REPLACEMENT OF THE HIP JOINT

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MY OWN INTEREST in replacement of the hip joint started while I held a Research Fellowship of the College from 1954 to 1957, working at the Buckston Browne Farm. This Farm is a unique institution in that its research workers are surgeons who are not primarily interested in the experimental method nor indeed in the furtherance of biological knowledge, but are committed to this work in order to push forward the frontiers of surgical achievement.

At that time I looked eagerly for a suitable experimental animal. The loading of the hip joint of a quadruped is, of course, in no ways comparable to that of man, but facilities at the Farm for the large apes were unfortunately unsuitable. The ostrich is the perfect experimental animal for hip surgery. It is due to the farsightedness and prudence of the Director of the Buckston Browne Farm that I was restrained from embarking upon this particular project.

The problems associated with the reconstruction of the hip joint in both osteo-arthritis and rheumatoid arthritis are manifest by the failures of the earlier methods. The classical Smith-Petersen mould arthroplasty, which developed almost 30 years ago, gave results which must now be regarded as largely indifferent. In the course of the operation the blood supply of the femoral neck is disturbed and the stump of the neck often becomes avascular. In addition the movement of the vitallium cup within the acetabulum commonly leads to increasing erosion of the pelvis.

The problem of the blood supply is overcome by removing the head and neck completely and using an intra-medullary prosthesis as a replacement. This operation, however, which succeeds so well in fractures of the femoral neck when the cartilage of the acetabulum is intact, gives a completely different result when the acetabulum is arthritic. In order to produce a satisfactory joint, one must clearly replace both articular surfaces. This is the basis of the total hip replacement. Having accepted that both halves of the joint must be reconstructed, the problem remains of how the surfaces should be designed, how they should be retained in position and of what materials they are best constructed.

Total replacement is not a new concept; as long ago as 1938 Philip Wiles performed six operations in patients with severe Still's disease. These joints, however, disintegrated, and subsequent studies have shown

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that any metal-on-metal articulation should not be made of stainless steel. In 1951 Haboush in New York inserted a vitallium ball-and-socket joint and it is interesting to note that at this time both components were cemented in place with acrylic. Unfortunately the joint dislocated some three weeks post-operatively and its subsequent fate is unknown. In the same year McKee in Norwich introduced a total hip replacement made of stainless steel, but his first three appliances became loose in less than a year and had to be removed. He subsequently redesigned this apparatus using cobalt chrome and the results were undoubtedly improved, but loosening remained a problem until in 1961 he turned to a cobalt chrome prosthesis in which both components were fixed in position with bone cement.

At the same time Charnley was engaged upon work combining a plastic cup with a stainless steel femoral head. The earlier cups were made o f teflon, and in the course of time the plastic wore and the products of wear produced an intense inflammatory reaction. During the last eight years he has been using a similar femoral head but matched to a high density polyethylene cup, both components being cemented into position. There is no doubt that to date the high density polyethylene wears exceptionally well and forms an articulation with a very low coefficient of friction. Although long-term results are not yet available, it seems likely that the plastic will have at least a 10-year working life.

My own interest in this problem started in 1960. At that time we were using a plastic cup which was cemented in position, matched to a titanium head. The initial results of this replacement were undoubtedly satisfactory, and for a year or two all appeared to be well. We then, however, found like Charnley that the plastic was starting to wear and that the products of wear were intensely irritant. Most of these replacements were eventually removed and pseudarthroses performed; in removing the cup which had been cemented in position, I was impressed by the poor bond which existed between the cup and the pelvis and felt that some more certain method of pelvic fixation was needed.

If one returns to a metal-on-metal articulation, there is abundant evidence that the most suitable material is the chrome cobalt alloy known as Vinertia in England and Vitallium in the United States. Its wear rate is low and, as far as we know at the moment, the products of wear are inert. We were satisfied that the femoral side of our total replacement was essentially sound, we were relying upon a Moore's prosthesis which had been in use for many years in fractures of the femoral neck and we did not feel that loosening of this prosthesis was a significant problem. The success of the intra-medullary femoral prosthesis depends upon the axial location of the stem which locates the flange in the correct position upon the cut surface of the femoral neck, and we felt that if a similar pelvic component could be produced, following the same axial line, both halves of the joint would be stable without the use of bone cement.

The axial line of the pelvis follows the buttress of bone which passes from the acetabulum just lateral to the greater sciatic notch, and a cup with a screw thread inserted into this bar of bone would be subjected to minimal stresses. To design a satisfactory cup was not difficult and we elected for a simple hemisphere with an internal diameter of $1\frac{5}{8}$ inch associated with a screw thread $3\frac{1}{2}$ inches long. We were left with the problem of locating the screw thread within the buttress of bone and this was solved by the production of a pair of directors which used the greater

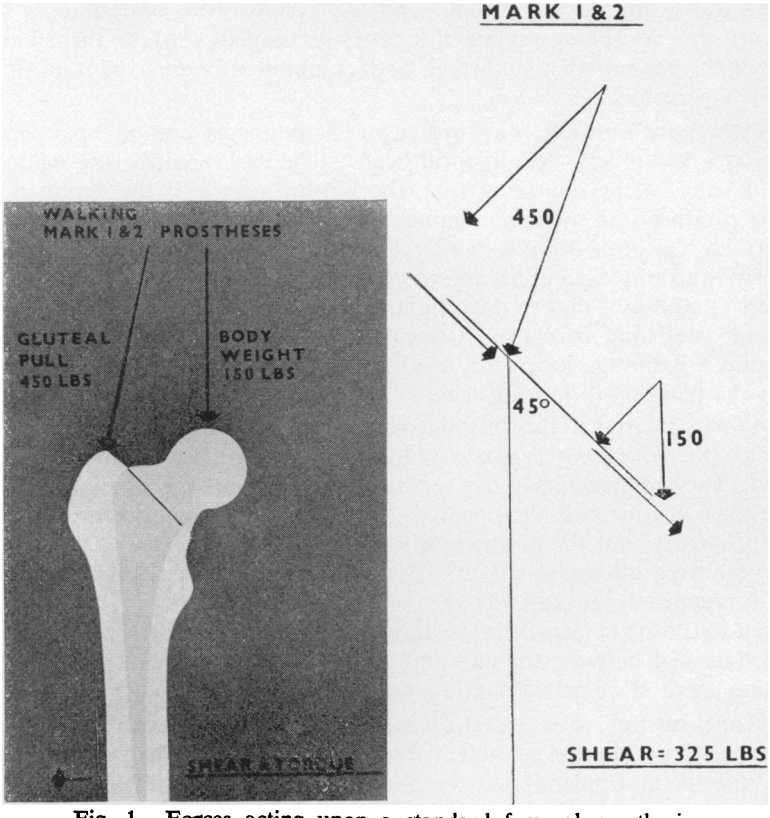

Fig. 1. Forces acting upon a standard femoral prosthesis.

sciatic notch as their guide. These directors centred the cup in the acetabulum by means of a mushroom, and positioned the screw thread by a loop which engaged in the greater sciatic notch; through the centre of the guide a wire was passed and over this a cannulated drill, and into the cavity so formed the cup could be screwed.

We were gratified to find, when we did this in the pelvis, that the mouth of the cup faced about 20° forwards and 20° laterally and, making a virtue of necessity, I regard this as the optimum position for the acetabular

component. It is certainly a stable one in the sense that we have had no dislocations and it certainly allows a free range of hip movement. Our femoral component at this time was an ordinary Moore's prosthesis matched accurately and lapped onto the cup.

We inserted 48 of these replacements: the initial results were quite satisfactory but we were concerned that the junction of the cup and the screw thread might be a point of weakness and we therefore redesigned the cup so that it could be countersunk into the pelvis. Our fears in this

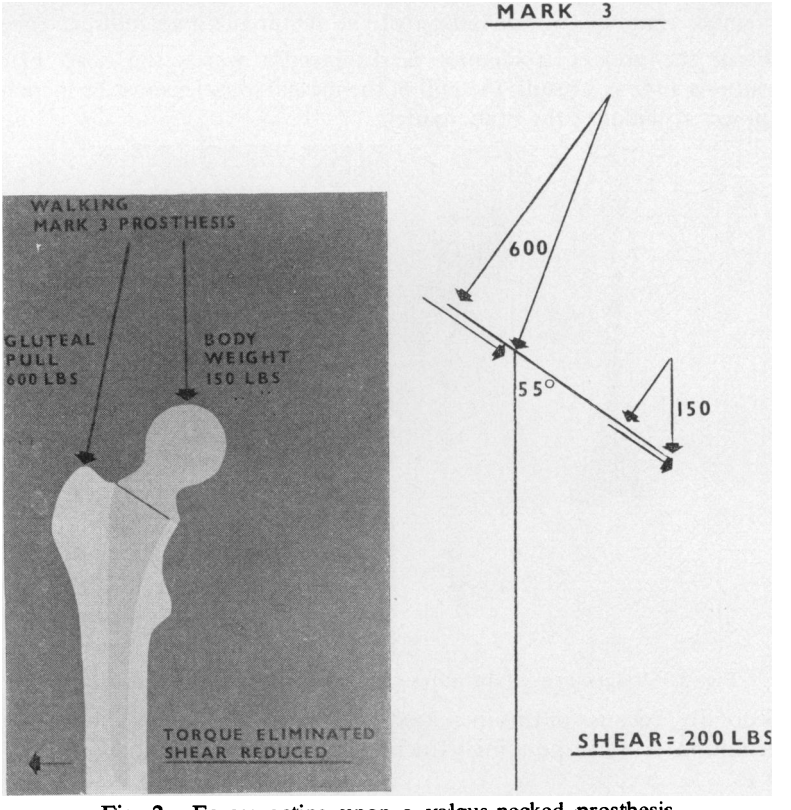

Fig. 2. Forces acting upon a valgus-necked prosthesis.

respect were only too well founded; in the course of time two of the original uncountersunk cups have broken and have had to be replaced by cups of the current design.

In some of our early patients, we had problems of instability of the femoral component and we have tried to eliminate this by re-orientating the axis between the head and neck of the prosthesis. If you look at an ordinary Moore's prosthesis in position in the femur, you will notice that the forces that act upon it—which are those of the body weight

matched by the pull of the muscles on the greater trochanter, which is approximately three times that of the weight of the subject when he is standing—result both in a tendency of the prosthesis to slide down the inter-trochanteric slope, and also to tilt so that its tip digs into the lateral femoral cortex (Fig. 1). The normal angle between the head and neck of a Moore's prosthesis is 135°, so one can calculate that if one increases this angle to 160° the prosthesis is completely stable. We have in fact adopted an angle of 150°, so that the tendency both to shear and to tilt are largely but not completely eliminated (Fig. 2). It is important to remember that this re-orientation of the femur has two indirect effects:

First, the greater trochanter is displaced towards the head of the prosthesis and, as a result, the pull of the gluteal muscles must be increased in power to balance the body load;

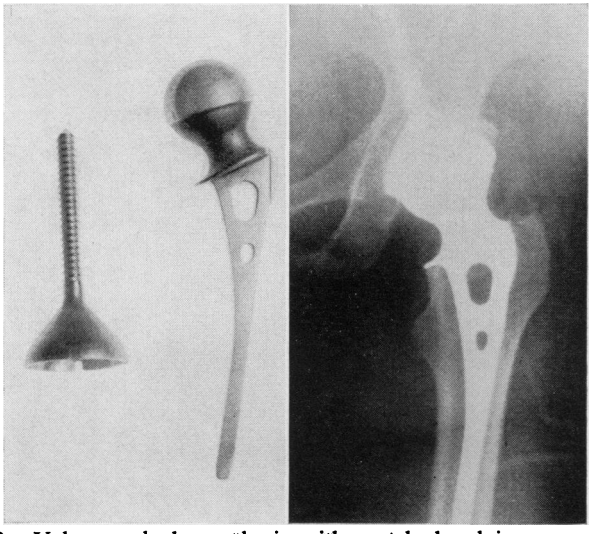

Fig 3. Valgus-necked prosthesis with matched pelvic component.

Secondly, because of this increased pull, the load carried by the artificial articulation is correspondingly increased, probably from about 600 to 800 lb.

Neither of these considerations has appeared to be of very great practical importance, but there is clearly a limit to the extent to which one can increase the valgus angle of the femoral neck without running into practical difficulties; indeed with several experimental prostheses in which the head-neck angle was 160°, we found that the glutei could not be developed sufficiently to produce the tension needed to balance the increased load.

We now use one of two prostheses differing only in the femoral portion: (*a*) the valgus-necked model for routine use (Fig. 3) and (*b*) the

straight-stem Moore's prosthesis for use when the medullary canal is unduly wide (Fig. 4)

Our experience with this type of articulation now extends over a period of seven years; we have in all undertaken almost 600 replacements and have maintained these patients under continuous review. I think it is important at the outset to state that about 90% of these replacements can be rated as excellent results, that is to say these hips are painfree, have more than a right angle of flexion and the patients who own them are able to walk independently as far as they wish. For ordinary practical purposes, they would pass as normal. Although our earlier patients were

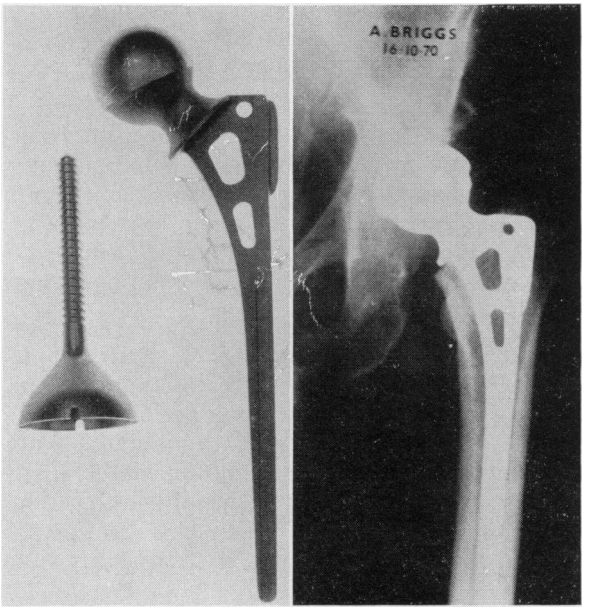

Fig. 4. Straight stem Moore's prosthesis matched to a cup—used when the femoral canal is unduly wide.

in the evening of their lives, we have gradually extended the indications for the operation with increasing confidence to the younger age groups. We have a number of patients in their fifties and some below this who are very active and some engaged in relatively heavy manual work without obvious discomfort or difficulties. This type of total hip replacement, and indeed all types of total hip replacement, are therefore capable of giving rise to a joint which is essentially normal; having said this, we should turn our interests to the failures, because these are the only patients from whom one will learn.

The first and most major failure is that the patient may not survive the operation or may not leave hospital; the common practical risk of this, as in so many other procedures, is that of venous thrombosis and pul-

monary embolism and just under 1% of our patients have in fact died from this cause. We have had a good deal of experience with prophylactic anti-coagulants in the past and I have never been satisfied that the risks of anti-coagulant procedure would justify their use under these circumstances. We have therefore relied on elevation of the foot, early bed exercises and relatively rapid ambulation, but have not hesitated to treat any patient with anti-coagulants when there has been the slightest clinical evidence of a thrombosis occurring. In the course of our experience with this operation, we have also had a mortality from other conditions which is probably incidental to operating upon patients who are mainly elderly; we have had two deaths of patients while in hospital from cerebral thrombosis, one from a bilateral broncho-pneumonia and another from massive gastro-intestinal bleeding associated with acute peptic ulceration.

The second major problem with any total replacement is that of infection; in this respect we have been relatively fortunate in that our overall infection rate has been under 1%, indeed we have had no joint infections during the last two years. Nevertheless, infection in any total hip replacement is, of course, a major tragedy and demands, if it is deep seated, removal of the implant and the production of a pseudarthrosis.

Restoration of joint movement after a total hip replacement is normally uneventful, indeed we are now surprised if we do not rapidly achieve a flexion range of 90°. Nevertheless, we have had four hips which have gone stiff after total replacements, both of them in bilateral cases. These were patients whose joints were initially stiff; they mobilized relatively rapidly, and then in the course of a few weeks the movements gradually diminished again and their radiographs showed progressive ossification around the joints. We have only explored one of these hips and found a dense mass of bone all round the new articulation; it seems fairly certain that this is a constitutional reaction rather than a local one and I think at the moment it is unlikely that a hip which goes stiff in this way can be mobilized by any revisional procedure.

One of the biggest problems of total hip replacement is that of loosening. It seems to be self-evident that if one puts in a replacement, whether cemented or not, there must inevitably be some difference between the elasticity of the bone into which the replacement is inserted and the implant which is introduced, and at the margins of the implant some movement must occur. In some patients one sees radiological changes which must be interpreted as loosening of the prosthesis; these changes are a shift in its position in comparable films and are often associated with a line of bone sclerosis indicating the original site of the implant. Not all patients with prosthetic loosening, however, complain of discomfort, indeed the mechanism of the production of pain in these patients is as yet by no means certain. We have had patients with undoubted

radiological evidence of movement, who never complained of the slightest discomfort, whilst we have others whose movement has only been demonstrated at exploration of the joint, who have complained of severe and incapacitating pain in the antero-lateral aspect of the thigh on weight bearing. One must accept, of course, that the tolerance of pain varies widely, but we certainly need more evidence about why the movement of a prosthesis within a bone produces pain. It seems possible that pistoning may play a part in the production of symptoms; it is known that bone is sensitive to rises in internal pressure and the sudden loading of a femoral component with a flange at the top, will produce a rapid increase in the pressure within the medullary canal. We have very rarely been able to associate symptoms with loosening of a pelvic component, although gross loosening will, of course, impair the quality of the articulation and the stability of the limb in question.

To date our revisions for loosening have numbered 3%, but with improving technique, and probably with improvement in the construction of the replacement, these seem to be becoming infrequent. We have found that symptoms for loosening are maximal in the first year or 18 months after the operation has been done, and that patients coming to revision for loosening do so usually after a year or two; it is very uncommon to see patients presenting with loosening four or five years after a replacement has been performed. Although this loosening rate of 3% is disturbing, it is important to point out that it is lower than the only loosening rate I have been able to find for cemented metal-on-metal articulations, which is 9%, and there is no doubt in my mind that a cemented femoral prosthesis, if it does work loose, is infinitely more painful than one which is uncemented. However unwelcome loosening may be as a symptom, it has given us the opportunity to examine some of the replacements a year or two after they have been in use and to estimate the wear which is likely to occur within the articulation. In the earlier replacements, some sludge formed at the lower part of the joint, but in a well matched articulation of the current design this is extremely rare. There is no doubt that the standard of engineering which is now applied to a metal-on-metal replacement is far higher than four or five years ago and, as a result, the wear is inevitably less.

There are three features in the construction of an artificial joint which appear to be of importance: first, the quality of the surface of the metal; secondly, the sphericity of the two articulating areas and, thirdly, the point at which within the articulation the load should be taken.

A fine surface finish is essential if a metal-on-metal joint is to work, as the high spots on the two metallic surfaces will inevitably come into contact and under certain circumstances cold welding can occur. The production of a high standard of finish demands polishing, and at the same time must not interfere with the overall sphericity of the component.

It is possible to measure by means of a Talyrond the quality of the sphere one is attempting to produce and it is now the custom to work to a tolerance of no more than one ten-thousandth of an inch. Prostheses which deviate more than this at the end of manufacture are rejected. The cup must be oversize relative to the sphere, leaving a gap of perhaps two- or three-thousandths of an inch between the two surfaces in which fluid may collect, and it is an advantage to relieve the apex of the cup in the form of a well (Fig. 5). This difference between the radius of the two articulating surfaces will mean that weight is borne near the centre of the cup; thus relatively small areas of metal are in contact and friction is diminished.

We have been agreeably surprised in looking at the joints which have been removed after several years use, how well they have stood up to

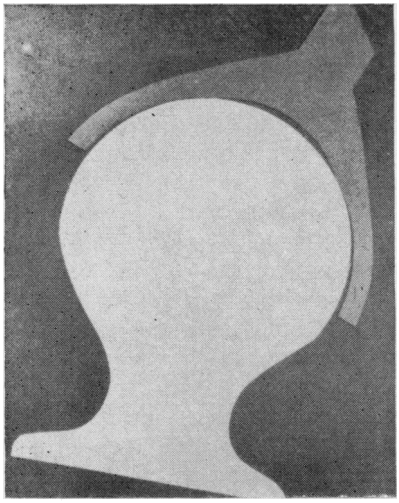

Fig. 5. The sphere is slightly smaller than the cup to permit central bearing.

movement within the body; indeed their condition is far better than the experimental studies of the hip simulator would suggest. There is no doubt that in a metal-on-metal joint the surfaces do, in the course of time, bed in and as a result the sphericity of the articulation tends to improve and the surface irregularities tend to diminish. This feature, together with the diminution of sludge in the joints, leaves us in no doubt that an articulation of this sort will last, as far as the implant is concerned, for the rest of the natural life of the patient. Indeed, it can be calculated that after 50 years use the loss of substance in terms of loss of metal on the surface, will be no more than one- or two-thousandths of an inch.

Loss of quality of the articulation, however, is not the only possible cause for late failure; it is possible that with the passage of time even the small quantities of metal which are lost from the joint surfaces may give

rise to reactions either locally or elsewhere in the body. There is, at the moment, no evidence that this is occurring, but there is no doubt that the metallic elements from which the alloy is created, cobalt, chromium and nickel will circulate within the blood and be removed from the region of the joint and can be found in tissues at some distance. There has been a suggestion recently that some patients might be sensitive to nickel and that this might produce a local reaction. Whether there is any substance in this argument, time must be left to tell. Most allergic phenomena are, of course, features of skin or mucous membrane rather than connective tissue, and it would be surprising if sensitivity reactions did in fact occur within the deep tissues.

If we are satisfied that the metal-on-metal articulation is going to last, and all the evidence suggests that it will in fact do so, are there any other possible causes in or around the joint which might lead to failure? I have already mentioned some of the earlier problems, infection and the formation of new bone; these are rare problems and they will become manifest in the first year. I have mentioned the problem of loosening which, if it occurs, is usually going to become manifest in the course of the first two or three years. There is no doubt that the problem of bonding a prosthesis firmly with bone is still an unsolved one and it is profitable in this connection to look at the possibility of producing a rather firmer link than that obtained within a simple metal implant.

The use of acrylic cement in this respect has proceeded rather hesitantly and cautiously and, although it has become accepted in most parts of this country, it is still viewed with some suspicion in the United States. The virtue of acrylic cement is that it can be supplied in the form of a powder and a liquid which when mixed will set in the course of seven or eight minutes; after a minute or two of mixing, one is left with a firm dough which can be inserted into a cavity or locked into position in holes in the skeleton and into which a prosthesis can be pressed and relatively firmly held. There is no doubt that in the past it has given rise to some problems, particularly if it is used in liquid state, where it tends to be toxic; and when it sets, it becomes very hot and might well be expected to damage the surrounding tissues. In fact the production of heat in the bone in which it is implanted appears to be of little significance, but if it strays into associated tissues, and particularly comes into contact with nerves, some destruction can occur. Assuming, however, that it has performed its function in the early stages, has set well and has given rise to no reactions, one is left with the problem of how the implant will stand up to the transmission of load from the metal through the cement into the skeleton. There is now a good deal of evidence that load transfer in this way can be achieved satisfactorily, at least for a number of years, and perhaps the only feature of concern in the use of cement at the moment is the fact that some patients with cemented prostheses have been

prone to develop late infections or sinuses which are often sterile on culture. There is no doubt in my mind that the infection rate in association with a cemented prosthesis is higher than one in which cement is not used; whether this is a specific reaction to the cement or whether it is due to the fact that a large mass of inert material has been inserted into the bone is at the moment uncertain.

There is no doubt that a satisfactory replacement can be performed in the vast majority of patients without the use of bone cement, but we have looked at the possibility that there may be certain groups which are particularly vulnerable to loosening in which the use of cement might be mandatory. Perhaps the most obvious example is the rheumatoid patient in whom the bones are often osteoporotic, sometimes as a result of the rheumatoid changes and sometimes increased by steroid treatment. Our experience with these patients, however, suggests that loosening is not a problem and that the osteoporotic bone hardens up after the replacement has been performed and is capable of carrying weight without difficulty. I am less certain about the patient with a senile osteoporosis after a total hip replacement; in this group, of course, reversal of the process of osteoporosis will not occur but, nevertheless, we have at the moment no evidence that loosening in these patients is a common problem. We are therefore not in a position to suggest that one group is more vulnerable, nor am I convinced that in the ordinary way a cemented replacement has any smaller chance of loosening, when applied over the broad spectrum of patients, than one which is uncemented.

There is some evidence that if one uses a metal-on-plastic joint, such as the stainless steel on high density polyethylene, which John Charnley has used with such effect, the problem of loosening is greatly diminished. This is, of course, a cemented replacement, but the risks of loosening are very much less than in a cemented metal-on-metal joint. One is therefore left with a choice between the risks of late loosening which is perhaps 1 or 2% in an uncemented replacement and perhaps a little higher when cement is used and the risk of wear in the metal-on-plastic joint. Whilst the loss of substance in the plastic cup is probably not a problem in that these cups will certainly last 10 years and probably longer, the products of wear may, of course, be irritant locally, as most plastics are, whereas the products of wear upon the metal-on-metal joint are, as we know, locally inert. A great deal of further experience clearly needs to be collected upon the late results of these replacements before one can select which of the present materials are the most suitable. There seems little doubt that we shall in the future see changes both in the alloys and the plastics which are available.

The success of total hip replacement has led to increasing interest in the possibility of replacement of the other major joints, particularly the knee and the ankle. There is little that can be done in the way of experi-

mental work to test the suitability of the design of an implant, and their use must therefore in the first place be limited to those patients who are grossly disabled, and for whom no orthodox method of treatment carries with it a reasonable prospect of relief. We have probably now passed this point in the field of total hip replacement and are treating patients whose disability is a little less severe and who might under some circumstances respond to other methods of surgical treatment. The increasing application of any surgical technique, however, carries with it a continuing responsibility for the evaluation of results and an equal willingness to present these results for the appraisal and criticism of one's colleagues.

FRENCH CONGRESS OF SURGERY, SEPTEMBER 1971

THE SEVENTY-THIRD French Congress of Surgery will be held on 27th September at 10.30 a.m. under the direction of Professor Pierre MALLET-GUY, at the Maison de la Chimie, 28 rue St. Dominique, Paris 7.

The Congress will continue on the same day at 2.30 p.m. as well as on 28th, 29th and 30th September in the mornings at 9.30 and in the afternoons at 2.30.

It will represent diverse activities of all branches of surgery and specialist associations.

Conforming to suggestions presented by the members of the French Association of Surgery during the seventy-second Congress, a larger place has been reserved for discussions between the speakers and their audiences. For this purpose the number of participants at the round tables has been reduced. Also, after the speeches of the Forum on surgical practices, a longer period has been reserved for discussions and questions from the members of the Association.

PROFESSOR CLAUDE OLIVIER

General Secretary of the French Association of Surgeons

Copies of an English translation of the programme, registration details, etc., may be obtained on application to the Editor of the *Annals*.