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ORTHOPEDICS BIOMATERIALS

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I. INTRODUCTION

Orthopedics is the area of medicine involved with the repair and treatment of the skeletal system. Generally this involves the treatment of diseases, deformaties, and fractures of bones and joints. The treatment of ligaments and tendons is often considered orthopedics.

With the possible exception of sutures and bandages, orthopedics is the largest consumer of biomaterials. The use of implant materials in orthopedic surgery is generally accepted clinical practice - this is not the case for heart or kidney devices.

One might divide implant procedures into two groups - reconstructive or generally non-life threatening and life-saving. Most orthopedic injuries are not life-threatening. The cardiovascular surgeon generally <u>must</u> do something - or his patient will die. He can therefore legitimately experiment, he can try new "unproven" methods and devices. Those of his patients who survive are generally grateful and satisfied - those who don't are dead, and cannot directly complain. The orthopedic surgeon is faced with different choices and priorities. His patients will generally live. He must be cautious of his treatment - he must usually go along with "accepted clinical practice".

We will discuss some of these "accepted clinical practices". The more experimental developments will be discussed next quarter.

II. INTERNAL FIXATION

A. Principles

The process of fracture healing leads to important clinical objectives in bone fracture fixation(4):

1. minimize all bone gaps - the fragments should be fitted together as closely as possible.
2. minimize relative movements - the fragments should be fixed as rigidly and as immobile as possible.
3. minimize damage to bone repair tissues - the periosteum and endosteum must be protected as much as possible.
4. minimize damage to the vascular supply.

The setting of fractures and splints and casts tend to accomplish one and two above for many common fractures - rest and immobility also helps. (Extended bed rest can produce skin and vascular complications in aged patients, however.)

If the fracture cannot be satisfactorly set and fixed by external, non-surgical means, then the orthopedic surgeon may choose to surgically intervene and internally fix the fracture.

Internal fixation attempts to accomplish objectives one and two while abiding to three and four as much as possible. Internal fixation basically consists of using screws, plates, nails, and other devices to rigidly fix the fragments together - strictly a fastening and fastener problem (see Figure 2).

"We cannot advise too strongly against internal fixation if it is carried out by an inadequately trained surgeon and in the absence of full equipment and sterile operating room conditions. Using our method, enthusiasts who lack self criticism are much more dangerous than skeptics or outright opponents". (Ref. 46, p. V).

The more rigid and immobile the fixation, generally the minimal amount of callus formation - just enough forms to fill the fracture line and external callus is nearly absent. "After a really rigid internal fixation (and provided it heals asceptically) callus develops in such small amounts as to be invisible. There is no periosteal callus, no intramedullary proliferation, and the fragments fuse together without any intervening tissue. . . This work of repair takes place without any apparent participation of the surrounding tissues".(1)

Poor fixation leads to inflammation and more extensive callus formation, longer healing times, or, if severe enough, non-healing. Fracture healing without visible callus formation is called primary healing.

The mechanical characteristics of callus are poor. Kuntscher(2) says that three week old callus can only extend about 10% before tearing - it cannot be sutured. Thus the slightest mobility at the fracture site can disrupt callus producing inflammation and slowing down healing.

Kuntscher(2) claims that healthy fractures will always heal if stable immobilization is achieved. If the fixation does not produce absolute immobilization, the fracture may still heal adequately by extensive callus formation - in such cases, however, adequate healing cannot be guaranteed.

B. Screw Fixation

Screws are used to compress fragments together, particularly if the fracture is an oblique or spiral one, and especially in and around joints (Figure 2). In cortical bone (Figure 1) the cortices can be used, to hold screws quite rigidly. In cancellous bone (Figure 2) more volume is available but the softer structure makes screw holding more difficult.

Once the surgeon selects the best geometry for fixing the fracture and selects the screws to be used, he drills a hole with a <u>sharp</u> low speed drill, ideally he then taps it with a <u>sharp</u> tap, and then carefully inserts the screw. Unfortunately, many, perhaps most, of today's popular screws are self-tapping. This procedure makes for more rapid fixation and a shorter operating time, but it also produces more bone damage. It has been shown that incortical bone self-tapping screws generate much more heat and damage to surrounding bone than tapping and then screwing. It has been shown that the splintered bone adjacent to self-tapping screws in cortical bone is replaced by connective tissue after sometime(46), the result is screw loosening and immobility of the fixation.

The very presence of a drilled hole plus the heat of drilling results in vascular distrubances which can produce a cylinder of dead bone 1/2 to 1 cm thick around the hole. Usually the resorption occurs nearly simultaneously with new bone formation, so that loosening does not occur, unless the bone has been more extensively damaged, such as by the use of self-tapping screws or excessive heat generation during drilling or tapping.

The optimum design of surgical screws is still being studied. Cortical screws generally function better if there is little or no binding to the proximal cortex; i.e., the lag bolt principle. Threads are usually cut the entire length of the screw, however, for ease in removal. The proximal hole is made about the maximum outer diameter of the screw threads so that little binding occurs and the two or more fragments can be compressed together.

The ASIF(4,5) cortex screws are only used in tapped holes, generally only the distal cortices doing the actual holding (Figure 1). The threads are nearly perpendicular to the screw axis for maximum holding, but the space between threads is rounded so that there can be only minimal tension on the bone between the threads. There is some controversy as to whether the screw head base should be conical or flat for direct bone fixation. The ASIF system uses conical heads (I'm not pushing this system - it simply is the only one I've come acress designed as a system - and the only one for which really adequate information is readily available. The more common sources of orthopedic devices do not readily furnish adequate technical information).

Nuts are available for use with cortex screws in cases where the cortices are too thin for adequate fixation.

Cancellous screws are distally threaded and are designed more on a lag screw principle, being wider and farther apart for use in the softer cancellous bone. Small washers are often used to prevent the head from sinking in. If adequate compression is not achieved because the bone is too soft to hold the screw, nuts can be used. Cancellous screws are usually self-tapping. The heat produced by self-tapping in cancellous bone is much less than cortical bone and is not considered significant.

Small screws for use in cancellous bone are called malleolar screws. Screws with thinner shanks and smaller heads are also available for certain applications. These are called scaphoid screws.

Drills with stops, drill sleeves, and drill guides are used in the ASIF system, as well as taps, countersinks, and special hexagonal-headed screw drivers with all but the scaphoid screws (Figure 1).

The torque involved in driving screws has been studied occasionally though torque-limiting screwdrivers are not generally used nor available.

Unfortunately there are almost as many different types of bone screws (and plates, nails, etc.) as there are famous orthopedic surgeons - with various screwdrivers to match. The ASIF system is refreshingly simple.

C. Plate Fixation

In many fractures screw fixation is not adequate and it is necessary to use plates to obtain rigid fixation. Fractures which are not oblique enough or which have more than two fragments cannot be treated by screws alone. The necessary rigidity and fixation can then be achieved by the use of a plate, plate plus fixation screws, or less often by the use of two plates.

The slides showed the procedure for the ASIF compression plate system. This is a relatively simple procedure with a minimum number of plates. Again there are a large number of plates available from other manufacturers, perhaps even more different plates than screws. Immortality seems to be easily achieved in orthopedics by simply designing your own plate, convincing someone to make it, and using it on a series of patients. Narrow, broad, and semi-tubular plates are available for the ASIF system. Some of the other types of plates were shown in a slide, reproduced from the cover page of the "plate" section of a popular orthopedic catalog.

The fixation of a plate directly on the periosteum necroses and kills the osteogenic tissue beneath the plate. Thus common practice is to carefully strip off the periosteum so that the plate can make direct contact with the bone, providing a more rigid fixation. Some feel, however, that it is safer to plate directly over the periosteum(1). Most plates lie flat against the bone - the fixation is probably more rigid this way.

D. Intramedullary Fixation

The methods of fixation we have discussed for cortical bone are all based on exterior fixation. Screws and plates are applied on the outside and fixed to the other side. There is another fundamental fixation method for cortical bone - using a large nail in the medullary canal.

This method was mainly developed by a German surgeon, Kuntscher during World War II and is now well-documented and widely used(2). Kuntscher claims that the endosteal blood supply is already largely destroyed when a fracture occurs by rupture of the nutrient medullary vessels (Figure 3). Plating produces a partial loss in the periosteal blood supply and therefore decreases periosteal healing activity. Intramedullary fixation, however, keeps the periosteal supply and activity intact.

An intramedullary nail is designed as a "negative nail" (Figure 4). A nail functions by the medium compressing against it. An intramedullary nail functions by compressing (expanding) against the medium. The cross-section of the nail is such that rotation is prevented. Elastic adherence is ideally present throughout the length of the cavity, resulting in a very rigid fixation which can even bear weight a few days later! As resorption occurs, the nail continues to expand to maintain adherence. The resorption is almost always slow enoggh that by the time the nail is fully expanded the fracture is completely healed.

Because of the changing cross sectional area of the medullary canel, the cavity is carved out to take a nail with a diameter large enough to provide fixation over as much of its length as possible. The nail is somewhat larger than the hole so that it is placed in compression (Figure 5).

One of the great advantages of this method is that with many simple fractures only a relatively small incision is needed.

Though Kuntscher advocates almost immediate mobilization and even weight-bearing(2), others are not convinced and recommend minimal weight bearing(4). Many surgeons feel that fixation is not as rigid as the screw-plate method(4). Kuntscher feels just the opposite(2).

The technique is obviously limited to the long bones where the fracture lines are somewhat centered and not too complex. If the fracture is within a few centimeters of the cancellous end, intramedullary nailing cannot be used (Figure 6). As the fracture becomes more complex and more fragments are involved the techniques becomes less useful.

This technique is widely used for the fixation of simple fractures of the long bones. The reaming out of the marrow cavity has not been shown to lead to any blood distrubances. In 35 - 40 year old or holder people, the marrow of the long bones is not usually participating in blood ceèl synthesis. Perhaps more importantly is that endosteal healing is most important in the long bones where intramedullary nailing tends to destroy endostealaactivity - though this is apparently not a serious problem

Intramedullary nailing has been thoroughly discussed at a recent symposium(6).

E. Other fixation Devices

Combinations of "intramedullary" and screw and plate fixations are widely used for fractures in the vicinity of the hip or near the joints. Such devices are usually angulated. A wide variety of single - and multiple-piece devices are available.

In addition to plates, screws, and intramedullary nails, wires, nails, staples, pins, and bands are often used. Bands are falling into disfavor as they often cause periosteal necrosis.

III. JOINT REPLACEMENT AND REPAIR

A. Trochanteric Fractures

The surgical management of defects of synovial joints, largely in elderly and rheumatoid patients, is one of the most challenging areas of modern orthopedic surgery. The joint which has received the most attention is the hip joint.

Joint disfunction may be due to joint defects or to fractures of one or more of the joint components. The case of a high fracture through the neck of a femur is illustrated (Figure 7). Any fixation of such a defect must withstand the various possible displacements illustrated in Figure 8.

Four possible surgical approaches to such a defect are (Figure 9):

1. A tri-fin nail - controls some rotation but drift complications are frequent.
2. Long low nail - limited by load carrying capacity of bone buttress on which it rests.
3. Crossed pins or screws - adequate as long as outer bone shell is intact - if it begins to crumble, as is often the case, then problems arise.
4. Composite device - achieves rigid triangulation by a bracket fixed to the femoral shaft. A sliding nail appears to be essential to provide for compression build up between the fracture surfaces. If the sliding mechanism is not provided, the nail tip can perforate the hip joint or the retaining screws on the shaft may be sheared. Some devices contain spring and screw mechanisms for sustained compression of the fracture surfaces. The nail part of such devices is commonly a tri-fin type.

It is important to realize that the upper region of a high neck femoral fracture may be deprived, either partially or totally, of its blood supply. Yet if union is good and patient is not too old, healing and union will occur. In many cases, however, if the patient is too old, complications will ensue, largely due to failure of the bone to revascularize.

B. Prosthetic Balls - the Hip Prostheses

In many situations the ball of the femur cannot be adequately salvaged by fixation alone. It may be pulverized or the fracture may be so complex that there is no hope of restoring suitable joint function. Under such circumstances the use of a hip prostheses is often indicated. A hip prostheses is an artifical femur head. Originally this was a cup attached to the femur by a pin - this is called a short stem prostheses - the Judet type being one of the earliest.

The Judet short stem prostheses are not suitable, due to mechanical design and to materials problems. Surgeons began to look at single piece longer-stem implants - this lead to the Moore Prosthesis - the approach here was to fix the prostheses in the medullary canal - like an intra-medullary nail. There are two fundamental problems with such an implant - friction and fixation. Depending on the age of the patient, his condition, activity, loads, etc., fixation may be adequate or inadequate; the prostheses may loosen and may even resorb its way right out of the bone!

There have been many attempts to solve the fixation problem. Several of the prostheses designs have holes in the stem portion in the bones that medullary or endosteal tissue may grow through and aid in the fixation; others have especially designed stems to prevent "walking" of the prostheses.

The other basic, and probably more successful approach, is to prefill the medullary canal with a filler (called a cement - and usually a mixture of PMMA and MMA monomer) and then to insert the prostheses - the cement polymerizes and sets around the prostheses, providing a relatively firm fixation and said to aid in the stress transference of the total system. Cement vs. non-cement comparisons have been made and it appears that aged cemented patients are better off than non-cemented ones.

The replacement of the head of the femur - though common - is still considered by many orthopedic surgeons to be somewhat experimental - it is only done as a last resort. If the prosthesis fails, and if it is not possible or deemed wise to insert another one, the surgeons only resort is to fuse the joint - with total loss of movement.

C. Acetabular Replacement

In many patients, particularly the aged, both the head of the femur and the acetabulum are in need of repair or replacement. Let us take the latter replacement, first. If the joint is hopeless and has lost most of its powers to regenerate tissue, an acetabular replacement or hip cup may be the best procedure. A cup with some means of fixation to the bone is attached, either by pins, screws, and acrylic cement. This then provides a smooth artificial surface on which joint function may occur.

D. Arthroplasty

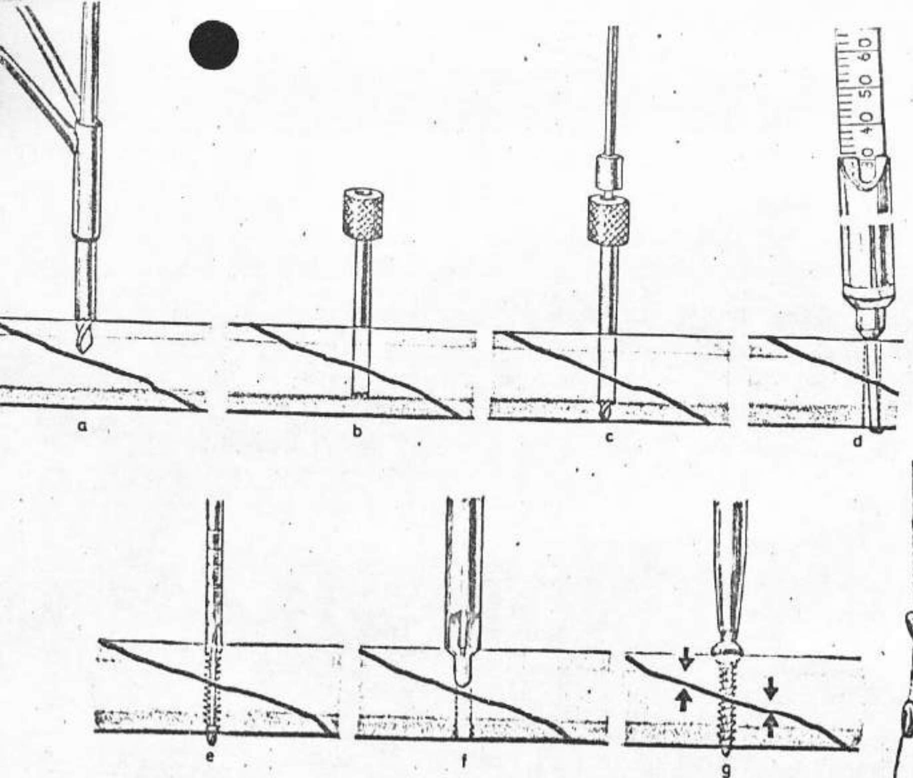
The above procedures are replacements for natural body components. They are all characterized by relief from pain, early resumption of weight-bearing (two to three weeks), and general improvement in motility. The disadvantages are that these are experimental procedures, fixation may deteriorate leading to wobble, possible fatigue fractures, possible implant migration, etc. Redoing such a procedure is difficult and often not successful or even cannot be performed. If such is the case, fusion may be the last step.

Many patients have restricted or severely painful joint function, though the femoral head and acetabulum may be in good shape. A time-consuming but very successful and well established clinical procedure is available for those patients who can withstand the long term immobility required (about six months). This is cup arthroplasty. This technique was developed in the late 1930's by Smith Peterson.

The procedure consists of removing the synovial tissue and cartilage from the mating surfaces of the femoral head and the acetabulum and reaming down to raw bleeding bone. The cells on this surface are multipotential cells; i.e., they have the capability to differentiate (specialize) depending on the environment they are exposed to. An arthroplasty cup is placed between the two raw and mating surfaces. This is a trickly operation in that everything must fit just perfectly. The cup is now an impermeable passive barrier between the two surfaces. If the patient places no load on the joint but moves it slowly and gently - the multipotential cells find themselves in a joint environment and differentiate to form fibrocartilage on each side of the cup. After a period of time minimal weight-bearing may begin and after a long period of rehabilitation, the joint is literally as good as new. Full mobility and weight bearing are achieved. The major problem is that the process takes about six months, during which time the patient is incapacitated. The extensive bed rest required makes this a difficult or even unwise procedure for aged patients - for such patients a total artificial hip may be the best solution.

Cup arthroplasty is the method of choice for those patients who can take it.

The cup is merely used as a separating medium; it essentially floats free between the two mating surfaces. We are using the cup as a tool to permit a physiological solution to the problem. Plates, screws, intramedullary nails, and hip-appliances are passive tools to permit a physiological solution. A total or partial hip replacement can in no way be considered a physiological solution to the problem.



ig. 1 (Ref. 4b, pp. 24-25)

Screw fixation after the fragments have been reduced.

a) Drill the near cortex with a 4.5 mm drill, using the 4.5 mm tap sleeve which acts as a drill guide.

b) Insert the special drill sleeve which has an outer diameter of 4.5 mm and an inner diameter of 3.2 mm into the hole that has just been drilled, and push it until it meets the opposite cortex. This drill sleeve will now allow an accurate hole to be drilled in the far cortex, even if the hole is placed obliquely.

c) Now drill the far cortex with a 3.2 mm drill, fitted with a stop.

) Measure the required screw length with the depth gauge.

) Tap out the thread in the far cortex with the short 4.5 mm cortex tap.

sing the special countersink tool, cut a proper countersink in the near cortex for rew head.

he screwdriver screw in the AO cortex screw but do not tighten it. The screws ally tightened when they have all been inserted.

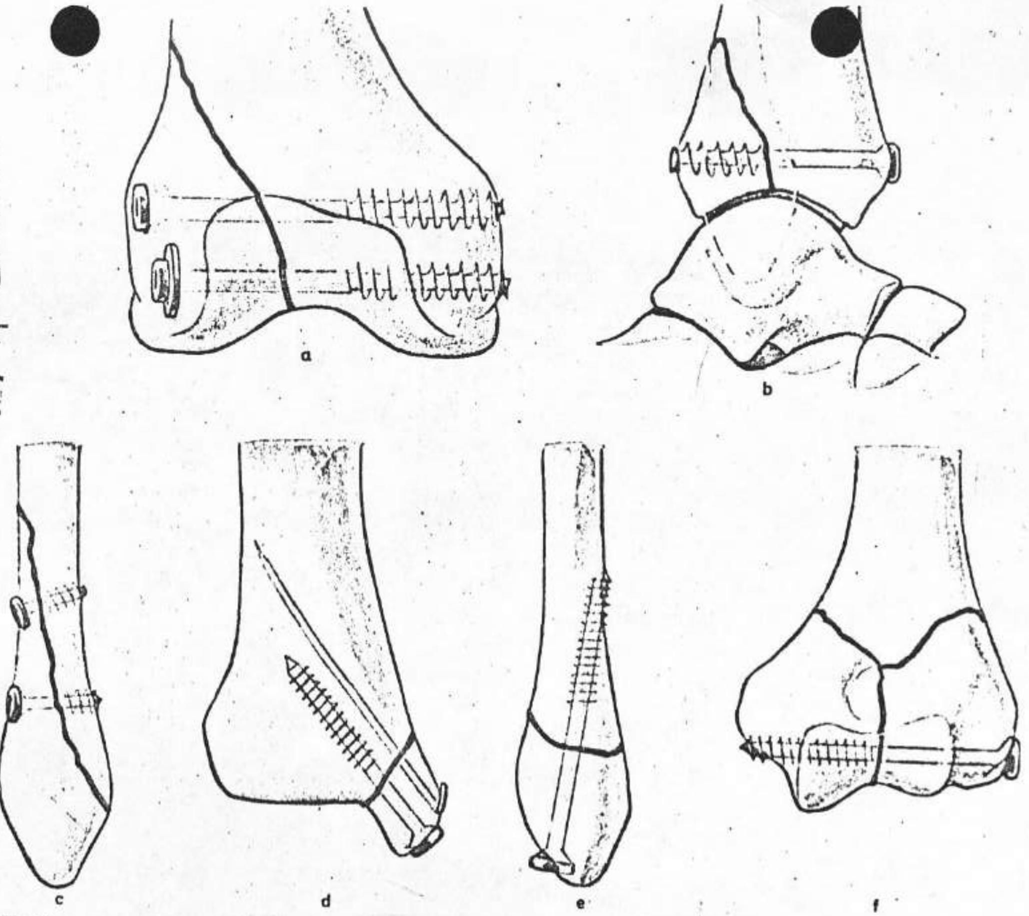


Fig. 2 (Ref. 4b, pp 20-21)

Some typical indications for the use of cancellous screws.

a) Fracture of a femoral condyle. Use two long threaded cancellous screws—one with a washer.

b) Fracture of the posterior lip of the lower end of the tibia (Volkmann's triangle). Use a cancellous screw with a short thread. Introduce it from the front backwards, so that it lies parallel to the ankle joint and just above it.

c) Long oblique fracture of the lateral malleolus. This may be stabilized with two small cancellous screws.

d) Fracture of the medial malleolus. Fix this fracture with one malleolar screw in combination with a second screw or a Kirschner wire to prevent rotation.

e) Fracture of the lateral malleolus. A short spiral fracture can be fixed with one malleolar screw which is introduced so that it lies obliquely in both planes and so that the tip penetrates the proximal cortex.

f) A Y-fracture of the lower end of the humerus. The first step is fixation of the humeral condyles with a malleolar screw.

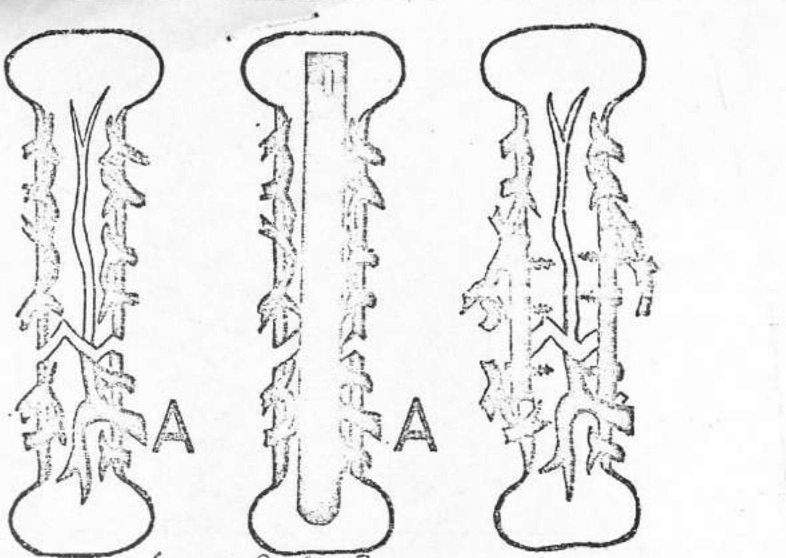


Fig. 3. from Ref. 2

Diagram of blood supply of a bone by the nutrient artery and the periosteum in a transverse fracture without displacement. The proximal branch of the nutrient artery was torn by fracture.

. After use of reamer and medullary nail the nutrient artery was completely destroyed; the periosteum remained intact; no disturbance of healing of the fracture.

: By use of wire loop or Lane's plate periosteal blood supply is additionally interrupted. Disturbance of fracture healing, danger of infection and sequestration.

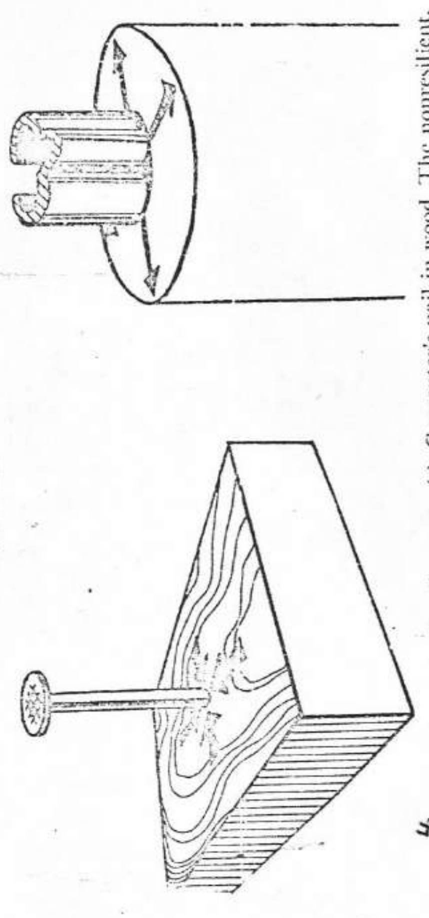


Figure 4: Principle of elastic adherence. (a) Carpenter's nail in wood. The nonresilient massive cross-section of the nail forces the elastic material (wood) apart. (b) the cross-section of the medullary nail is compressible and resilient, thereby achieving elastic impingement in the nonelastic bone shaft. (Ref. 2)

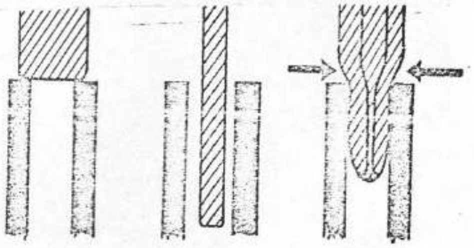


Fig. 5 (Ref. 2)

The tip of the nail is shaped like a wedge. This enables the nail to be reduced in its cross-section and to impinge itself elastically.

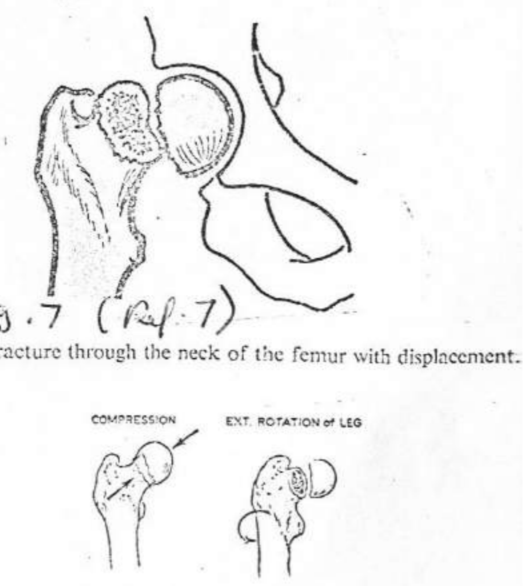
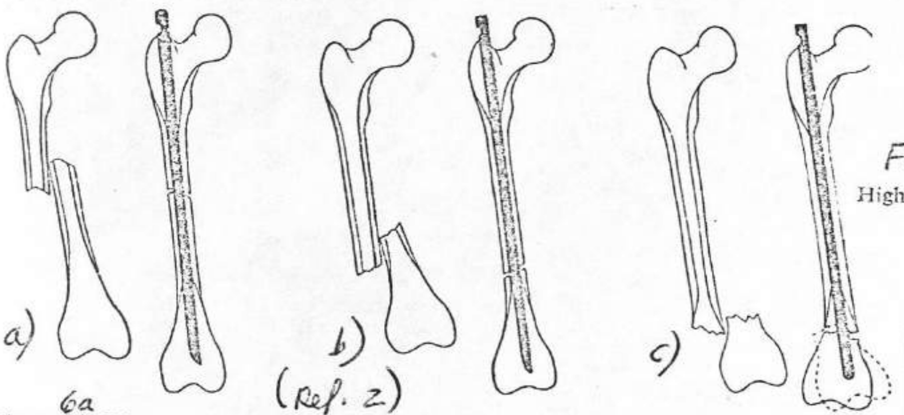


Fig. 7 (Ref. 7)

High fracture through the neck of the femur with displacement.



(Ref. 2)

Figure ~~24~~ 6a: The stability of an osteosynthesis depends on the location of the fracture. A transverse fracture in the middle of the femur is very suitable for nailing. The nail is impinged in a sufficiently long and equally wide tube in both fragments.

6b

Figure ~~25~~: The stability of an osteosynthesis depends on the location of the fracture. A [illegible]lar fracture as shown in Figure 24, however, considerably closer to the knee joint. The osteosynthesis is stable although the nail is only 3 cm inside the distal fragment. Angulation and lateral displacement are prevented by the nail, and rotation by gearing of the fragments by muscle pull.

Figure ~~26~~ 6c: The stability of an osteosynthesis depends on the location of the fracture. Similar transverse fracture as shown in Figure 25, however, still a few centimeters closer to the knee joint. The osteosynthesis is no longer stable; lateral displacement as well as angulation are possible

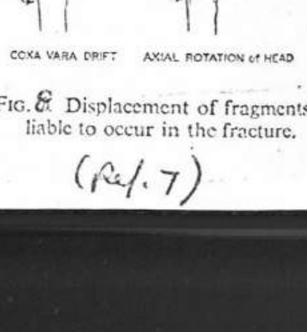


FIG. 8 Displacement of fragments liable to occur in the fracture.

(Ref. 7)

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IV. Total Hip Replacement

When both the femoral head and the acetabulum are too diseased or damaged to be saved, and particularly if the patient has severe pain and greatly restricted mobility, the surgeon has two choices: fusion of the hip or total hip replacement.

The total artificial hip consists of a femoral head prosthesis mated with an acetabular cup.

The major requirements of a total hip bearing are (9):

1. A 20° oscillation on loaded half-cycle, followed by unloaded half-cycle.
2. Sliding speeds from 0.75 - 1.5 ft/min.
3. Stresses on hemispherical bearing of about 100 to 300 psi.
4. Maximum external diameter of 50 mm.
5. Maximum angular range of motion of at least 100°.

Metal- metal bearing surfaces have been one of the more common types - the various McKee-Farrar prosthesis being the best examples today. Both pieces are generally Co-Cr-Mo alloy, because of its hardness, lower frictional resistance, and greater corrosion resistance(10). These implants function quite well in the vast majority of cases, though their in vitro or laboratory performance is poor. The normal hip fluids probably help lubricate, though one cannot expect synovial fluid of normal properties to be present for several months following hip surgery (9). There has been some concern about wear and wear debris and even seizing of the joint (10).

In 1960 McKee began using a Polymethyl methacrylate (PMMA) - methyl methacrylate (MMA) material as a "cement" - actually a filler and load transfer medium. The natural acetabulum must be reamed and gouged out, as much as 1/2 inch in depth. In addition several depressions or pits are created to provide acetabular - pelvic anchorage for the cement. The prongs of the prosthetic cup also serve to mechanically adhere the cement to the cup. The result is an acetobular cup "fixed" to bone via a PMMA-MMA cement. The cement acts to help transfer and distribute the load from the cup to the bone. McKee claims the success rate has increased from around 90% in 1960 to around 98% by December, 1969 (10).

A variety of other metal-metal hip prosthesis are available. The Urist-Moore implant (11) has been used without cement, though some surgeons are now using it with cement (11). The Gaenslen cup has been used with the Moore femur head (12) - the Gaenslen cup (Fig. 11) is attached to the pelvic bone by screws.

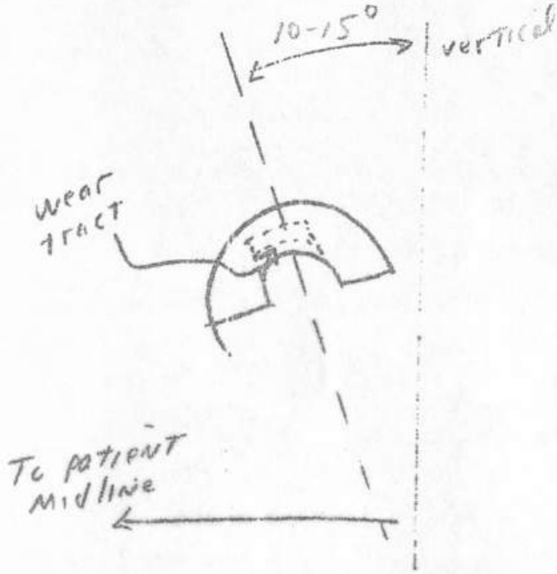
The Ring prostheses involves an acetabular cup which includes a long Threaded stem. The cup is screwed into the bone and remains firmly attached. Cement is not usually used with the Ring total hip. Ring claims that his "Mark II and III" designs have not exhibited fracture complications at the cup-screw junction (13). McKee claims (10) that ... "The use of a long screw to fix the acetabular component results in tremendous stress at the junction between the screw and the cup, and there is always the danger of stress fracture of the metal at this point. Furthermore, variations in the size and shape of the pelvis such as occur in congenital dislocations of the hip, would make it very difficult to insert the screw correctly, and there is always the likelihood of the screw penetrating the pelvis." (Reference 10, page 102.)

The advantage of a hip which does not require the use of the acrylic cement is that it simplifies surgery. It also eliminates the uncertainty with the use of a toxic monomer and with the possibility of polymer degradation.

There has been a great deal of concern about metal-on-metal wear and wear debris, though McKee (10) and Ring (13) imply that wear is not of major concern.

There is a great interest in metal-polymer hips, the so-called low friction artificial hips. This area was pioneered by Charnley (9). He designed and built prostheses consisting of plastic acetabular cups and metal femur heads. During 1958-61 Chainley used such a prostheses in 300 operations. The implant consisted of a Teflon cup (polytetrafluoroethylene) and a stainless steel head. This series is especially noted for its high failure rate, due largely to the poor wear resistance of pure Teflon. The extreme wear evident in this series produced a number of directly measureable effects.

The Teflon socket did not wear by enlarging the cup diameter in the transverse direction. The steel head bored into the cup to produce a roughly vertical wear track, about 10° to 15° on the vertical axis.



Such a result says that the resultant force on the hip is roughly vertical " The rate of wear was not clearly related to the weight of the patient," (Reference 9), but perhaps related more to the patients activity.

Charnley used a range of head sizes from 22 1/2 mm to 41 mm in diameter. The smaller heads showed less volumetric wear than the larger heads, even though the linear wear track of the smaller heads were greater, as is to be expected. Chamley's conclusions was that the smaller heads produce less wear debris and are therefore preferable. Heads smaller than about 22 mm tend to dislocate readily, thus placing 22 mm as the lower limit as head diameter.

The wear of the Teflon head was not due mainly to cold flow (creep), but was apparently adhesive in nature. Adhesive wear is dependent on load and on sliding speed or distance rubbed per cycle. As the diameter of the bearing increases, the distance rubbed per cycle must increase, and the stress decreases. "The element of 'distance rubbed' may be rather more important in deciding the amount of material pulled off a surface than the load on the surface." (Reference 9).

Charnley's in vitro wear data showed that an ultra high molecular weight polyethylene material (HMP) was about 500 times better in wear resistance than the Teflon. His in vivo results produced a maximum wear rate (linear wear) of 1cm/3years for Telfon, and 0.1 cm/5 years for HMP - or HMP was about 16 times better than Teflon, in vivo.

So in 1962 Chainley began using HMP cups and stainless steel femur heads for hip replacement, having done some 3800 up to late 1969.

The short term and 5 year results are very encouraging. About 96% of the patients are free of pain, 62% having good to excellent mobility, (74% of the patients in the series were disabled prior to the operation, 98% had severe pain). (See Reference 9 for additional statistics).

The present popular Charnley prosthesis consists of a HMP cup and a stainless steel head, with a small diameter (about 22mm). Some suppliers use a Co-Cr-Mo femur head. Charnley showed that there is virtually no difference in wear behavior between the two metals (against HMP), so he uses stainless steel.

The small socket size has a number of advantages in addition to decreased volumetric wear. The small diameter permits a thick socket to be used, up to 1 cm. thick. Chainley claims this thickness acts to absorb impact energy and transfer the load, thus decreasing the frictional torque at the cup/bone junction. A small diameter is generally easier to make hemispherical with a high surface finish, thus costs are lower than for a larger diameter femur head.

Charnley also pioneered the use of the PMMA-MMA 'cement' back in 1958 for 'fixing' the implants and aiding load transfer. The elastic moduli of HMP, and the acrylic cement are in the same range and fairly close to that of bone (16). The system can thus transfer stress much more effectively than a metal cup.

There is no question that the 'low friction' small diameter Charnley prostheses is the most popular total hip device. Some 10,000 of these devices have been implanted in Europe (14).

Several total hips partially based on the Charnley approach have been studied (see handout of illustrations). The Charnley-Muller consists of a 32 mm HMP cup with a matched Co-Cr-Mo head (15). These have been used in a much smaller number of patients than the Charnley - it is still too early to make reliable comparisons.

A most unique design which reminds me of a cross between a cup arthroplasty and a total hip is the "Trunnion-Bearing" hip (17) (see Figs. 12 and 13). This hip consists of a conventional femoral shaft ending in a polished cylinder. A polyester femoral head is loosely fitted over the cylinder. The final component is a conventional metal cup. The result is essentially a plastic ball "free-floating" between a metal cup and shaft. This concept evolved from 1961-63, but the first device was implanted in 1968.

Over 200 were implanted as of August, 1969 (17). Only 2 complications related to the prostheses have turned up so far.

Some of the unusual properties and advantages of this hip are:

1. Movement occurs at 2 different areas, which should lead to less wear at the respective wear surfacaes.
2. A good circulation of lubricant is realized (there is a hole in the plastic head to permit fluid transfer in and out of the inner cylinder zone.).
3. The plastic head can be simply replaced if head wear is excessive.
4. The two fluid surfaces should help absorb shocks.

The heads and cups range from 37-42 mm diameter. The femoral component is available with three different cylinder lengths. The cylinder is 16 mm in diameter. (Reference 17.) The author did not say whether or not acrylic cement is used. This is a novel and unique approach to the hip problem which merits close watching.

The McKee-Farrar prosthesis (metal-on-metal type, no cement) and the Charnley prosthesis (metal on HMPE, cement, small diameter) are clearly the two most popular total hip devices. They appear competitive in terms of success and complications statistics. There does appear to be a greater tendency for the McKee-Farrar to loosen (18). The operation is quite difficult and the proper setting of a total hip is very critical. Like most complex surgical procedures, the more you do, the better you get - and the better the statistics become. It is therefore very difficult to compare statistics from the various groups - particularly small samples and newcomers.

It is interesting to note that all of the total hip devices were developed by European surgeons, and primarily British surgeons. Charnley, McKee, and Ring are all British.

The results of total artificial hip surgery are quite spectacular - "miraculous", according to the papers. Patients with severe pain and disability are restored to a decent, relatively pain-free, and mobile state again - at least for a few years, and perhaps for 5-10 years or more.

Even Charnley says (Reference 2, p.21): "...caution must be exercised in treating osteoarthritic patients if they are not so severely disabled as not to be able to postpone the decision to have surgery until the leaders of the profession are themselves quite free of all reservations. I have no hesitation in advising this form of surgery to patients, of any age, who cannot walk without canes or crutches, who are unable to work, and who have severe pain. Generally speaking, if patients are not very disabled, I advise them to postpone a decision for another year or two to give us time for further assessment of our late results."

V. Other Total Artificial Joints

Complete artificial joints are also available for the finger joints, for the shoulder, for the elbow, for the knee, and even for the toes. With the exception of finger joints, these are not common, generally clinically accepted, procedures. They will be discussed next quarter.

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17. B. G. Weber, "Total-Hip Replacement with Rotation-Endroprosthesis," in Reference 8, pp. 79-84.

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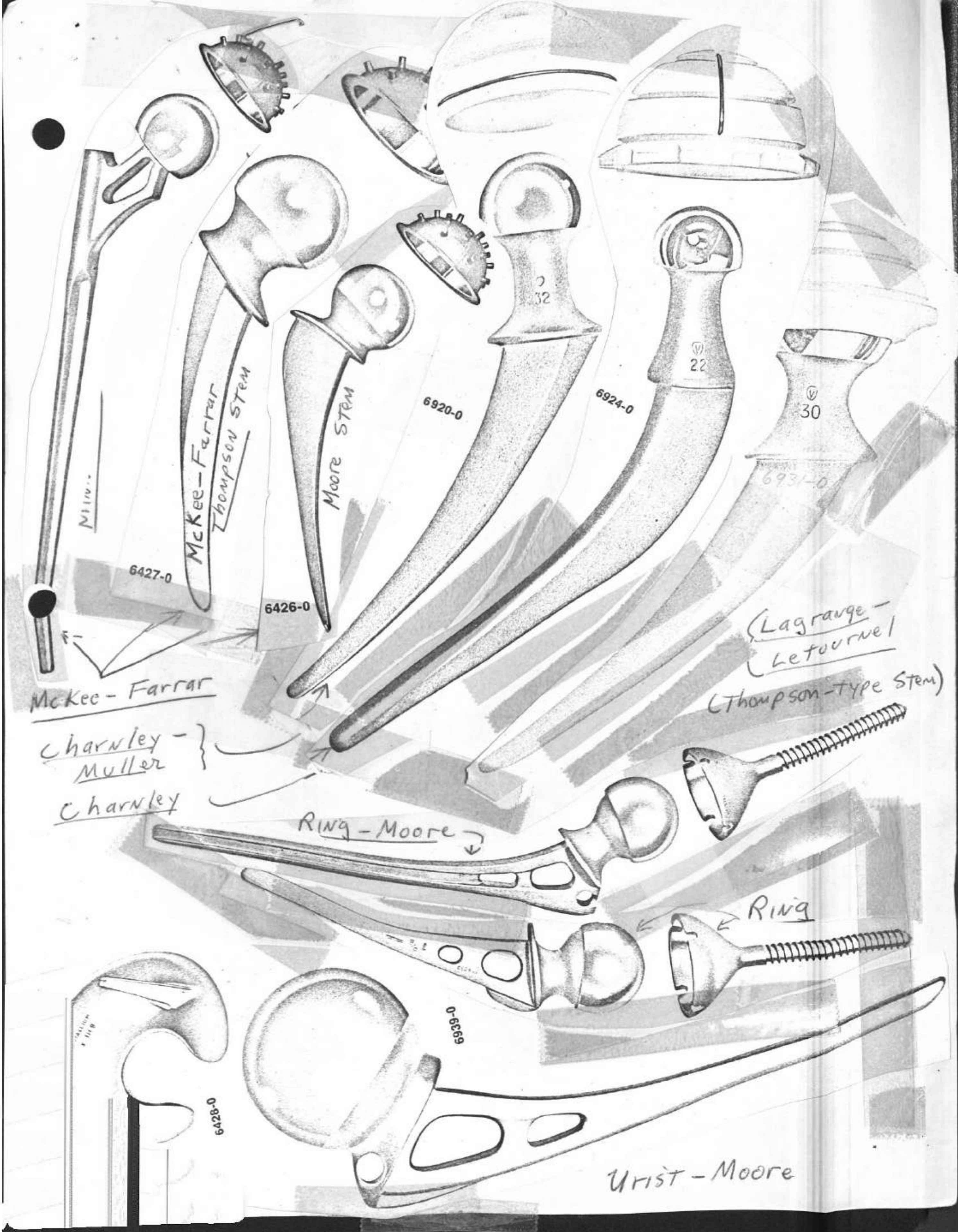

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McKee-Farrar Thompson Stem
Moore Stem
McKee-Farrar
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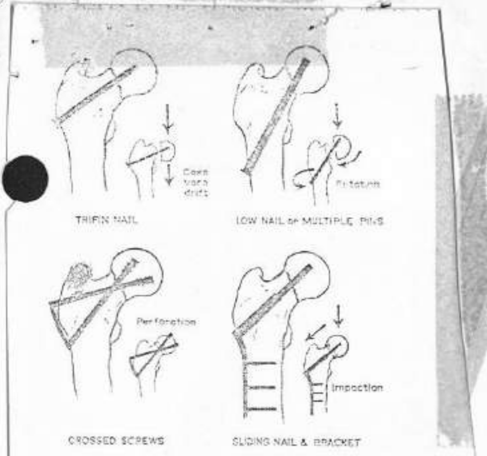


FIG. 9. Four principles of fracture fixation. (Ref. 7)

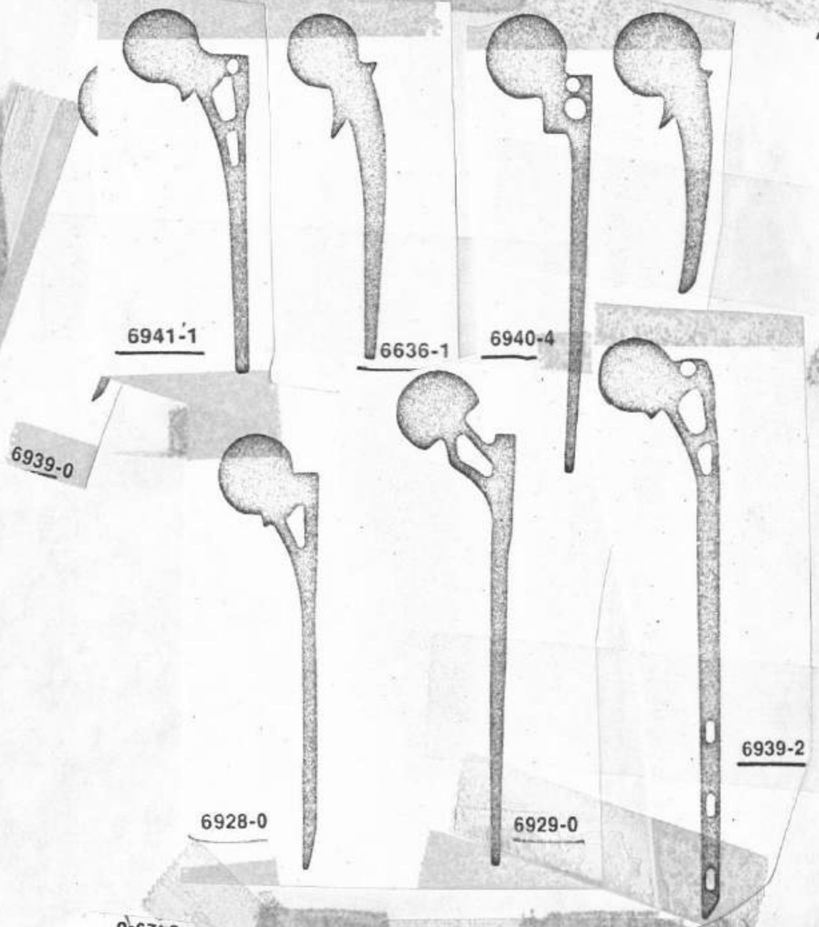
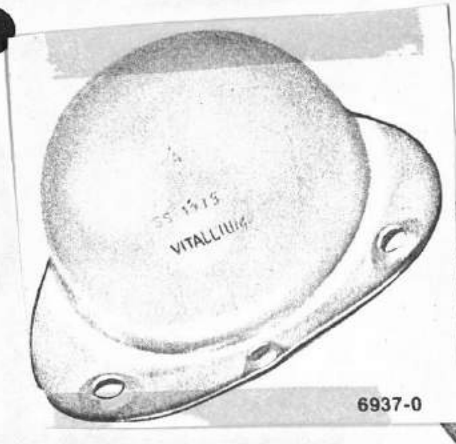


Fig. 10 Femoral Head Prosthesis (see notes)



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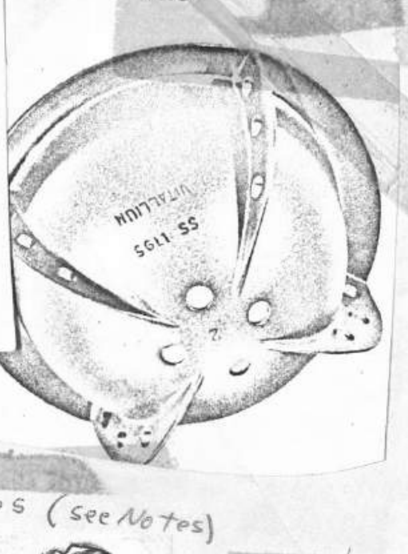

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Fig. 11 - Acetabular Cups (see Notes)

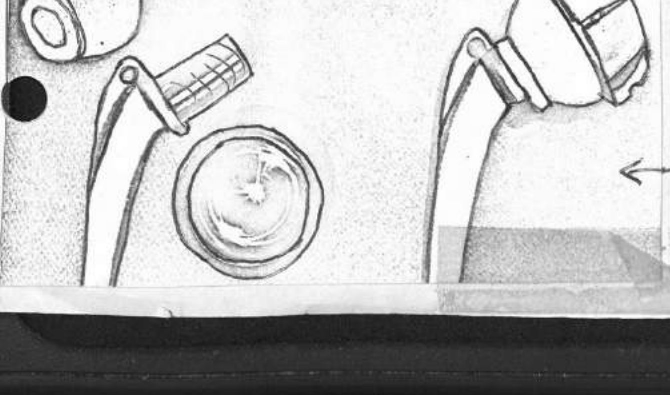

FIG. 12. The actual rotation total endoprosthesis. A. The components: femoral part with rotation cylinder and socket of chrome-cobalt alloy. Head of plastic material. B, The assembled prosthesis. (Reprinted by permission of the author from Z. Orthop. 107:304-315, 1970.) (Ref. 17, p 81)

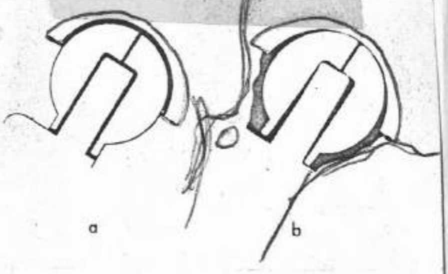

FIG. 13. Loose fitting of the prosthesis. A, Loose fitting allows joint fluid to circulate from one joint compartment to the other. The head is in effect "floating." B, The small relative movements between the 3 parts cause pump- and shock-absorbing effects. (Reprinted by permission of the author from Z. Orthop. 107:304-315, 1970.) (Ref. 17, p 81)