point will therefore not be dwelt on further here.

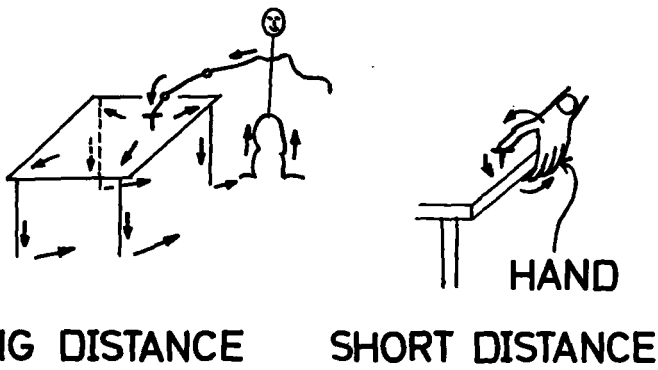

Figure 1. Force flow. Thumb tack in a table.

I admire the skill with which the surgeons gain access to different parts of the body and fasten appliances there. But when it comes to the designing of the appliance I feel that a mechanical engineer might be a valuable link between the orthopaedist and the manufacturer of the parts of the metal appliances.

What I intend to elucidate here is the properties of a screw and of a nail. In other words: what can a nail or screw do? But this is not enough. The question must be expanded to read: What can a nailed or screwed joint do, for it is such appliances that we want to create. I do not know whether this problem has received any attention in the orthopaedic literature. At any rate, I have not seen any articles on it.

The purpose of a joint is to fix displaced or movable parts. This means that the splint must be strong enough to withstand forces tending to break or bend it. The forces must be taken up by the mechanical construction.

Below are a few recommendations I give to my students at Chalmer's Tekniska Högskola.

Rule I

Visualise all the forces as a stream or flow of force. It flows something like an electric current and makes a circuit (Fig. 1).

It is as a rule advisable to choose a short force-flow circuit.

The circuit should be determined and designed by a mechanical engineer, who should also see that the various parts can stand the forces they are to be exposed to. The flow of the force should not be offered various paths, but should be confined to a single well defined one.

Rule II

In the same way all twisting moments together form a moment flow, which also forms a closed circuit (Fig. 2).

The circuit should be short and the various parts should be strong enough to tolerate the flow.

When designing a nailed or screwed joint the first question to be answered is: What are the directions, the magnitude and the sequence of the forces to which the appliance will be subjected.

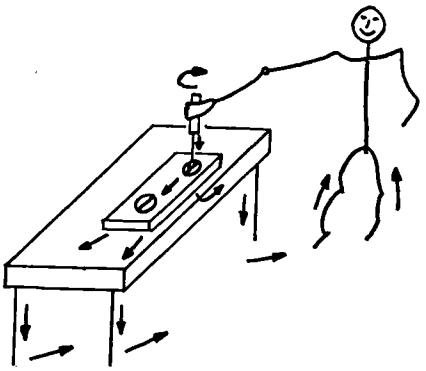

Figure 2. Torque flow. Tightening of screw.

If numerical values are not available for such forces, they should be estimated and overestimated rather than underestimated.

Not until this has been done is there any sense in discussing the actual design of the appliance.

NAILS

Nail Joints

A joint usually has several cooperating nails. Let us first consider a joint with two nails (Figure 3). The nails may be round or angular.

Figure 3a illustrates a joint made of perspex nailed tight to a wooden support. The joint is designed to take up forces P_x, P_y and a moment M_z, all of which tend to shear the nails. Elastic deformation bends the nails a little. A force P_z which is directed downwards, does not affect the nails. If P_z is directed upwards, it tends to extract the nails. The result depends entirely on the elastic pressure between the nail and the piece of wood and its ability to retain the nail by friction.

No nail should be exposed to such forces unless it is securely fastened in the lower part. Box-nailers hammer the nail right through the wood and then bend its tip. One can also in some way or another produce a sort of barb to prevent withdrawal of the nail from the lower part.

Figure 3b shows a spaced joint with (or in extreme cases without) springs in the space between the parts. Even 3a should be drawn in this way because there is always a certain amount of play or elasticity in the pieces assembled. The more obvious elasticity in 3b can equally well take up P_x, P_y and M_z. But the nails are deformed more in bending and the parts therefore move appreciably in relation to one another.

Interesting is the downwardly directed P_z. Using simple values, let us suppose that after nailing each spring is compressed wiith a force of 10 kp (1 kp = 2.2 lbs), then an extracting force of 20 kp will be acting on each nail. When P_z increases from 0 to 40 kp, the nails will be completely unloaded and the springs will be compressed with $4 \cdot 10$kp by P_z. To press the upper plate down over a nail would require, say

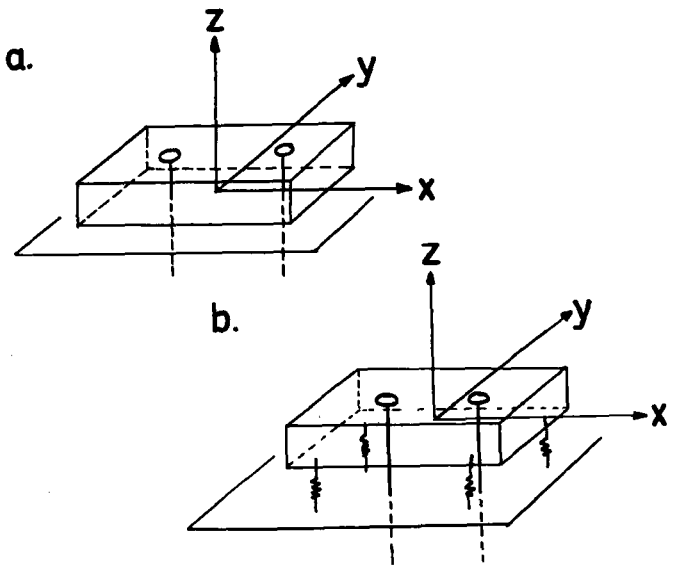

Figure 3. Nailing. a. Tight, b. Untight.

50 kp, to overcome the friction. While P_z increases from 40 to 140 it will have no effect on the springs, but each nail will increase its load from 0 to 50. If P_z is increased further, the forces of the nails persist and the springs take up 0.25 (P_z–100).

When P_z is afterwards removed, the upper plate is lifted and then friction exerts a pull of 50 kp on every nail, which tries to extract the nail from the lower part of the construction.

From a technical point of view a joint with such play is unacceptable. I would forbid P_z. Mechanical play wears out a joint, and what do the springs think of massage. They may be healing bone surfaces.

Single Nail

It is very difficult for a single nail to transfer torque about its own axis. Otherwise it acts as a nailed joint.

To cope with this torque the nails are made angular or flanged. This prevents rotation, but since the lever is extremely short the moments acting can produce enormous forces in the material around the nail.

I must confess that I cannot understand why a three flanged nail should be better than a one- or two-flanged one.

Insertion of Nails

As a rule the nail itself produces the hole it is fastened in. Insertion of nails onto bone must be done with extreme care to prevent the surrounding bone from cracking or splitting. Therefore the holes to receive the nails are sometimes prepared in as gentle a way as possible, *e.g.*, boring and broaching. But the hole most always be widened by the actual nail if the latter is to be retained by elastic friction.

I feel it would be a great advantage if the nail could be held in position by a barb instead of by friction.

When, in the course of nailing, the tip of the nail reaches the lower part, it tends to separate the two parts from one another unless there is a very good support for the lower part.

Personally, I think nailing is a very crude operative procedure. I do not know how the forces inside the nail behave (during insertion of the nail). I do, of course, appreciate the precision of the direction of the nail made possible by pre-insertion of a small cylindrical guide in the bone.

Removal of Nailed Joint

When designing a nailed joint, consideration should also be given to the possibility of its removal, should it prove desirable. I presume that orthopaedic nails must be designed in such a way that they can be readily extracted, since the healing process or disturbances during this process may make it necessary to remove or replace the joint or replace it by a more suitable one.

Screws

The principal difference between a nail and a screw is that the screw can withstand traction forces without being dependent on the aforementioned friction between its own surface and that of the surrounding material. The screw is instead dependent on the shear strength of its own threads and that of the recipient material. Metal is as a rule strong enough, but in bone the threading cut by the screws may not be.

For a screw or nut not to become loose there must be sufficient friction between its threading and the recipient material unless, of course, some special locking device is used.

Screwed joints can take up the same type of loads as nailed joints. If angular in cross section and fastened by an exterior nut, a single screw can take up a torque about its axis. The screw need not rotate in its hole due to this nut.

Mounting of a Screw

A screw must first be screwed in to get a certain traction preload. This preload gives primarily the friction locking action just mentioned. Due to this preload the two jointed pieces do not part elastically when the working load acts on the joint.

Figure 4 shows a metal splint with 2 screws fastened to a base plate. When the driving force P_{DRIVE} is not acting the screw is drawn by the force P_{MONT}. Then the screw is elastically deformed, as shown in the diagram, and compresses the support elastically. When P_{DRIVE} is exerting its action, the screw lies against the support with a tightening force of P_{TIGHT}.

If the screws are not drawn tight enough, there will be a certain amount of play in the joint, which is rarely acceptable.

When the screw is screwed tight, the moment of the screw spanner is transmitted down to the shank of the screw and to the support under the head of the screw or the nut. It is then transmitted further as a moment-flow back to the hand tightening the screw (Fig. 5).

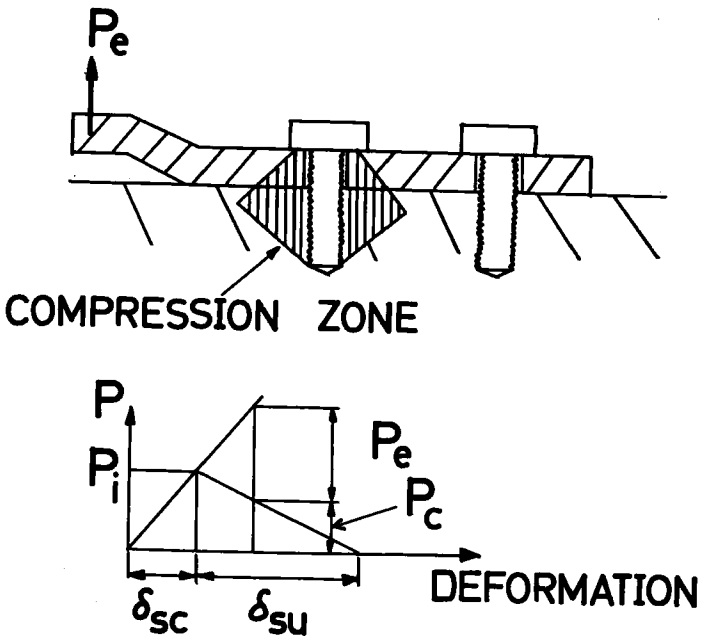

Figure 4. Tightening of screw.

P_i = *Inital screw load.*
P_e = *External load.*
P_c = *Contact load.*
δ_{sc} = *Screw elongation.*
δ_{su} = *Support compression.*

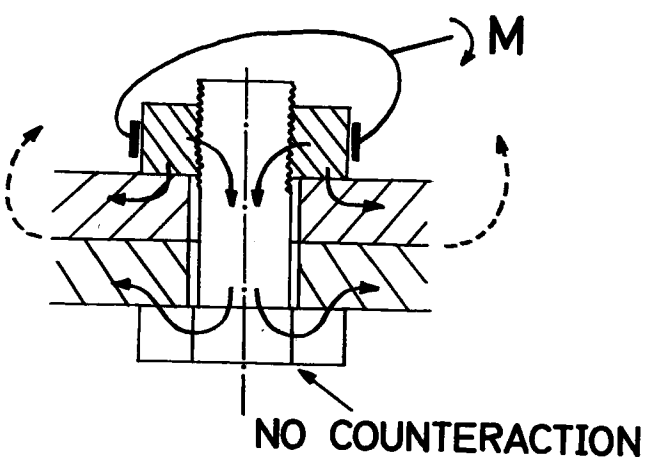

Figure 5. Flow of tightening torque.

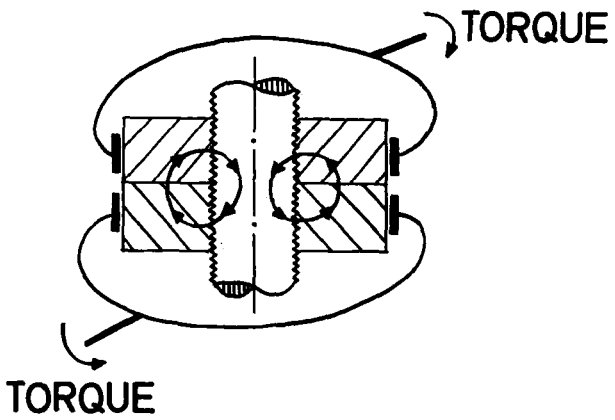

Figure 6. Lock nut. Only internal force flow.

Locking of the Screw

In those cases where screws or nuts are liable to become loose I would recommend attempts to find a suitable construction. Generally speaking, I would recommend two nuts. They should be screwed tight against one another so that the friction thereby produced in the threads will hold them firmly. They can be drawn very tight because there is no body tissue in between them (Fig. 6).

Effect of Bone Tissue

Both nails and screws are dependent on the ability of the bone to retain its elasticity, for the nail must fit tight and the screw must hold its grip. The construction should therefore be such that the bone will keep its rheological properties as long as the splint is to be worn. I feel that experiments of the *Sedlin*'s type might be useful in assessing what the bone can tolerate.

The Three Flanged Nail for the Femoral Neck

This nail sometimes loosens and slips. This is what I think happens.

When the nail is being inserted the two fragments are not firmly held together (Fig. 7). It is probably held by friction at both ends. The site of the fracture may be regarded as an elastic intermediate layer. When the patient is walking, a large pulsating axial force P_x acts on the left half of the head.

This force is taken up partly, say $\Theta \cdot P_x$, by the friction grip at the head of the screw and the rest $(1-\Theta) \cdot P_x$ is transmitted through the resilient fracture zone. This zone determines the compression distance which is also the distance the nail head slips out of the bone. This slipping of the nail held by friction results in development of heat. What happens when P_x disappears? That depends on the value of Θ.

a) $\Theta < 50$ per cent, say 30 per cent. The spring carries 70 per cent of P_x, when P_x is in action. As P_x disappears the spring load decrease is prevented by the friction force in the right fragment. This friction force has now the opposite direction. The spring load will remain at 0.30 P_x which is balanced by the friction of the right fragment. It should be observed that the same force tries to draw the left end of the nail from

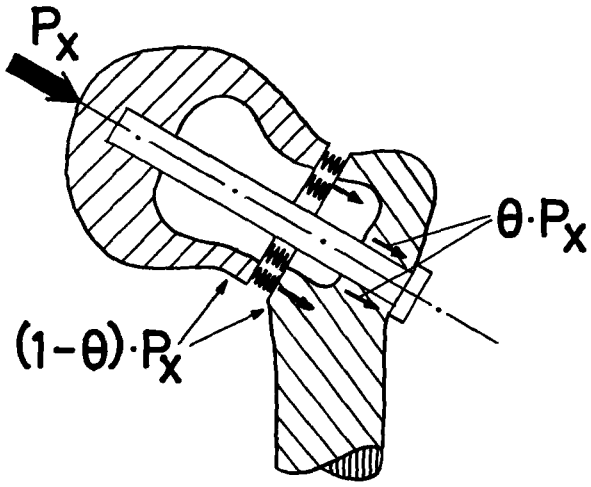

Figure 7. Collum nail.

its hole. If the friction grip of the left end of the nail is smaller than that of the right end, the nail slips out of the left hole. When $P_x = 100$ per cent is again applied the spring resists with 30 per cent, while the friction in the right fragment changes direction. While the spring is compressed from 30 per cent to 70 per cent the nail slips to the right again etc. In fortunate cases the nail may slip back again into the left hole.

If the friction grips are not equal when the nail is slipping to the left and to the right, I can imagine that the nail may work its way out.

b) $\theta > 50$ per cent, say 60 per cent. The spring carries only 40 per cent of P_x and cannot reverse the friction to slipping in the other direction. The right friction is reversed without slipping of the nail to a value of 40 per cent. This force will then draw out the left end of the nail. If the two ends have identical frictional properties, there will be no risk of nail slip.

In the light of the simple considerations above I would recommend that the head of the nail also be a barbed. Provided the healing of the fracture is not promoted by kneading and that the fractured region does not tend to contract.

The plate that is screwed to the femur to hold the nail in position does not appear to be so very good. It places large demands on the screws. Can the screws always fill these requirements? Or can the force seek one way or the other by itself. A properly mounted splint eliminates massage of the fracture area and prevents shortening of the fractured region during healing.

Concluding Remarks

Attempts should be made to find out the most suitable designs from a purely mechanical point of view of screwed and nailed appliances for various orthopaedic purposes. In cooperation with orthopaedists these designs should then be modified to satisfy the medical requirements. I think that close cooperation between mechanical engineers and orthopaedists in this respect should prove fruitful.

BONE AS MATERIAL FOR OSTEOSYNTHESIS

CORTICAL BONE AS MATERIAL FOR OSTEOSYNTHESIS

by *I. Alvik* (Oslo, Norway)

INVESTIGATIONS ON THE OSTEOGENESIS IN AUTOTRANSPLANTS OF BONE

by *H. Bohr, H. O. Ravn & H. Werner* (Copenhagen, Denmark)

Recently it has been shown by *Langenskiöld* and *Puranen* (Scandinavian Orthopaedic Meeting in Helsinki, 1964) that fresh autografts of bone have a more intense uptake of Tetracycline than autografts, which have been kept for one hour in air or three hours in saline, indicating a greater osteogenic power in fresh autografts.

In order to study this phenomenon more closely, the bone formation in autografts transplanted under various conditions was observed through repeated labelling with Tetracycline. A graft was taken by hand drilling from both iliac bones of rabbits. Some of the grafts were immediately replaced, while others were kept for one hour in saline or exposed for one hour in air before replacement. 5 days after the transplantation the animals had an injection of Terramycine (Oxytetracycline) and 5 days later an injection of Ledermycine (Demethylchlortetracycline) was given. The animals were killed 15 days after the transplantation and decalcified specimens about 70 μ thick were prepared from the transplantation sites. Through microscopy in ultraviolet light it was possible to distinguish between the bone formation at the time of labelling due to different fluorescent colours of the Tetracycline compounds used. Out of a total number of 70 transplantations 15 were made with fresh autografts, 15 with autografts kept in saline, 16 with autografts exposed to air and 10 with "Kieler" grafts (processed calf bone) to the iliac bone as a control. Further 6 fresh autografts and 9 "Kieler" grafts were transplanted to soft tissue, subfascially on the back of the animals. From the table it is seen that in about half of the fresh autografts and of the autografts kept in saline bone formation could be demonstrated between labelling on the 5th and 10th day after transplantation, while in autografts exposed to air only 14 per cent of the sections showed distinct double labelling. 10 days after transplantation the bone formation was also more pronounced in the fresh

Summary of Postoperative Bone Formation Percentage of Sections.

Graft	Transplantation		Bone formation on transplants days after operation			Total callus formation
	Method	Site	5	10	15	
Auto	Fresh	Bone	54	80	89	95
Auto	Saline	Bone	42	72	95	100
Auto	Air	Bone	14	62	83	95
"Kieler"		Bone	0	5	70	100
Auto	Fresh	Soft tissue	0	91	91	91
"Kieler"		Soft tissue	0	0	0	0

autografts and in those kept in saline than in the autografts exposed to air. 15 days after the transplantation, however, the bone formation was about equal in the different groups of transplants to bone, including "Kieler" grafts. In the fresh autografts transplanted to soft tissue bone formation was usually observed from the 10th day, but no bone formation could be demonstrated in "Kieler" bone transplanted to soft tissue. In a supplementary experiment an injection of Ledermycin was given to 4 animals one day before transplantation of fresh autografts to the iliac bones. An injection of Terramycin was given 5 days later, and the animals were killed 10 days after the transplantation. From this experiment it was shown that in the majority of fresh autografts new bone is already produced from the first day after transplantation.

THE FIRST STAGES OF ASSIMILATION OF A BONE ISOGRAFT STUDIED WITH 3H–THYMIDINE

by *J. Delu, A. Bertelsen & Bro-Rasmussen* (Copenhagen, Denmark)

Since the work of *Reichard & Friedkin,* demonstrating the utilisation of desoxyribosides in the biological synthesis of polynucleotides, thymidine in its tritiated form has largely been used for localisation of cell nuclei in their DNA synthesis phase.

Regions of proliferative activity can be detected in many tissues and the differentiation of cells from one stage to another can be investigated.

Studies of this kind have been carried out on normal growing bone in an attempt to determine which cells can be considered to be osteogenic or precursors of the osteoblasts, how rapidly they divide and differentiate into blasts and cytes.

Although sex-chromatic studies had already demonstrated that a certain amount of the bone newly laid down after transplantation was due to the activity of graft cells. *Ray & Sabet* were the the first to use 3H–Thymidine in the study of bone graft. They were able to demonstrate that labelled isograft cells could produce new bone, for they showed labelled osteocytes 2 weeks after transplantation in unlabelled animals. Unfortunately they reported some osteocytes labelled in the graft at the time of transplantation.

It is our purpose to study the very first stages of assimilation of a labelled isograft in an unlabelled animal.

6-week-old white mice were injected with 1 μc/gr of their body weight 4 times at intervals of 6 hours and were killed 2 hours after the final injection. The upper tibial metaphysis next to the growth plate was excised and put immediately into normal saline, and cut into small pieces of 1 to 2 mm^3, which were inserted in the anterior chamber of the left eye of 40 6-week-old mice highly inbred with the donors, as an isogenous cancellous graft.

The same experiment was carried out with albino wistar rats. The hosts were killed at the following intervals after transplantation: 1, 2, 3, 3½ days, then every 6th hour until 5½ days, then 6, 7, 9, 11, and 17 days. The vessels were perfused with 1:1 2 per cent blue berlin + micropaque mixture. The specimens were then fixed in neutral formalin, decalcified in 18.5 per cent Versen, embedded in paraffin and cut into 7 μ sections. The sections were put on gelatine glasses and after removal of the paraffin were dipped in 1:2 diluted photographic emulsion Ilford K 2, allowed to

dry and then stored for 6 weeks at a temperature of 4°. The sections were then developed and stained with haemotoxylin eosin and mounted.

Results:

At the time of transplantation, 32 per cent of the osteogenic cells, and 17 per cent of the osteoblast-like cells were labelled (in mouse). There was no labelling of the osteocytes. By vessel injection it could be seen that some of the labelled cells were included in the vessel wall.

It was not possible to obtain injection of the graft vessels before the 4th day. Most of the transplants were injected by the 5th day. Before vascularisation was established many cells died but labelled cells appeared to have more resistance, as the percentage of labelled cells showed an increase inside the graft. Outside the graft, cellular connection was established between the outgrowth of graft cells and the granulation tissues from the host. Labelled fibroblast-like cells were seen outside the graft.

As soon as the vascularisation was reestablished, the number of cells increased considerably inside the transplant. By the 5th day, 62 per cent of the cells were labelled, but the number of grains per cell was markedly decreased. In the injected specimens some of the labelled cells appeared to be included in vessel walls.

Pictures of resorption and osteogenesis were seen from the 5th day onward, and most of the grafts showed them by the 6th day. Cells were labelled in relation to these phenomena. No osteoclast was seen before the 6th day, and these may have contained labelled nuclei side by side with unlabelled nuclei. No labelled osteocyte was seen before the 7th day.

Conclusions:

These experiments give further support to the theory that living cells from the transplant actively contribute to:

fibrous fixation of the graft to the host bed
vascularisation of the graft
bone resorption and new bone formation.

TREATMENT OF PSEUDARTHROSIS WITH DEPROTEINISED HETEROGENOUS BONE

by *K. Baadsgaard-Sørensen* (Copenhagen, Denmark)

Pseudarthrosis on the diaphysis of both ulnae was produced in 23 rabbits by resection of the bone and interposition for 6 weeks of inert material. Transplantations with fresh autogenous bone and with deproteinised heterogenous bone ("Kieler" bone) were made as onlay grafts and a comparative study of the healing was performed during the interval from 2 weeks to 4 months. Two days before the animals were killed they received an injection of Tetracycline and of Ca^{45}. Through histological studies and investigations on the undecalcified specimens ground to 100 μ thickness it was shown that the healing effect was decisively lower with "Kieler" bone than with autografts. New bone formation corresponding to the pseudarthrosis was seen in all the autografts, but only in 20 per cent of the grafts with "Kieler" bone. No immunological reaction against the "Kieler" transplants was observed histologically.

It was concluded that deproteinised, heterogenous bone is not suitable for the treatment of psuedarthrosis.

TREATMENT OF PSEUDARTHROSIS WITH DEPROTEINISED HETEROGENOUS BONE. AN EXPERIMENTAL STUDY

by *R. Movin* (Copenhagen, Denmark)

BONE TRANSPLANTATION WITH THIN CORTICAL GRAFT FROM TIBIA

by *E. Madsen* (Sorø, Denmark)

Pseudarthrosis and delayed fracture union were treated by transplantation of a 3–4 mm thick cortical graft from the upper end of the tibia, fixed as an onlay graft by 4 vitallium screws. Resection of the bone ends was carried out only when the fracture position was unacceptable. Bone chips from the local callus were placed around and superficial to the fracture site.

51 operations are reported. 49 of these ununited fractures healed after the operation. One of the two failures was caused by bone infection.

Healing time:	1½ – 2 months	24 cases
	2 – 3 months , ...	13 cases
	3 – 4 months	6 cases
	4 – 6 months	4 cases
	6 – 8 months	2 cases

DISCUSSION:

H. Heikel (Borgå, Finland)

OSTEOTOMIES

THE INFLUENCE OF COMPRESSION ON THE REPAIR OF EXPERIMENTAL OSTEOTOMIES OF THE FEMORAL NECK

by *P. Rokkanen & P. Slätis* (Helsinki, Finland)

The beneficial effect of compression on the healing of fractures of spongious bone is well established. Fractures of the femoral neck, however, constitute a special problem, since the femoral head is often thus deprived of its blood supply and as a result becomes more or less avascular. In order to investigate the repair process of experimental osteotomies of the femoral neck with special reference to the use of compression, the following experiments were performed.

On 42 full-grown rabbits the left hip was opened, the ligamentum teres severed and the femoral neck osteotomized with a circular saw. The fragments were held together with a bolt, introduced through the center of the femoral head and tightly fixed with a nut on the lateral side of the femoral shaft. In 24 animals a spring load was added to the device, exerting a continuous 30 g/mm^2 compression on the fractured bone ends. The healing of the fracture and the subsequent changes in the femoral head were investigated radiographically, histologically and by a tetracycline labelling technique 1, 3, 6 and 12 weeks after the operation.

In the groups of animals, in which continuous compression, on the fractured bone ends was applied, more rapid fracture repair was observed. The avascular necrosis of the femoral head, following luxation and osteotomy, could not, however, be lessened, and the trabecular breakdown and flattening of the femoral head was profound in these experimental groups.

It is concluded that continuous compression on an avascular spongious fracture fragment should be used with caution, since the necrotic bone cannot withstand continuous pressure when reorganized by invading regenerative tissue.

OSTEOARTHRITIS OF THE HIP JOINT AND INTERTROCHANTERIC OSTEOTOMY

by *K. Kallio & O. Klossner* (Helsingfors, Finland)

Altogether 152 osteotomies of the MacMurray type for osteoarthritis of the hip joint were performed at the Helsinki University Orthopaedic Clinic during the years 1956–1963. The follow-up examination extended to 136 cases: 57 males and 79 females. The osteoarthritis was regarded as primary in 91 cases and as secondary in 45 cases. Internal fixation of some kind was always used: the first 8 cases had a supplementary hip plaster spica but all the other 128 cases were treated in skeletal traction, usually for 3 to 6 weeks. The observation period was above two years in 94 per cent of the cases, and 1–2 years in 6 per cent of the cases only. The patients' own assessment of the result is seen in Table 1. How the hip pain was relieved by the osteotomy is seen in Table 2.

Table 1. The patients' assessment of the result.

	Primary osteoarthritis	Secondary osteoarthritis	Total no. of cases	Percentage
Definitely better	68 cases	31 cases	99 cases	73
Somewhat better	18 cases	10 cases	28 cases	20
No change or worse	5 cases	4 cases	9 cases	7
Total	91 cases	45 cases	136 cases	100

These patients came for surgical treatment at a rather late stage of the disease. The preoperative range of the extensio-flexion movement (measured without anaesthesia) was below 60 degrees in 47 per cent of the cases, and in 35 per cent of the cases both hips were affected at least to some extent. Nevertheless the results seem to be surprisingly good. The preoperative pain had disappeared or was relieved in 90 per cent of the cases. The results seem to have been lasting, as during the observation period pain returned in only 10 per cent, although fixation of the fragments had not been rigid.

The results were better if a) the operation was performed at a comparatively early stage of the disease when the range of flexion movement was more than 60 degrees, b) the medial displacement of the distal fragment was one half the diameter of the bone or more in primary osteoarthritis, c) the fragments were tilted to a varus or valgus position instead of being in the same direction as before the osteotomy.

Table 2. Effect of osteotomy on hip pain.

	Primary osteoarthritis	Secondary osteoarthritis	Total no. of cases	Percentage
No pain during the observation cases	32 cases	18 cases	50 cases	37
No pain at first but pain returned to some extent	11 cases	2 cases	13 cases	10
Pain was relieved	41 cases	19 cases	60 cases	43
The operation had no effect on pain	7 cases	6 cases	13 cases	10
Total	91 cases	45 cases	136 cases	100

In concluding we would say that the patients seem to be surprisingly satisfied with the results of an intertrochanteric osteotomy for osteoarthritis of the hip, either primary or secondary, even when the operation was performed at a rather late stage of the disease. Nevertheless, some patients spontaneously regretted that they had not had the operation earlier. If a patient has disturbing pain and good mobility in the hips an intertrochanteric osteotomy offers a reliable solution to the problem. Theoretically an early osteotomy seems to be advisable. But it may be asked: are the patients anxious to have the operation if they have no noteworthy pain?

FIXATION WITH BOSWORTH'S SPLINT BY INTERTROCHANTERIC OSTEOTOMY

by *Ulf Lucht* (Odense, Denmark)

In the Orthopaedic Clinic of Odense Bosworth's splint was used for fixation in 64 intertrochanteric osteotomies during the period 1957–1964. 57 osteotomies were performed for the treatment of osteoarthrosis coxae and 7 osteotomies for the correction of wrong positions in the hip. Bosworth's splint, which is made of vitallium, is a straight blade-plate. It is easy to position and does not require an X-ray control on the operating table. The splint fixes rotation, flexion and abduction and supplementary external fixation with a plaster of Paris is normally not necessary. 43 osteotomies healed within 3 months and 13 healed within 6 months. In 3 cases there was delayed healing with a healing time up till 1 year and in 5 cases non-union occurred. The cause of delayed healing was a bad contact on the osteotomy site. In 2 cases the non-union was due to bad contact combined with great displacement, in 1 case a wrong placing of the osteotomy line, in 1 case a wrong placing of the splint and in the last case non-uion occurred after primary healing as the patient fractured the collum femoris 1 year after the osteotomy. On the basis of the examination of the literature and my own experiences, the following factors must be observed, if one is to avoid complication in the shape of delayed healing and non-union when using this form for internal fixation.

1) Correct intertrochanteric placing of the osteotomy line.
2) Correct placing of the splint whose point must penetrate the cortex over trochanter.
3) Good contact between the bones before fixation of the splint on corpus femoris: one must ensure that trochanter minor does not hit the caput femoris.
4) No charging before X-ray healing.

THE RESULTS OF OSTEOTOMY AND OSTEOSYNTHESIS IN COXARTHROSIS

by *Svend Rosendahl & Jørgen Ernst* (Copenhagen, Denmark)

Sixty patients with osteoarthritis of the hip were followed-up 2–5 years after upper femoral osteotomy with osteosynthesis. Two thirds were females in the 6th and 7th decade and the original diagnosis was primary osteoarthritis (21), incongruent hip (26) and other conditions (18). A good or fair result was obtained in 39 cases, unchanged or bad in 21 cases (40 per cent).

The placement of pin or plate in the trochanter makes no influence to the result of the treatment and postoperative fixation with plaster cast improves neither the healing nor the final result. There is no relation between the results and the different sort of plates and pins used for fixation of the osteotomies.

In 21 valgus-osteotomies there were 7 pseudarthroses.

In 29 varus-osteotomies there were 8 pseudarthroses.

In 15 osteotomies with simple displacement there was pseudarthroses in 2 cases.

In the 17 pseudarthrotic cases the osteotomies were placed below the lesser trochanter in 10 and in one case there was a psoastenotomy. The intertrochanteric placement of the osteotomy is important in obtaining better fixation from the psoas tendon, and so psoastenotomy should be avoided.

RESULTS OF INTERTROCHANTERIC VALGUS OSTEOTOMIES IN HIP ARTHROSIS

by *Bengt Tillberg* (Härnösand, Sweden)

During the years 1956–1960 97 intertrochanteric osteotomies were performed at the Institute for Cripples, Harnosand; two of these were bilateral and carried out according to the technique described below. The present results are based on personal follow-up of all cases.

Indications:

Primary arthrosis with aching while resting and pain on weight-bearing together with flexion of at least 60 degrees and adduction ability are essential indications. Age at operation was in 13 cases 41–50 years, in 51 cases 51–60 years and in 31 cases 61–70 years. There were 50 men and 47 women and a minimal observation period of 5 years and an average of 6.4 years.

Operative Procedure:

Intertrochanteric wedge osteotomy with lateral base according to the calculated degree of valgus in its turn depending on the preoperative adduction ability. Correction of malpositions, medial displacement of the femoral fragment and fixation with nail-plate ad modum McKee-Nissen. Physiotherapy after 3 weeks and weight-bearing after 6 weeks.

Postoperative Complications:

There was 10 per cent delayed skin healing without positive bacteriological culture, 10 per cent thrombosis and 6 per cent pseudarthrosis which were reoperated on and healed.

Subjectively 70 per cent completely satisfied, 18 per cent satisfied apart from stiffness and 12 per cent dissatisfied owing to unchanged trouble and 7 of these were reoperated on according to another method—hip plasty or arthrodesis.

16 per cent completely free from pain, 42 per cent insignificant pain of short duration, 9 per cent had solely weight-bearing pain, 3 per cent had aching only at rest, 30 per cent had both weight-bearing pain and rest aching but 18 per cent of these were considerably better than before the operation. In all, 88 per cent of the cases were found to be improved as regards pain. 87 per cent manage the activity of daily life without much trouble. 57 per cent have no stick, but 36 per cent use one. 57 per cent have returned to wage-earning, mostly light work, but 18 per cent have returned to industry, forest and agricultural work. Out of the 43 per cent who have retired, half manage to look after their home themselves.

Clinically no change in mobility is found generally, but in 70–80 per cent the malpositions are corrected.

Radiologically according to conventional evaluation a joint space, increased in breadth or more sharply marked, is observed in 56 per cent and more or less healed cysts in 50 per cent.

Conclusions:

The operation seems to be a relatively simple method of halting a destructive arthrosis process, lessening the patient's subjective troubles, and correcting possible malpositions while mobility is scarcely affected.

RESULTS AND COMPLICATIONS IN INTERTROCHANTERIC OSTEOTOMIES

by *I. Goldie & C. Hirsch* (Gothenburg, Sweden)

OSTEOTOMY OF FEMUR IN PATIENTS WITH CEREBRAL PALSY

by *Ingulf Medbø* (Oslo, Norway)

In an attempt to correct deformities of the lower extremities in patients with cerebral palsy a rotation osteotomy was performed in the subtrochanter region of femur in a number af patients.

This paper concerns the results in 27 patients. In 13 cases the operation was performed unilaterally, in 14 cases bilaterally, in all 41 osteotomies.

In 12 patients the osteotomy was the only operative procedure, in 15 patients the osteotomy was combined with soft tissue surgery.

The indication for osteotomy was partly some sort of dysplasia or maldevelopment of the hip-joint, partly walking difficulties because of internal rotation and adduction contracture of the hip-joints.

The osteotomy was performed in the subtrochanter region.

The lower fragment was rotated externally and fixed with one metal plate placed laterally or, in the older age groups, with two metal plates at a 90° angle.

At the time of surgery 26 of the patients were in the age group 5–19 years and one was older than 20 years.

They were followed up 1 to 10 years postoperatively, on an average 2½ years.

With the operative technique used there was solid healing of the osteotomy 3–6 months postoperatively in 40 out of 41 operations. In the last case a slight instability at the site of osteotomy necessitated a reosteofixation 16 months postoperatively resulting in solid healing.

There were no operative complications otherwise. No angulation of femur was observed at the site of osteotomy. One case suffered a fracture of femur in the subtrochanter region about one year after solid healing because of falling during walking-exercises.

Judging from this material there seems to be no risk of delayed healing of bone or tendency to angulation at the site of osteotomy because of assymmetric muscle pull in patients with cerebral palsy.

The functional effect of the osteotomy however, seems to be somewhat doubtful. There is therefore reason to believe that soft tissue surgery is to be preferred in patients with cerebral palsy. Bony corrections should most likely be used only as complementary procedures and perhaps with better results in adults than in the younger age-groups.

SHORTENING OF THE FEMUR by *John Hald* jr. (Oslo, Norway)

Femoral shortening is mostly performed on account of the unequal length of the lower extremities. The method of operation varies, osteotomies with overriding have been used, later reports have recommended resection of the femur. The osteotomies have been made transverse, oblique or step-formed, and different ways of internal fixation have been tried, intramedullary nails, nail-plates, screws. Additional fixation with plaster is widely used.

Material:

At our department 30 shortenings of the femur were performed in the years 1951–1964, 17 women and 13 men. Age distribution 15–40 years, average 22 years.

Preoperative Diagnosis:

Sequelae fract. femoris	6
Sequelae osteomyelit., coxit., gonit.	6
Extremitates inferiores inequales	6
Luxatio coxae congenita	5
Sequelae poliomyelit.	4
Sequelae epifysiolysis capitis femoris	2
Sequelae talipes equino-varus	1

Methods:	Fixation	
Osteotomy	Metal suture	1
Oblique with overriding	Intramedullary nail	6
Transverse and resection	Two vitallium plates	8
„ „ „	One vitallium plate and one plate of cortical,	
„ „ „	homologous bone	15

Postoperative fixation		Weight-bearing	X-ray union
None	5	11 months	11,6 months
Hip plaster spica from the day of operation	6	6.5 months	6.5 months
Hip plaster spica after healing of the operation wound	19	6 months	6.5 months

Complications:

Primary non union	4
Infection	1
Refracture	1

Results:

Clinical and roentgenological healing in all cases.

Length difference after correction:	0 – 2 cm	14
	2.1 – 5 cm	14
	5 cm	2

Three patients are using orthopaedic shoes.

Discussion:

The shortening operations were in all cases unilateral to correct different leg-lengths. Maximal shortening was 6 cm, minimal 4 cm, average 4.9 cm.

In the period 1959–1964 the method of our department was a subtrochanteric, transverse osteotomy, resection of the femur and primary internal fixation with one vitallium plate and one plate of cortical, homologous bone and sufficient screws. In this way an exact shortening was obtained, and the use of the bone-plate added the benefit of bone transplantation.

In the whole material complications were rare, but the time for healing of the complicated cases was considerably increased (up to 25 months). One patient still has infection with discharge after two years. Three of these patients had no plaster spica.

The results were satisfactory with good function and strength of the operated extremity.

Conclusions:

1. Femoral shortening is no simple procedure.
2. Resection of the femur and fixation with one vitallium plate and one plate of cortical, homologous bone seems to be a good method.
3. Long hip plaster spica is needed for 4–5 months.
4. Complications are rare, but their healing takes considerable time.

Summary:

In the period 1959–1964 femoral shortenings were performed by a subtrochanteric, transverse osteotomy, resection of the femur and fixation with one vitallium plate and one plate of cortical, homologous bone with sufficient screws. Long hip plaster spica was applied for 4–5 months. The results were good, the complications rare, but apt to take a considerable time to heal.

DISCUSSION:

T. Jerre (Västerås, Sweden)

When plates of current type are used in intertrochanteric osteotomies for fixation, it happens now and again, that the fixation is unsatisfactory because the plate obtains insufficient support medially in the proximal fragment. The result is a medial displacement of the distal fragment and a varus formation at the site of the osteotomy (Figure 1).

This complication as a rule produces indeed no destructive effects, but it is the cause of delayed healing.

In order to achieve a better fixation the author together with civil engineer Elov Tornros from Stille-Werner, Stockholm, constructed the instruments shown in Figure 2.

Following the customary intertrochanteric osteotomy with medial displacement of the distal fragment the plate is applied in the normal way. The plate, which is pointed at its proximal end, is hammered in until it has certainly perforated the trochanter corticalis. By means of further hammering inward the position of the plate is finely adjusted so that the angleplate obtains the desired grip laterally of the cortex of the proximal fragment. In order to ensure an exact fit the angleplate is supplied with the middle part in five varying lengths. It can be applied moreover in two positions proximally-distally on the plate. The angleplate should be placed so that a space of about 5 mm arises between the lower edge of the cortex of the proximal fragment and the mid-part of the angleplate; this is in order to permit compression at the osteotomy site. The plate is afterwards fixed to the femur with three screws and the angleplate (by means of preformed holes in the plate) by two screws passing through both the outer and the inner cortex of the femur. The plate has been

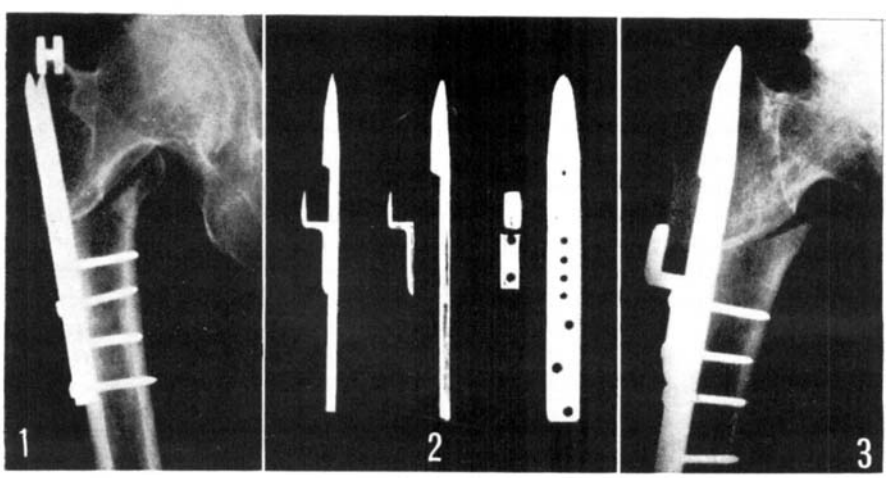

Figure 1. The most pronounced displacement in the author's series.
Figure 2. The instrument.
Figure 3. Case 1 (4 weeks after operation).

made at least up to this time in one standard size only. The osteotomy should be sited therefore under the guidance of the X-ray picture, so that the length of the plate permits its point to perforate the trochanter corticalis. With a very strong skeleton therefore the osteotomy should not be made too obliquely.

During the past month the author has used this instrument in three operations (Figure 3). Technically no difficulties arose and the primary fixation is very stable. The patients were allowed to get up 3–4 days after the operation and then walked with full weight-bearing using two crutches for support.

The primary results in these three cases have been considerably superior to those achieved previously by the author when he used conventional plates of various types.

H. Dahl (Oslo, Norway)

O. Johansson (Stockholm, Sweden)

L. Unander-Scharin (Malmö, Sweden)

The indication for unilateral osteotomy are indeed pressing when taking into consideration the often considerable incorrect weight-bearing which arises in the back if no corrective splint is used. Corrective splints, shoe elevation etc., are aids which are often not accepted by the patients.

The indication area for bilateral shortening osteotomy is extremely narrow.

A number of methods for shortening have been reported. At the Orthopaedic Clinics in Harnosand and Malmö a subtrochanteric osteotomy has been evolved in which the fixation is made with nail and plate according to MacLaughlin. In this we were anxious to place the topmost nail on a level with the trochanter minor and above the osteotomy. A plate with 7 holes has always been used. Early getting up has been adopted without any plaster fixation. Out of 20 bilateral cases operated on according to this principle only 1 case increased delayed heeling. This case was supplemented by the placing of a bone graft above the osteotomy.

H. Støren (Oslo, Norway)

Regarding the second part of Medbø's lecture: "The Effect of rotation osteotomy on the function of the lower extremity in these patients"—then the results he has obtained confirm the old and well grounded principle that no bone operation should be undertaken in a spastic malposition until muscular balance has been achieved, that is, until the effect of the muscles producing the malposition is eliminated to a suitable extent. At the annual congress of the Norwegian Surgical Association in 1937 I gave a lecture, based on follow-up investigations and direct observations, in this theme ("Tendon transpositions in spastic conditions of the lower extremities"—reproduced in the "Norsk Magasin for lægevidenskapen", August, 1938). It has been shown that the principle maintained here—and particularly illustrated in the results of operations on the feet—was a correct principle to follow, not only in the case of feet, but also in spastic malpositions which affect the upper parts of the lower extremities. Rotation osteotomies of the femur secondary have, only rarely been necessary in the relatively large number of operations of this kind which I have performed during the course of the years.

If the procedure is limited to the bone operation, as I have seen done, and has

evidently been the case in part of Medbø's series, the spastic muscles which predominate will in a large number of cases gradually bring back the malposition. A derotation then results on the femur. But soft tissue operations make special demands on the surgeon. Apart from the absolutely rational technique he must have good personal experience and every patient must be observed over a good period of time in advance, owing to the variable nature of the symptoms so often present in these patients. Dr. Medbø is fully correct to say that each case should be carefully evaluated preoperatively.

I hope that Doctor Medbø will continue to work on this very important and interesting subject and I believe that he will find much material on which to base future research if he studies what has been previously achieved and the experience accumulated on this subject in our own country.

E. Sandaa (Sandvika, Norway)

H. Novotny (Oslo, Norway)

CLINICAL PROBLEMS ON OSTEOSYNTHESIS IN FRACTURES OF THE EXTREMITIES

A TECHNICAL NOVELTY: A.O.-COMPRESSION PLATE AND SCREW

by *E. Moberg & G. Hansen* (Gothenburg, Sweden)

A METHOD FOR ACUSTIC REGISTRATION OF FRACTURE HEALING

by *A. Jernberger* (Stockholm, Sweden)

In collaboration with M.D. *Bertil Jacobson* at the Department of Medical Electronics at Karolinska Institutet, a method has been developed for measuring the transmission of vibrations through callus in healing fractures.

At the middle of tibia an electromagnetic vibrator is fixed with a nail. The vibrator is run by a tune generator at frequencies from 20–10 000 cycles/sec. One microphone (piezoelectric crystal) is fixed to the vibrator and obtains the oscillations of the vibrator-nail and another two microphones are fixed with nails in the same way to tibia at a constant distance proximally and distally to the vibrator, and these two obtain the oscillations transmitted through the bone. The voltage of the electric current from the oscillations transformed by the microphones will be reduced when the oscillations are transmitted through the bone and much more when there is an instable fracture or pseudarthros situated between the vibrator and one of the other two microphones.

The electric current from the microphones is passed through three amplifiers to a three canals recorder, while the tune generator runs from 20–10 000 cycles/sec. Meanwhile the sinusoidal appearance of the current from the microphones is controlled on an oscilloscope screen.

The spectrum of resonance frequencies and transmission variations from a patient with a 6 month old instable tibia fracture is demonstrated. The loss of transmission capacity is large over the fracture compared to that over intact bone of the same leg

and to that of the uninjured tibia of the other leg. On a preparate the very slight transmission of vibrations over intact fibula is shown and the very good transmission between tibia fragments with a minimum of cortical contact of bone.

The method has to be more refined if an evaluation of resonances and loss of transmission capacity is to give exact information of the fracture stability.

OSTEITIS FOLLOWING OSTEOSYNTHESIS—TREATMENT AND PROGNOSIS

by *P. Thestrup Andersen* (Copenhagen, Denmark)

During the period 1.8.1960 to 31.7.1965 a total of 376 osteosyntheses were performed on extremity fractures in the Surgical Department R of the Gentofte Hospital, Copenhagen. Among these cases 7, or 1.6 per cent of the total series, developed postoperative infections in the form of osteitis. These patients were 4 males and 3 females in the age range 43–81 years.

Age Sex	Cause	Type of Fracture	Primary treatment	Course
43 ♀	Skating	Uncompl. comminuted fr. of lower leg	Immediate osteosynthesis (Eggers method)	Staph. aureus, exposed osteosynth. material
59 ♂	Traffic-accident	Compl. fr. of lower leg (uncompl. fr. of femur and scapula)	Reduction of lower leg fr. Osteosynth. of femoral fracture	Non-healing of lower-leg fr. Cerclage osteosynth. with bone graft. (17) Staph. aureus
74 ♂	Traffic-accident	Uncompl. fr. of lower leg (oblique fr.)	Osteosynth. (Lane method)	Exposed bone + splint. Staph. aureus
56 ♂	Fall in street	Uncompl. fr. of lower leg (oblique fr.)	Osteosynth. (Lane method)	Abscess in wound, exposed splint
78 ♂	Fall at home	Subcap. fr. of fem. neck	Alloplasty (Moore method)	Pt. senile, incontinent. Esch. coli inf. in wound. Died 3½ month later
81 ♀	Fall at home	Pertroch. fr. of the femur	Osteosynth. (MacLaugh-method)	Severe Staph. aureus infect., alarming. Therefore, osteosynth. and traction material were removed
78 ♀	Fall at home	Pertroch. fr. of the femur	Osteosynth. (MacLaugh-method)	Severe Staph. aureus infect., alarming. Therefore, osteosynth. and traction material were removed

One patient (a 78-year-old man) died of sepsis 3½ months after alloplasty by the method of Moore. Of the remaining 6, four had comminuted fractures of the lower leg and 2 comminuted pertrochanteric fractures.

The principles of treatment after the infections became manifest were conservative. The osteosynthesis material was not removed until the fractures were stable.

After-treatment consisted in long-continued splinting.

Treatment with antibiotics was guided by cultures and sensitivity determinations and was continued until the skin had healed completedly and the general condition (assessed by the temperature, E.S.R. and Hb level) was normal.

The prognosis in the cases treated here was good.

One patient had died of an irrelevant cause at the time of follow-up.

The other 5 had no symptoms from their osteitis.

In deciding the indications for osteosynthesis regard must be paid to the patient's physiological age and the type of fracture, while an open fracture *per se* does not

Systemic after-treatment	Local after-treatment	Duration of bandag.	Follow-up
Antibiotics *only* after culture and sensitivity determ.	Plaster cast, splint removed 5 mo. afer removal of sequestrum	1 year 9 months	2 years later. Fit.
Antibiotics *only* after culture and sensitivity determ.	Plaster cast. Osteosynth. material + sequestr. removed 8 months later	1 year 4 months	1¾ years later. Fit.
Antibiotics *only* after culture and sensitivity determ.	Plaster cast. Splint not removed	3 months	4 years later. Fit.
Antibiotics *only* after culture and sensitivity determ.	Splint removed 3 mo. later, fr-healed	3 months	4½ years. Fit.
Antibiotics *only* after culture and sensitivity determ.			
Antibiotics *only* after culture and sensitivity determ.	Removal of osteosynth. mater. 3 mo. later. Drainage. Removal of sequestr. Traction	Bed rest 8 months	Healing w. 7 cm shortening. Walks with 2 English canes
Antibiotics *only* after culture and sensitivity determ.	Removal of osteosynth. mater. 1 mo. later. Drainage, traction	8 months Bed rest 4 months Fract. and wound healed	Had died of irrelevant cause

contra-indicate surgery. In the case of elderly, debilitated patients with severe, comminuted fractures it is well to make the indications strict.

DISCUSSION:

O. Lindahl, K. Moberg, E. Madsen, K. Solheim, I. Palmer, A. Jernberger, S. Friberg, C. Hirsch, H. M. Dencker.

EARLY DIAGNOSIS OF INTERPOSITION IN FRACTURES WITH THE AID OF A VIBRATOR by *Hans Dencker & Erik Moberg* (Gothenburg, Sweden)

It is important, in definitive treatment of a fracture, to ascertain at an early stage whether the healing process is hindered by soft-tissue interposition between the fracture ends. Considerable observation time may be lost before the situation is clarified. To simplify the problem a vibrator has been constructed with which interposition can often be definitively diagnosed.

A schematic diagram of such an apparatus is given in Figure 1. It consists of a vibration generator, an amplifier, and a measuring instrument. A tone is produced by the generator at a frequency of 1000 Hz, and a transducer is employed to convert the sound to mechanical vibrations. The vibrations transmitted through the bone are taken up by a receiver which varies with the size of the vibrations. The amplifier is composed of a function and sensitivity selector, and of a filter which eliminates irrelevant vibrations. The apparatus is fitted with a logarythmic amplifier which simplifies the measurements.

With normally healing bone and with fractures having contact of the ends of the bone, the vibrations are always conducted at a level giving measured values of more than 70. With interposition of soft-tissues considerably lower values, not more than 30, are obtained. Low values, < 30, always mean interposition, while high values, > 70, do not always indicate that the contact between the broken ends is sufficiently good to obtain satisfactory fracture healing within an acceptable time, because only minor contact is adequate to conduct the impulses at full level.

The vibrator is particularly useful with fractures of the femur or humerus. With forearm and lower-leg fractures, the method is not as reliable; the presence of interposition can be hidden by conduction of the impulses via an intact bone or a bone which permits transfer through the fracture region.

To summarize: Interposition with regard to femoral and humeral fractures can be definitively diagnosed with the described vibrator.

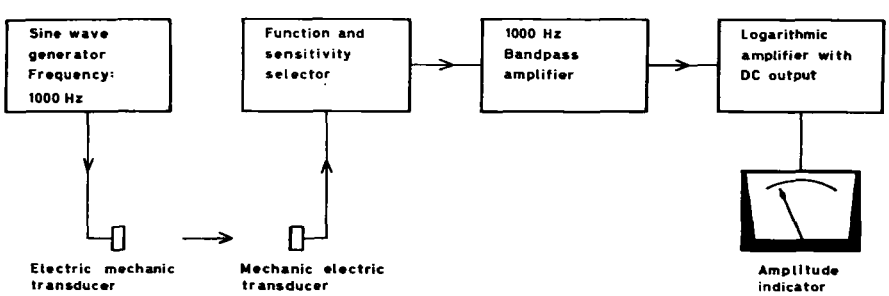

Figure 1. Schematic diagram of the vibrator.

FRACTURES OF THE FEMUR

FIXATION OF FEMORAL SHAFT FRACTURES BY TWO STRONG VITALLIUM PLATES by *E. Madsen* (Sorø, Denmark)

Fractures of the shaft of the femur (28 transverse, 6 comminuted and 1 oblique) have been treated by fixation with 2 strong vitallium plates placed laterally and anteriorly on the shaft, and each fixed by 4 vitallium screws with a good hold on the cortical bone. This fixation is so solid that active mobilisation can be started at once. The method is preferred to Küntschner's nailing where fixation is often insufficient, particularly in preventing small rotation movements. Poor fixation may result in delayed union, shortening and angulation, and there is a risk of bending or breaking of the nail. Furthermore, should infection complicate nailing, it will tend to be serious and invalidating.

These possible complications have been avoided using 2 strong vitallium plates. 35 cases have been followed up.

Results:

Ideal	24 cases
Good	7 cases (knee 180/40–65°, normal gait and working ability)
Fair	2 cases (knee 180/40–80°, shortening 0–1 cm, angulation 0.3°)
Bad	2 cases (knee 180/50–130°, shortening 0–1 cm, angulation 0.3°)

There was only one case of shortening (1 cm) and one case of angulation (2–3°). There were no cases of infection.

Healing time:	1½ – 2 months	20 cases
	2 – 3 months	8 cases
	3 – 4 months	5 cases
	4 – 5 months	1 case
	5 – 6 months	1 case

FEMORAL SHAFT FRACTURES by *K. Solheim* (Oslo, Norway)

In the 10-year period 1955–1964, 242 patients with femoral shaft fractures were treated at Surgical Department III, Ullevål Hospital, Oslo, Norway. The majority of the patients over 20 years of age was treated with operative reduction, internal fixation and early active mobilization (Figure 1).

Plating was the most common procedure employed (Table 1). All deaths amongst the operated patients were due to bronchopneumonia and cardiac failure in old patients. There was no deaths of embolism or severe thrombo-embolic complication in the operatively treated group, while 4 patients died suddenly of pulmonary embolism or fat embolism in the group treated with traction only. The 6 other deaths in the traction group were due to other injuries. Only one case of arterial injury was encountered; treated successfully with "intimectomy".

The patients were in most cases treated by tibial traction before operation (Table 2). No case of infection was encountered amongst the open fractures.

The plating was supplemented with wiring in some cases and two plates were used

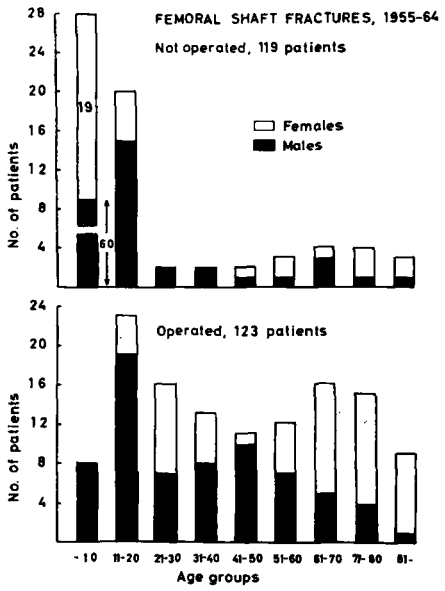

Figure 1.

Table 1. Femoral shaft Fractures, 1955–64.

	No. of pat.	Deaths	Osteomyel.	Re-op.	Removed plate, etc.
Plating	72	3	1	7	11
Wiring	19	2	1	2	6
Nailing	16	1	–	–	7
Suture	14	–	–	–	1
Others	2	–	–	1	–
Traction	119	10			

in 11 patients, one laterally and one anteriorly placed (Table 3). In the one case complicated with osteomyelitis, the infection subsided when the plate was removed.

Six patients had to be re-operated; in four this was due to fracture of the plate and in two, due to non-union. All these patients were successfully treated by new plating with two plates and autogenous transplantation of cancellous bone. Nail plating was used in some cases of fractures through the upper and lower part of the femoral shaft, with the nail in the caput femoris or in the femoral condyles, respectively.

Of the 72 patients treated with plating and mobilization immediately after the operation, 63 were followed up 7–90 months postoperatively. Nine were dead. In 3 cases the result was not good (poor knee joint function). Two of these patients,

however, were operated after 3 months in skeletal traction. In the remaining 60 patients, the anatomical and functional results were excellent.

Table 2. Femoral shaft fractures, 1955–64.

	No.	*Time injury – oper.*
Plating, 72 patients		
9 *open,*	7	mean 22 days (7–56 days)
	2	12 and 19 weeks
63 *closed,*	2	immediately
	59	8 days (2–28 days)
	2	12 weeks

Table 3. Femoral shaft fractures, 1955–64.

	Osteomyel.	Re-op.	Removed plate, etc.
37 plating (one plate)	–	6	5
7 plating and wiring	–	–	–
13 nail plating	1	–	4
4 nail and wiring	–	–	1
11 plating (two plates)	–	–	–

OSTEOSYNTHESIS WITH A THICK MEDULLARY NAIL IN NON-UNION OF LONG BONES by *L. E. Laurent* (Helsingfors Finland)

The material consists of 26 cases of non-union located in 12 cases in the tibia, in 8 cases in the femur, in 4 cases in the humerus and in 2 cases in the radius and ulna respectively. The medullary cavity was reamed out with the aid of hand burrs and a pneumatic burr. The pseudarthrosis was then fixed with a thick medullary nail. The diameter of the nail was 14–16 mm in the case of non-union of the femur, in non-union of the tibia 11–15 mm, of the humerus 11–14 mm and of the radius and the ulna 6 mm. Open operation was carried out in all cases except in two of non-union of the tibia when closed nailing was performed. In 10 cases the osteosynthesis was completed with a free bone graft. The method seems to be very suitable in cases of non-union of the shaft of the femur or the tibia permitting mobilisation and weight-bearing very soon after operation. Immobilisation in a plaster cast could be avoided in all cases of non-union of the femur. In six of the cases of non-union of the tibia a walking plaster cast was used for six weeks. The method was less suitable in the case of non-union of the humerus, because the nail loosened and the head of the nail caused irritation of the shoulder joint.

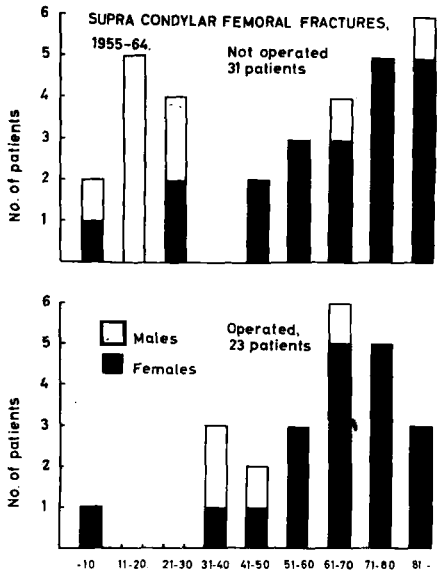

Figure 1.

SUPRACONDYLAR FEMORAL FRACTURES by *K. Solheim* (Oslo, Norway)

In Surgical Department III, Ullevål Hospital, Oslo, Norway, 54 patients with supracondylar fracture of the femur were treated in the 10-year period 1955–64 (Figure 1). The non-operated patients were cases without dislocation of the fracture or, in a few cases, patients in too a bad condition for operation. The majority of the

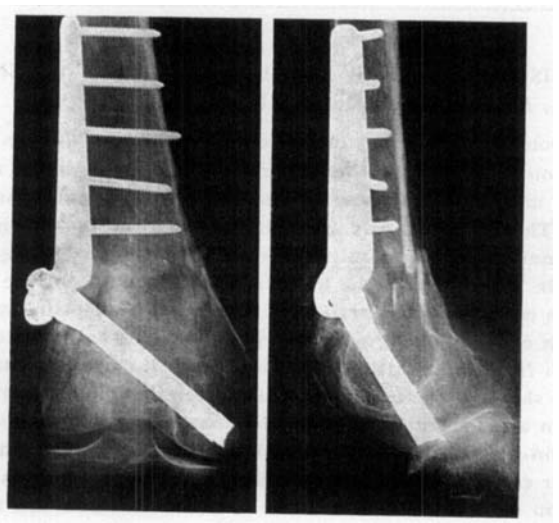

Figure 2.

patients were elderly women and this has an important bearing on the choice of the method of treatment. Most of them have osteoporotic bones and furthermore, they will not tolerate a lengthy immobilization. We therefore treat this fracture with open reduction, internal fixation with a McLaughlin's nail plate and early mobilization. The threeflanged nail is placed through the femoral condyles, and this gives a good fixation also in cases where the condyles are dislocated from each other. After reduction, the plate are screwn tight to the nail and fixed to the femoral shaft with screws engaging both cortices (Figure 2). In this way, a firm fixation of the small distal fracture fragment to the proximal is secured, permitting early mobilization.

Table 1. Supracondylar femoral fractures.
Results

Excellent	Gate normal
17 patients	No pain
	Extension normal
	Flexion at least 120°
Fair	Some pain
2 patients	Use stick
	Extension normal
	Flexion 35° and 90°

Observation time, mean 16 months (6–35 months)

With this method, 22 patients were treated. Only one case of arterial injury was encountered, successfully treated with "intimectomy". There was no case of post-operative death but one case of non-fatal pulmonary embolism, and 3 cases of wound infection, one of which was severe, requiring removal of the nail plate.

In 3 patients, redislocation occurred; in one case due to fracture of the plate and in a further two cases re-operations were performed due to increasing valgus deformity. The further course in these 3 patients was uneventful. Some patients experience pain over the nail head due to a bursa forming. In 6 patients, these troubles required the removal of the plate nail.

The results of the treatment of this difficult fracture along the above-mentioned lines have been very satisfactory (Table 1).

DISCUSSION:

E. Moberg, G. Danckwardt-Lilliestrom, P. Slätis.

FRACTURES OF THE LOWER LIMB

STABLE OSTEOSYNTHESIS A.M. KUNTSCHER IN THE TREATMENT OF FRACTURES OF THE CRUS by *P. O. Grönblom* (Vasa, Finland)

Immobilisation of fractured extremities has its disadvantages. Although quite good results in fracture healing can be obtained, there are such drawbacks as heavy plaster casts, restricted motion, muscle atrophy, permanent joint contractures, and as a result of all this, mental strain. Stable osteosynthesis a.m. Küntscher, where a thick medullary nail is used, does not require immobilisation at all, and the patient can tread on the fractured leg while the process of healing is going on.

In the Central Hospital of Vasa, Finland, fractures of the crus have been treated by the technique since 1960. In this report only the earliest cases, 32 in number, with an observation period of more than four years, on an average, have been considered.

The duration of treatment in hospital was 2½ weeks. Mobilisation of the joints was begun as soon as the pain in the wound was relieved, and when discharged from the hospital all these patients walked with the aid of crutches and began partial weight-bearing. After 2½ months the crutches were abandoned. In some cases the patient was able to walk without support two weeks after the osteosynthesis.

Complications accompanying the osteosynthesis itself are splinters in either of the fragments when the nail is hammered in. The ream may also make a score in the cortex, and in these cases plaster casts have been applied to avoid complications in connection with weight-bearing. The point of fracture was opened and open reduction was made in five cases. There was no infection in this group.

A follow-up of the material 4–5 years later shows no restriction worth mentioning in the functions of the knee and ankle joints. No later fistulations or refractures were reported.

From experience gained from complications and from the point of view of advantages it may be concluded that the technique is very good in a selected osteosynthesis material. If the fractures of the tibia are too low down or in case of long spiral fractures this method is not convenient. The medulla nail should be as thick as possible, at least 12 mm in diameter and sufficiently long to ensure stability. The place of entry should be as high up on the tibia as possible to give the medulla nail bending elasticity and to diminish the danger of splintering. The nailing should preferably take place at once, but in cases of infected open fractures not until the risk of infection has been eliminated. X-ray control is necessary for successful osteosynthesis. The length and thickness of the medulla nail should be carefully measured before operation. If the osteosynthesis fulfils the requirement of stability, this permits a certain amount of weight-bearing after 2 weeks, and the patient can return to work long before consolidation has taken place.

INTRAMEDULLARY NAILING OF TIBIAL SHAFT FRACTURES. A COMPARISON WITH CONSERVATIVELY TREATED CASES by *P. Slätis & P. Rokkanen* (Helsinki, Finland)

The series consist of 32 fractures of the tibial shaft in 31 patients treated with intramedullary nailing. In all cases the operation was performed within 6 weeks after the fracture. The intramedullary canal was reamed out and a heavy nail introduced through the tibial tuberosity, using a closed nailing technique.

The fractures were classified according to the trauma mechanism, degree of primary dislocation, degree of comminution and severity of soft tissue injury. From a series of 125 conservatively treated tibial shaft fractures 53 fractures/52 patients with a comparable type of fracture and soft tissue injury were extracted for comparison with the nailed material. The conservatively treated control group included 10 fractures subsequently bone grafted due to delayed union.

The results of treatment in the two groups 1 year after the accident were evaluated.

There were no clear-cut differences in walking and working ability between the nailed and conservatively treated cases. Of the nailed cases, 84 per cent had resumed work, compared with 87 per cent in the conservatively treated group (including the grafted cases). The best results of intramedullary nailing were obtained in fractures with slight displacement, no comminution and only slight tissue injury, if any. The indications for intramedullary nailing of tibial shaft fractures should be limited to cases where fracture retention proves difficult with plaster and/or where the fracture is complicated by superficial soft tissue injuries. Intramedullary nailing has no place as a routine procedure in the treatment of tibial shaft fractures.

OSTEOSYNTHESIS AND SOFT TISSUE INJURY IN FRACTURES OF THE SHAFT OF THE TIBIA by *Per Edwards* (Malmö, Sweden)

My conclusions were based on data from 492 fractures of the shaft of the tibia in adults, treated in Malmö General Hospital 1949–63 and on observations from more than 3,500 fractures surveyed from the literature. The former group consists of a control series (311 fractures; 1949–60) and a prospective series (181 fractures; 1961–63). The technique of osteosynthesis was discussed with regard to three types of fracture—long oblique, closed and open transverse or comminuted fractures. Special attention was paid to the development of osteomyelitis. The two series differ in that in the prospective series particular attention was paid to associated skin lesions with the object of preventing bone infection. The frequency of osteosynthesis in the different types of fracture was similar in the two series. In the prospective series blind nailing was performed to a large extent in transverse and comminuted fractures, and primary transplantation of skin was carried out in fractures with large wounds. The following conclusions could be made:

1) There is a close relationship between skin necrosis and osteomyelitis.

2) Long oblique fractures are well suited for open reduction and internal fixation. There is a minute risk of complications from this treatment.

3) In closed transverse and comminuted fractures treated with open reduction there is a high frequency of complications—osteomyelitis in more than 10 per cent. Closed methods including blind nailing should be preferred.

4) In open transverse and comminuted fractures, whether treated by osteosynthesis or not, there is a high incidence of complications—18 per cent of osteomyelitis in the control series. Osteomyelitis can to a large extent be prevented if skin incisions are avoided in the fracture area and primary skin transplantation performed when needed. Even if a fully stable fixation is not attained osteosynthesis may increase the chance of a successful skin grafting.

Reference: Per Edwards (1965) Fracture of the Shaft of the Tibia: 492 Consecutive Casss in Adults. Importance of soft tissue injury. *Acta orthop. scand.* Suppl. 76.

CERCLAGE IN FRACTURES OF THE TIBIA by *K. E. Hagelin* (Sweden)

DISCUSSION:

L. Moberg, C. Hirsch, S. Olerud, H. Nissen-Lie, P. Edwards, E. Thomasen, V. Oram, O. Lindahl, K. Dohn.

FRACTURES OF THE RADIUS AND THE ULNA

FRACTURES OF THE RADIUS AND THE ULNA TREATED BY A SPECIAL METAL PLATE by *P. Forssblad* (Gothenburg, Sweden)

DISCUSSION:

E. Moberg, C. Hirsch, E. Madsen, I. Palmer, V. Oram, K. Solheim, S. Olerud, H. Heikel, P. Forssblad, R. Movin, E. Thomasen, P. Slätis, L. Hagelström, I. Alvik.

VARIA

A SIMPEL METHOD OF TRANSFIXATION IN ANKLE JOINT FRACTURES by *H. S. Mattsson* (Sweden)

OSTEOSYNTHESIS IN CLAVICULAR PSEUDARTHROSIS by *Knud Jansen* (Copenhagen, Denmark)

Non-union of clavicle fractures occurs in approximately 0.1 per cent. Forty cases were referred for treatment to the Orthopaedic Hospital of Copenhagen within 15 years.

Thirteen cases were treated by physiotherapy, three by resection and seventeen by osteosynthesis with bone graft, screws, Kirschner wire or cerclage. Five out of twelve cases were healed by one operation, one out of four was healed after two interventions, and one case was operated thrice without success.

Total failure: 11 out of 17.

A new process has been applied in eight cases, one of which had two earlier operations.

Technique:

Incision parallel to one half inch inferior to the clavicular bone. Incision of periosteum, and subperiosteal dissection of bone ends. Resection of sclerotic bone ends (⅓–½ inch).

Fixation by a threaded Steinman pin, which by an electric drill is passed retrograde into the medial part, perforating the anterior cortex medially. After approximation of bone ends, the pin is drilled past the fracture line and into the lateral fragment until stability has been achieved (one to two inches), and the pin is cut leaving one inch free subcutaneously. A cortico-cancellous bone block (approx. 2 by

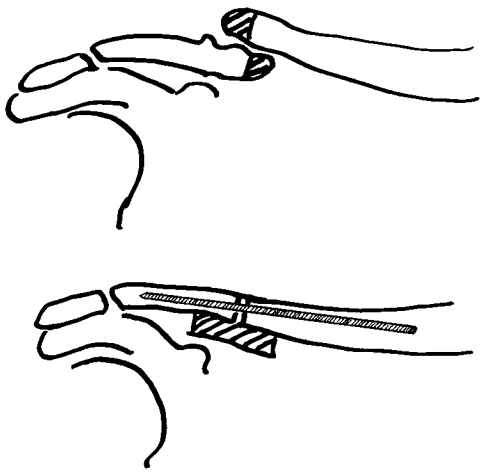

Figure 1.

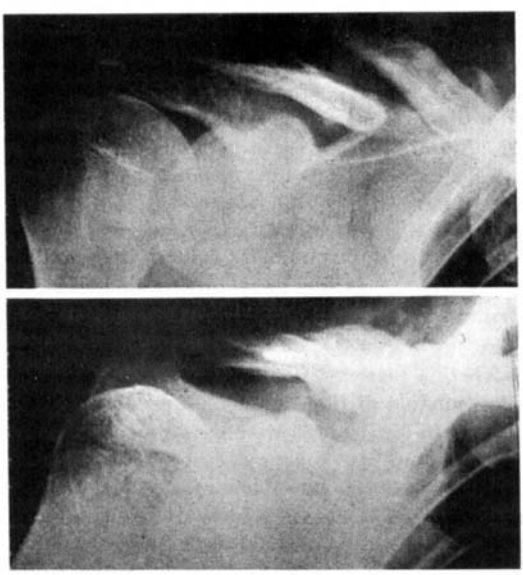

Figure 2.

½ by 3/9 inch) is taken from the ilium and fixed below the fracture by a heavy silk suture which is placed longitudinally and passed through vertical drill holes in graft and clavicle. The suture is tightened by pushing wedge shaped bone pieces between thread and upper surface of the bone.

Periosteum, platysma and skin are sutured.

A plaster shoulder spica is applied for 12 weeks. The application may be postponed until the 3rd or 4th postoperative day.

Problems:

1) The selection of pin size should be made by evaluation of the bone diameter.
2) By bone drills should be omitted as this may damage the bone cortex.
3) The plaster bandage period was in one case reduced to 6 weeks. In spite of promising X-ray findings, pain and superfluous callus formation indicated a new bandage 6 weeks later, and union was achieved.

Complications: Wound drainage occurred in two cases. Both healed after local revision.

3 pins were removed later, the indication being soreness at the medial subcutaneous end of the pin.

Results: In all eight cases solid union was achieved.

One case had slight acromio-clavicular symptoms. Otherwise all patients had relief and restoration of function.

DISCUSSION:

H. Støren (Oslo, Norway)

From observing the work of the orthopaedic clinics alone one easily gains the impression that clavicular pseudarthroses occur more rarely than is in fact the case. I have the impression that in Norway a large number of our general surgical departments have had experience of a case from time to time,—and they can on the whole demonstrate good results from the various methods employed. Lane's plate and thin cortical tibia transplants often seem to be used, but correctly inserted metal wire sutures with tibia transplant seem to have given equally good results. In the unsuccessful cases which I have received for reoperation, technical errors during operation or during postoperative treatment have existed. When resection of the outer clavicular end is involved, then in each case this (in my opinion less favourable) treatment ought not to extend medially of the roracoclavicular ligaments.

More difficult than the simple clavicular pseudarthroses are the defect pseudarthroses.

The ideal aim in treating these is: firm healing, without shortening, and prevention of damage to the function of the shoulder joint during lengthy immobilisation. This was achieved by the following procedure in a transport worker aged 47 who had been unable to work for more than a year due to a 3–4 cm large defect in the midpart of the clavicle following removal of an intermediate bone fragment owing to pain after a clavicle fracture. The pain was almost absent after the removal, but the arm was powerless—he could not support himself on it and he could not resume work.

The sclerotic bone ends were resected by means of a normal intraclavicular longitudinal incision. A Rush pin was introduced from the medial side and one from the lateral side through holes drilled in the medullary cavity with an awl. Two T-shaped tibial transplants were made so that the vertical thick section—constisting of periosteal cortex, cancellous bone—corresponded to the gap between the two bone ends when they were maximally separated from each other. This section was then pressed into the defect in this position and the horizontal "wings" of the T adjacent to the chiselled-off upper surface of the clavicle were fixed to these by cerclage. After this the shoulder joint could be moved without causing movement at the fracture site.

The arm was placed in an abduction splint for 6 weeks—but passive exercises of shoulder and elbow joint were carried out daily. After 8 weeks he commenced active movements. After 6 months the cerclage wires were removed as they showed a tendency towards eroding. X-ray showed at this time abundant bone formation. He was now allowed to take up light work. The treatment result was full mobility of the shoulder joint—no muscle atrophy and both shoulders equally abroad. The two Rush-pins have not been removed. He walks with them now after 9 years and has no difficulty with them. He has been employed full-time as a heavy worker during the whole period. There is a fundamental difference between this method and *Nicoll*'s—an *active* pressure is exerted in my method by the two fragments towards the transplant from both sides.

This case is described in *Acta Chir. Scandinav.* **132**, 243–247, 1966. Operative Correction of Clavicular Defect. A new surgical method.

FRACTURA COLLI FEMORIS—THE STEEP NAIL

by *Johs. Spotoft* (Kalundborg, Denmark)

Fracture colli femoris is an increasing medical-social problem. The number of cases has redoubled in the course of ten years, and soon ten per cent the beds in a general-surgical ward will be occupied by these fractures.

As long as the treatment is not centralized, the simplest method, yielding good results, is to be recommended.

This is a three-falanged nail placed very steeply, resting on the medial collum cortex and fixed in the firm caput so as to slide down into trochanter concurrently with the collum resorption. In this way there will constantly be a functional pressure at the site of fracture so that healing will be facilitated.

In the course of 20 years this method has resulted in my hands in more than 95 per cent healing and very few re-operations.

A NEW NAIL FOR TREATMENT OF MEDIAL FRACTURES OF THE NECK OF THE FEMUR by *N. Rydell* (Gothenburg, Sweden)

RESULTS OF OPERATIVE TREATMENT WITH CERCLAGE IN TRAUMATIC RUPTURE OF THE PUBIC SYMPHYSIS

by *Åke Gustafsson* (Linköping, Sweden)

The group consists of 8 patients with traumatic lesion of the pubic symphysis. The material consists of patients treated 1960–65 at the Sahlgrenska hospital, Gothenburg. The patients were treated operatively by cerclage of the ruptured symphysis. The cerclage wire was put through the foramina obturatoria instead of, as usual, through drill-holes in the os pubis. By this modification no cutting through of the bones was seen to occur. The results could be followed up in 6 patients and were encouragingly good. Compared with the results of nonoperative treatment published in the literature, there is a shorter period of bed-rest and a much shorter period for return to ordinary work. Operative fixation in these lesions by means of cerclage through the foramina obturatoria is therefore recommended.

DISCUSSION:

P. Holstein, I. Palmer, K. Jansen, E. Moberg, H. Støren, G. Wiberg, R. Movin, S. Friberg, I. Alvik, A. Nachemson, K. Haug, N. Rydell, H. K. Dahl.

ARTHRODESIS

ARTHRODESIS OF THE SHOULDER, A CLINICAL EXAMINATION

by *Karl-Erik Olsson* (Enskede, Sweden)

68 shoulders were operated on with arthrodesis at the Orthopaedic clinic of Karolinska Institutet, Stockholm between 1941 and 1966. The reasons for the operations are seen in Table 1.

Symptomatically the operations were performed because of paralysis in 56 cases, stiffness in 5 and pains in 7 cases. There was contraction power before the operation in the muscles of the shoulders in all patients. All shoulders were intraarticularly fixed, 34 per cent without and 66 per cent with screw or nail. The former group is most represented in the younger ages, before the epiphysis-line closed. It was not proved if the different methods of osteosynthesis have anything to do with the growth of the arm after the operation.

The fixation of the humerus to scapula at the operation in abduction, forward elevation and rotation ought not to be the same in every cases. The position must be judged with regard to the strength in the muscles of the shoulder, the mobility of the elbow joint and the future use of the arm.

Roentgenologically 87 per cent of the arthrodesis healed at the examination in 1966. Of the rest 85 per cent seemed to be functionally improved because of the increased stability in the shoulder from the fibrous callus.

The ability to reach the mouth and the back of head with the hand of the operated arm, and to dress, for instance, to pull down the shirt, everything without pain, these are all taken as signs of subjective improvement.

Table 1.

	Number		Total	% of the mat.
Causes of operation				
Polio-myelitis	15	30	45	66
Fracture	1	10	11	16
Nerve-injury	–	3	3	4.5
Arthritis-arthrosis	2	1	3	4.5
Tuberculosis	1	1	2	3
Congenital paralysis	1	3	4	6
Total	20	48	68	
% of the material	29	71		100

Objective improvement has been stated to occur after an increase of abduction and forward elevation more than 30 degrees, a backward elevation of 30 degrees and an ability to get the operated arm close to the thorax in adduction. The functional results are shown in Table 2.

Table 2.

	Functional improvement in %	
	Subjective	Objective
Causes of operation		
Polio-myelitis	68	100
Fracture, nerve-injury	70	70
Pains-stiffness	45	82
Rest	89	89
Total	70	91

INDICATION AND TECHNIQUE IN HIP JOINT ARTHRODESIS

by *Nils Lindström* (Härnösand, Sweden)

Indications for arthrodesis exist in:

1. Invalidising unilateral complaints.
2. Bilateral changes with slight changes on the one side.
3. Severe bilateral changes, where arthroplasty is contemplated on the one side.
4. Pareses, as a stabilising operation.

The back must be clinically and radiologically satisfactory, the patient must have free mobility in the knee joint without arthrosis changes, the patient's occupation must not be a hindrance and the age limit should be 60–65 years.

In general there are two types of arthrodesis operation, extra-articular and intra-articular. The former is only used exceptionally in cases other than tuberculous and arthritic affections, but has become of great importance as a complement to intra-articular arthrodeses.

Previous conventional arthrodeses produced a large percentage of pseudarthoses and the lengthy postoperative plaster immobilisation had a deleterious effect not only on the mobility of the knee but also involved greater risk for these generally elderly people. The results improved after Watson-Jones pointed out in 1934 that it was impossible to achieve fixation in plaster alone and introduced internal fixation.

Stinchfield & Cavallaro (1950) presented 117 hip joint arthrodeses due to lesions other than tbc with 23 per cent pseudarthroses and *Stinchfield* (1952) 108 cases of arthrosis deformans with 22 per cent pseudarthroses. *Robinson* published 120 cases in 1956 operated on by Watson-Jones himself with 94 per cent bony ankylosis, *Max Lange* (1958) 500 cases with 85 per cent bone healing and *Merle d'Aubigne* (1964) 290 cases with 84 per cent primary bone healing.

In all these cases there was lengthy plaster fixation and as I considered it desirable to avoid this fixation I evolved my own method in 1947 and have used this since then. It consists of a partial intra- and juxta-articular arthrodesis with an ileum graft + simultaneous nailing with a three-flanged nail. The patients are allowed

to lie free in bed and to get up and put weight on the leg as a rule after 6 weeks.

During the years 1947–1965 I myself operated on 84 cases. 2 died post-operatively, 1 from an embolism and 1 from shock; the obduction showed tbc. gland. suprarenal, 1 patient died of carcinoma hepatis so early after the operation that the result could not be evaluated. 81 patients remain therefore, of which 78 achieved primary bone ankylosis and a further 1 after reoperation. This produces figures of 96.3 per cent primary bone ankylosis and 97.5 per cent after a re-operation. Free mobility in the knee joint existed in 72 cases, a further 7 had more than 90 degrees flexion and only 2 below 90 degrees flexion. 75 of the patients had been working, 7 at lighter work, 49 at office or industrial work and 19 in heavy work.

The operation is thus capable of giving good results with a large percentage of bony ankylosis and good mobility in the knee joint after a brief period in hospital.

DISCUSSION:

L. Unander-Scharin (Malmö, Sweden)

It should be a sound principle that the best possible fixation is to be obtained in hip joint arthrodesis, whether by using Lindström's three-flanged nail or the screw and plate adopted by Ivar Alvik or Kalen's three point fixation with Nyström nails. My experience is almost exclusively restricted to Lindström's method of fixation. It is very important that fully effective compression is achieved. If this compression is obtained, the prospect of early getting up can be considered, preferably without plaster fixation as this must be regarded after all as significant weight-bearing.

The reason for getting the patient up early is not only lack of accommodation and a general feeling that it is important to get the patient "mobile". Research has been carried out by *K. Rodahl, N. C. Birkhead, J. J. Blizzard, B. Issekutz Jr. & E. D. R. Pruett:* "Physiological Changes during lengthy bed rest". These authors who kept quite healthy individuals in bed discovered: 1) reduction of heart volume, 2) striking orthostatic hypotension, 3) diminished work capacity on the cycle ergometer, 4) increased calcium excertion.

Similar findings have been made by other authors also. The calcium excertion is said to be caused by, amongst other things, lack of use of the long bones and to contribute to a general osteopenia. This argues in favour of the desirability of early getting up.

At the Orthopaedic Clinic in Malmö, getting up early without plaster fixation after hip joint arthrodesis was put into practice in 7 cases. Early getting up is considered to mean after approx. 10 days. The series comprises 7 patients. 6 of these healed without complications.

The pre-conditions for such a measure are that: 1) the patient has a good bone skeleton, that is, no osteopenia or other sign of deficiency in the skeleton, 2) that the patient is fit enough, so that full collaboration can be expected, 3) that the staff is fully informed of the whole procedure so that there is no carelessness, 4) that the nail is fixed in an absolutely satisfactory manner.

INVESTIGATION OF THE STABILITY OF EXPERIMENTAL HIP JOINT ARTHRODESI by *R. Kalén* (Stockholm, Sweden)

RESULTS OF ARTHRODESIS OF THE KNEE JOINT

by *P. Salenius & R. Kivilaakso* (Kristinestad, Finland)

At the orthopaedic hospital of the Invalid Foundation in the period 1946–1965 arthrodesis of the knee was performed on 106 patients, 59 of whom were men and 47 women. In no case was arthrodesis performed bilaterally. The youngest patient was 15 years of age and the oldest 76. The longest observation period was 20 years and the shortest 1 year. 100 patients submitted to follow-up examination, and information is lacking in respect of 6 patients only.

The main indication for arthrodesis was tuberculosis of the knee. Among the after-effects of polio an instabile joint which hindered walking indicated the necessity for arthrodesis. Pain after fracture was the result of secondary arthrosis. 7 such cases resulted from gun shot wounds, 5 from accidents at work and one only from a traffic accident. Among other reasons may be mentioned the after-effects of osteitis and injury to soft tissues of the knee region, where faulty position or instability were indications for arthrodesis.

Four main methods were used for arthrodesis of the knee joint, and of these the Charnley method was used on 53 patients, the largest group. In 17 cases two spongiosa screws placed crosswise over the arthrodesis area and reaching to the opposite condyle of femur or tibia were used. In 9 cases two metal wire coils were placed at the ends of opposing tibia and femur and the resected surfaces pressed together with a third coil between. Operation was performed in 27 cases without internal metal fixation.

Table 1 shows the methods used and the consolidation times achieved.

Table 1.

Method	No. of cases	Consolidation			Fibrous union	No information
		under 3 m	3–6 m	over 6 m		
Charnley	53	35	11	3	3	1
Screw fixation	17	5	5	5	2	–
Metal wire	9	2	4	1	–	2
No fixation	27	4	3	10	7	3
Total	106	46	23	19	12	6

Six patients experienced low back pain. Three complained of pain in the ankle after prolonged walking, and two of pain in the hip on same side.

Of fibrous union cases rearthrodesis was performed on ten, and in nine of them consolidation followed. One remained unsuccessful.

There were 12 cases of necrosis at the edge of the wound; this was cured without treatment, and did not delay recovery. In one case a more prolonged infection arose in the area of arthrodesis, and was cured later. In three patients infection necessitated amputation from the thigh. Two cases of temporary peroneal paresis occurred, and two of arterial thrombosis.

The follow-up examination showed that arthrodesis of the knee joint was indicated when pain, inflammation or instability as a result of paralysis made walking dif-

ficult for the patient. After arthrodesis patients are as a rule able to move freely: the majority experienced no discomfort worth mentioning, and were capable of performing heavy physical work.

Though all methods used led to consolidation in the most cases, the best results were quite clearly obtained by the Charnley method, which usually produced consolidation within three months.

The majority of complications and pseudarthroses occurred in cases where no internal fixation was used.

Patients in general were satisfied with the results of their operations, and the only cases to be regarded as bad are those in which infection made amputation necessary. These were very few, however, in relation to the total number of arthrodeses.

POST-TRAUMATIC ARTHROSIS IN ANKLE AND FOOT TREATED WITH ARTHRODESIS by *Helge Fjermeros & Rolf Hagen* (Oslo, Norway)

The basis for a development of secondary arthrosis is present if a fracture in ankle or foot has changed the anatomical and biomechanical relationships after union. The most common causes are intra-articular fracture lines with joint incongruity after reposition. Another possible pathogenetic factor may be an increased strain upon the talonavicular and calcaneocuboid joints after a fracture of the calcaneus, if the subtalar articulations are not accurately reduced anatomically.

Oeparative Technique:

The ankle joint is exposed through a posterior incision along the lateral or medial border of the Achilles tendon according to the correction of a varus- or valgus deformity. The articular cartilage is completely removed and the malleoli are osteotomised obliquely if necessary. Bone chips are packed in the resection space and firm fixation is established by 2 staples. An arthrodesis of the posterior subtalar joint can eventually be performed through the same incision. By triple arthrodesis the involved joints are fixed with 3 staples.

The patient is discharged 2 weeks postoperatively with a walking plaster cast. Weightbearing is allowed after 2 months and usually the cast is removed 4 months postoperatively.

The Series:

During the period 1954–1964, 58 patients (62 feet) with post-traumatic conditions were treated with arthrodesis. 24 women and 34 men were re-examined, the average age by operation was 46 years and the average observation time 5 years. The material consists of 35 malleolar fractures, 21 calcaneus fractures and 6 fractures of the navicular bone. The time period from the original trauma to arthrodesis was 15 years for the malleolar fractures, but only 5 years for the calcaneus fractures.

Follow-Up Studies:

Pseudarthrodesis definitely occurred in 3 patients (5.2 per cent). Two of these patients have been reoperated upon with success. 3 patients (14.3 per cent) with ankle fusion presented a subsequent arthrosis of the subtalar and tarsal joints unrelated to the original trauma, which necessitated an arthrodesis. Most of the

patients with ankle arthrodesis had painless, but decreased movement in the subtalar joints, while on the other hand, the Chopart and midtarsal joints revealed increased mobility. The patients with a small equinus degree were much dependent on this movement in the sagittal plane. Patients with subtalar fusion complained of difficulties in walking on uneven ground. 28 belonged to the group "excellent", 21 "good", 5 "fair" and 8 "poor".

Summary and Conclusion:

93.1 per cent have regained their working ability, and 79 per cent of the patients to the groups "excellent" and "good". In walking with shoes, a limp was absent in 80 per cent. Without shoes, limping was more frequent, especially if the equinus position exceeded 15 degrees.

In ankle fusion the heel should be placed in the 0-position or in slightly valgus. An equinus of 5 degrees is considered generally to the best position for a man, and 10 degrees for a woman.

The development of secondary arthrosis is slower after ankle than after calcaneus injuries. Patients with considerable pain and walking inability after calcaneus fractures need a triple arthrodesis within the first year.

The disadvantages of an arthrodesis are rather small as compared to the preoperative complaints.

POST-TRAUMATIC ARTHROSIS IN ANKLE AND FOOT TREATED WITH ARTHRODESIS by *A. Langenskiöld* (Helsingfors, Finland)

THE TREATMENT OF SCOLIOSIS by *Erik B. Riska* (Helsingfors, Finland)

The material comprises 60 patients, 40 of them girls and 20 boys, treated at the Orthopaedic Hospital of the Invalid Foundation in Helsinki during the period 1962–1965. Of these patients, 26 had idiopathic scoliosis, 24 paralytic scoliosis after polio, and 10 scoliosis of other origin. Eight of these 10 cases had congenital malformations of the spina. In 35 cases, the scoliotic curvature was localized in the thoracic spine, 19 patients had a thoracolumbar curve. In 27 cases the deformity exceeded 60 degrees.

Table 1. Incidence of pseudarthrosis. Idiopathic, paralytic, and miscellaneous scoliosis.

Type of bone added	Cases	Pseudarthroses	
		No.	Per cent
Banked autogenous tibial bone	10	3	30
Autogenous tibial bone kept in the open air 1–2 hour's	17	7	41
Fresh autogenous tibial bone	33	1	3
Total	60	11	18
Bone-bank bone treated before 1962	96	31	32

Preoperative correction of all cases was carried out with the Milwaukee brace. Most of the patients were aged 13–15 years at operation. In all instances, Cobb's method of spinal fusion was employed. In 10 cases, bone grafts were taken from the tibia two weeks prior to the operation and stored in the bone bank. In 17 instances, the tibial cortical bone and cancellous bone from the condyle was taken first and placed in a bowl, whereupon the leg wound was closed. Then the spine was exposed and the fusion area prepared, whereupon the grafts were put into place. In 33 cases the operation was carried out according to the current method of this clinic. To begin with, the spinal bed was prepared. Then the cortical tibial bone grafts and cancelleous bone from the condyle were taken and inserted immediately and in this way afresh. No post-operative complications occurred. The mean follow-up period was 25 months. At the final follow-up examination, most patients' spine had grown to their final size.

Table 2. Correction obtained following surgery. Idiopathic, paralytic, and miscellaneous scoliosis.

Type of fusion and of bone added	No. of cases	Average net correction		No. of pseud-arthroses
		Degrees	Per cent	
Cobb-type fusion with banked autogenous tibial bone	10	13	18	3
Cobb-type fusion with autogenous tibial bone kept in the open air 1–2 hours	17	10	14	7
Cobb-type fusion with fresh autogenous tibial bone	33	16	28	1
Total	60			11

Table 3. Forty-four cases with good treatment result correlated with the type of bone added.

Type of bone added	No. of cases	Average net correction	
		Degrees	Per cent
Banked autogenous tibial bone	5 out of 10	21	28
Autogenous tibial bone kept in the open air 1–2 hours	9 out of 17	15	22
Fresh autogenous tibial bone	30 out of 33	17	30
Total	44 out of 60	17	28
Bone-bank bone treated before 1962	25 out of 96	15	22

Pseudarthroses occurred in a total of 11 cases out of 60, *i.e.* in 18 per cent. Table 1 shows the incidence of pseudarthroses in the fusion area correlated with the different methods of grafting autogenous bone. The results clearly reveal the superiority of fresh transplants to the other transplant types. The results obtained with homogenous bank-bone used before 1962 are also shown. Table 2 presents the correction obtained in the entire material. Here too fresh bone grafts in vital condition appear to be clearly superior to autogenous bone transplanted in other ways. Table 3 shows that clinically as well as roentgenologically good results were obtained in 44 cases out of 60. With fresh bone grafts good results prevailed in 30 out of 33 cases. With bone grafts banked for two weeks results were good only in half the cases, and a similarly fair result was obtained in the group whose transplants had been kept for 1–2 hours outside the organism. The mean net correction was 17 degrees or 28 per cent.

GUEST LECTURE

STANDARDIZATION OF SURGICAL IMPLANTS

by Mr. *Norman Capener* (Great Britain)

Mr. Norman Capener presented an outline of the work done by a committee of the British Standards Institution which has led to the development of a standard for the design of screws and plates used as surgical implants. The work of this committee started in 1957 and the first standard was published in 1962 (B.S. 3531).

Careful consideration was given to the size and design of screws and to the related holes or slots in bone plates in order to provide optimum mechanical strength. It was evident that there was a need for standardisation of the size of screws and the related holes or slots not only to ensure that correctly matching components were used but also to ensure the use of the correct size of twist drill and screw driver. The mechanical problems provided by fractures of the major long bones of the lower extremity of adults have been shown to make desirable the use of screws of 4 mm nominal size. The increase of the screw size from that commonly employed by surgeons, namely 3.6 mm, is very small compared with the added strength which is gained. The nominal size of surgical screws (4 mm) has been designed in metric dimensions in accordance with current trends in British medical practice. Further consideration is to be given to the specification of screws of smaller size for future revisions of the standard. With the exception of the holes or slots in plates to receive the screws, other details of design of surgical implants have been excluded from the scope of this specification.

Metals for Surgical Implants

In the work of the British Standards Committee, great assistance was provided by the metallurgists, by screw designers, by the experimental work of surgical instrument makers who all did much practical work in support of the committee's

studies. There was, however, one piece of scientific work which I would particularly commend to you, namely that of Dr. John Scales of the Institute of Orthopaedics at the Royal National Orthopaedic Hospital in London. Those of you who are familiar with the two articles which he and I wrote in the British Volume of the Journal of Bone and Joint Surgery in February 1965, will be aware of the general conclusions but will have less knowledge of the precision of his approach. It is my intention to spend the greater part of the time available, in outlining this which I do with his agreement and with his material. It is a model of method which merits recognition and further application. The conclusions arising from his work are as follows:

Apart from dimensions, the strength of the screws is dependant on the type of metal and the processes used in working the metal.

It is possible with certain screwdrivers in use in operating theatres to apply a torque force of such magnitude as to exceed the torsional yield stress and to break any surgical screw having a core diameter of less than 0.120″. The influence of core size and tensile strength of the metal on the torsional yield stress of screws having a nominal external diameter of 9/64″ (3.6 mm) and 5/32″ (4 mm) has been investigated.

Of the five groups of screws tested, the most suitable was that having an external diameter of 4 mm (5/32″) and a core size of 0.119″. The average Vickers Pyramid diamond hardness number of the screws indicated that the wire from which the screws were made had a tensile strength of approximately 78 ton/sq. inch. Tensile tests of the wire carried out by the manufacturers showed that its actual tensile strength was 70.5–73.5 tons/sq. inch. The mean torsional yield stress of the screws was 47 lb. inch, with a minimum value of 43 lb. inch. When the group 9/64″ screws are compared with the group 4 mm (5/32″) screws, it is found that 13 per cent (0.014″) increase in the core diameter gives a 44 per cent increase in the mean torsional yield stress.

In the lower limb of an adult a screw may be highly stressed and thus a screw with the best mechanical properties is required. Experiments with human bone using self-tapping and non-self-tapping screws have shown that less torque is developed during the insertion of the self-tapping screws.

There is a great variation in mechanical properties of human bones. The maximum extraction force to pull out a self-tapping 4 mm (5/32″) screw inserted in one cortex of the human femur was 0.720 tons or 1612 lbs, while the minimum extraction force with the same type of screw inserted in another bone was 0.110 or 246 lbs. Both screws were inserted in holes drilled with a 0.125″ drill. The use of intermittent or continuous rotation is an important factor affecting torque developed during insertion of a screw. If a non-self-tapping screw is inserted by intermittent rotation into both cortices of a bone and a clearance hole is not drilled in the proximal cortex, then the torque developed may exceed the torsional yield stress of the screw. The growth of bone into the flutes of a self-tapping screw is said to be responsible for the breaking of screws when they are removed. Perhaps the failures are initiated during the insertion of the screw?

An 0.125″ drill is the most suitable size to use with a 4 mm (5/32″) screw, having a nominal core diameter of 0.118″. If the bone is exceptionally hard then a drill of 0.1285″ can be used.

There are a number of factors which can bring about or initiate the failure of a

surgical screw. Failure of a screw on insertion can be prevented by limiting the torque applied to the screw, and a torque limiting screwdriver has been developed. With this driver all screws may be tightened to the same degree.

If the correct diameter of hole is drilled in bone and a screw having optimum mechanical properties is inserted using a torque limiting screw driver, it is possible to prevent many failures of surgical screws.

It was this work which guided the B.S.I. committee in deciding upon the 4 mm screws as the most satisfactory one for use in the lower limb long bones of adults. The advantages of the self-tapping screw were also clearly shown. The disadvantages of this, however, are in the difficulty of removal because of the growth of bone into the tapping flutes. A difficulty which may result in excessive torque being applied with resultant breakage. This work suggests that there is advantage to be gained by first tapping a screw thread in the drill hole. Then the screw thread in the bone will be a cleaner one because there will be no blockage of flutes by the bone debris. Under such conditions, a non-self-tapping screw can be used and thus the greatest strength can be retained at the tip of the screw stem and, of cource, the screw can then be removed with less risk of breakage. Such conclusions are, of course, supported by the work of Allgower and Müller in A.O. of Switzerland.

Weakness in the use of any screw may develop by another type of defect in use. This is the passage of a screw through two cortices of bone with equal threading of both. Dr. Scales has shown that the strength of a screw in one cortex is, for practical purposes, adequate. There are mechanical advantages in having the thread upon the distal cortex. Therefore surgeons should ream out the proximal cortex to a larger drill size so that the screw will not cut a thread on it, thus will be prevented the increased torsional stress that will be met when a screw passes between two threaded sections of material,—the stress being due to the tendency of a screw to force these two sections apart and thus increase the load. As a result of a research carried out by screw manufacturers for us, it was decided that 20 threads per inch should be the British Standard because it was shown that greater extraction resistance is provided by the intervening sections of bone than with the closer pattern of 32 threads per inch. Naturally one asks if an even greater size of screw would have advantages. Undoubtedly it would be so, but there appears to be a risk that a larger drill hole than that advised for the 4 mm screw, would provide a greater risk of fracture of the bone at this point. In any case, according to Dr. Scales work, the screw of 4 mm diameter has more than adequate strength in most circumstances of used properly.

I will not discuss at any length the question of the materials used. The British Standards specified three possibles, firstly an austenitic stainless stell of low carbon content, the latter being in the neighbourhood of 0.08 per cent; chromium 18–20 per cent, nickel 8–10 per cent and molybdenum 2–3.5 per cent. The second material was cobalt-Chrome/molybdenum alloy. The third was titanium. Stainless steel of the quality mentioned is an almost ideal material but still has a slight tendency to pitting or crevice corrosion. How important this is, I do not know in view of the greater risk involved in the mechanical deficiencies of technique which Dr. Scales has mentioned. Cobalt-chrome alloy has a disadvantage in its extreme hardness and difficulty to work and the fact that it is a cast product which has, at any rate for screws, some tendency to brittleness. Titanium is lighter than these

other alloys, is a pure metal and in certain situations has real advantages. I will not discuss this further.

The corrosion resistance of austenitic steel has been improved recently by raising the chrome and nickel content. A small revision of the British Standard material for steel is now being published but its use will still be compatible with the existing standard material.