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Instructional lecture

Evolution and future of surface replacement of the hip

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Abstract: Surface replacement is a bone-conserving alternative to total hip arthroplasty and is a significant development in the evolution of hip arthroplasty. Surface replacement with polyethylene bearings was largely abandoned, primarily because of component aseptic loosening caused by tissue reaction to high-volumetric polyethylene wear. For patients with osteonecrosis and collapse of the femoral head but with preservation of some acetabular articular cartilage, precision fit, hemisurface replacement of the femoral head only has emerged as the treatment of choice. The survivorship of our series of patients, performed in the 1981–84 era (average age, 32 years), has been 85% at 5 years, 67% at 10 years, and 42% at 16 years. In the absence of polyethylene, there has been no loosening. Revisions were for cartilage wear. The procedure is now much improved with instrumentation for non-trochanteric osteotomy approaches and off-the-shelf components in 1-mm increments. For arthritic hips, a new era of surface replacement has emerged. With metal-on-metal bearings, the volumetric wear has been reduced 20–100 times from those with polyethylene, and there is no penalty for the large ball size. The devices are now conservative on the acetabular as well as femoral side. Hybrid or all-cementless fixation is superior to earlier all-cemented devices. In those patients, the results with up to 4 years have been complication-free, with an absence of pain and a return to high functional levels, including participation in sports. Forty patients have received a Conserve Plus with interference fitting of the acetabular component with sintered beads to obtain fixation. Although the follow-up is short, surface replacement with the large ball size is extremely stable, and dislocation is rare.

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Key words: metal/metal hemi-, full-surface hip replacement

Introduction

Surface replacement represents a significant development in the evolution of hip arthroplasty. It is a direct descendant of the cup arthroplasty originally conceived by Smith-Petersen.[47] Surface replacement is a bone-conserving alternative to total hip arthroplasty that restores normal joint biomechanics and load transfer and ensures joint stability. Historically, these appealing characteristics have been recognized by several investigators, and various designs and biomaterials have been used. In the early 1950s, Charnley experimented with a cementless all Teflon double-cup arthroplasty.[14,15] Loosening of both components due to rapid wear and an intense tissue reaction resulted in clinical failure and abandonment of the procedure. In the mid 1960s, Müller and Boltzy used a metal-on-metal (Co-Cr-Mo) resurfacing system which was a press-fit.[35] Despite satisfactory early results, this system was abandoned because of loosening of the components. In 1970, Gerard in France also implanted metal-on-metal resurfacing prostheses, with motion occurring not only between the components but between the components and bone.[21,22] Since total hip systems using fixation with cement were very successful in the short term, it was only after the exploration of revision of the stems that resurfacing became refined, with acrylic fixation in the mid 1970s being used in five different countries.

Cemented surface replacement systems using a high-density polyethylene acetabular component and a metal femoral cup were first implanted in Italy by Paltrinieri and Trentani,[38] followed by Furuya in Japan,[19,20] Freeman in England,[17,18] Capello et al. in the United States,[13] Amstutz et al. in the United States,[4,5,11] Wagner in Germany,[51] and Tanaka in Japan.[49] Wagner in 1982 used a

ceramic femoral component, but no results have been published.

Resurfacing procedures addressed the problem of preserving femoral bone stock at the initial operation and also had the potential of easy revision since the femoral canal was not violated. Most resurfacing systems were challenged by selecting for surgery young and/or high activity level patients who often had acetabular (developmental dysplasia) or femoral head (advanced osteonecrosis) bone stock deficiencies. The early results were encouraging but the longer follow-up was often disappointing.[1,12,25,26] Because of unpredictable results, resurfacing procedures were largely abandoned in the 1980s, except at the University of California, Los Angeles (UCLA), where resurfacing was used on a highly selective basis, with porous acetabular components for younger patients who would require at least two replacements in their lives. Although failure is multifactorial, it is now understood that bearing wear debris-induced osteolysis is the main problem.[8,12,27,28,31,36,40,41] Surface replacement failure was primarily due to the high volumetric polyethylene wear, and secondarily to a large prosthetic head; the failure was not due to high frictional torque, neck fractures, or osteonecrosis of the femoral head. The large diameter of surface replacement components results in polyethylene wear rates which are four to ten times higher than that of conventional total hip arthroplasties with femoral diameters of 28 mm.[29] Howie et al.[28] reported on the histologic analysis of 72 retrieved Wagner resurfacing specimens. They demonstrated the presence of polyethylene wear debris and macrophage activation at the cement-bone interface even in solidly fixed prostheses. Our own studies of retrieved specimens have also shown the presence of fixed prostheses and the presence of variable amounts and sizes of polyethylene wear debris provoking a histiocytic response along the cement interfaces.[3] The role of polyethylene debris in the failure of surface replacements is further amplified by our results of surface hemiarthroplasty for Ficat stage III or early stage IV[16b] osteonecrosis of the femoral head,[8,23] where cemented femoral components of similar design were implanted articulating against the host acetabulum. In the absence of polyethylene, no loosening or osteolysis was observed more than 15 years postoperatively.[10] Those hips which have required reoperation were revised for groin pain associated with deterioration of the acetabular cartilage. The retrieved femoral head specimens showed no evidence of osteolysis, were viable, and the cement-bone interface remained intact. The concern that resurfacing of the arthritic femoral head would cause osteonecrosis has not been substantiated by our human retrieval studies. More recently it has been verified that the femoral head remains viable in the vast majority of cases.[28]

The THARIES experience

The THARIES[1] (Total Hip Articular Replacement using Internal Eccentric Shells; Zimmer, Warsaw, IN, USA) was developed at UCLA Medical Center in 1973.[2,4,5,11] The prosthesis was cemented and consisted of a Co-Cr-Mo femoral component, and an all-polyethylene acetabular component. Both components were eccentric, with polyethylene maximum wall thickness of 3.5–5.5 mm (in small, medium, and large components) in the weight-bearing areas. The technique was designed on the principle of resecting all non-viable femoral head bone but also preserving as much of the head and neck as possible, to allow fixation of the prosthesis. There were six femoral shell sizes, with diameters ranging from 36 to 54 mm at 3- and 4-mm increments. One of the unique features of the THARIES development was the design and evolution of specialized instruments to obtain a consistently reproducible reamed femoral head. A special femoral neck pin-centering guide was crucial in avoiding violation of cortical bone during femoral preparation. Although the procedure was intended to preserve maximum bone stock, acrylic fixation of the acetabular component entailed, in some instances, the removal of a larger than desired amount of pelvic bone to allow for polyethylene and acrylic cement.

Between June 1975 and November 1984, 322 of 586 THARIES were implanted at UCLA by the senior author. The mean patient age at the time of surgery was 51 years (range, 20–67 years). The primary diagnoses were consistent with this young population and included osteoarthritis, 53%; osteonecrosis, 16%; development dysplasia, 10%; rheumatoid arthritis, 7%; post-trauma, 5%; slipped capital femoral epiphysis (SCFE), 4%; and other diagnoses, 5%. Fifty-five percent of patients were male, with an average weight of 81 kg, whereas females had an average weight of 62 kg. The average follow-up was 117 months, with 172 patients followed up for more than 10 years at last review (Fig. 1a–c). There have been 189 revisions, of which only 4 were due to femoral neck fractures. This suggests that this complication can be avoided with proper surgical technique and adequate instrumentation and implant design.

Aseptic loosening of one or both components was responsible for 97% of the failures. There were 56% acetabular failures alone, 31% femoral failures alone, and in 10%, loosening of both components was present at revision surgery. With revision as the endpoint, the 5-, 10-, and 16-year survivorship for the entire group was 88%, 48%, and 26%, respectively (Fig. 2). The best survivorship of hips was in males with osteoarthritis, who had larger components than women; survivorship was 91% at 5 years, 66% at 10 years, and 43% at 15 years (Fig. 3).

Table 1 shows the results by etiology for survivorship based on any revision, femoral failure, or acetabular failure. The best survivorship was in the osteoarthritis (OA)/post-trauma (PT) group which contains relatively older men. For all groups, except those with osteonecrosis, the survivorship at 12 years was significantly better on the femoral side than on the acetabular side; there was very little difference between the femoral and acetabular survivorship for osteonecrosis patients. Therefore, the femoral failure rate was higher and durability less in patients with osteonecrosis after surface replacement than for other etiologies.

Since the OA patients tended to be older and the other patients tended to be younger a comparison was made between the different etiologies based on patients younger than 50 years at surgery. There was

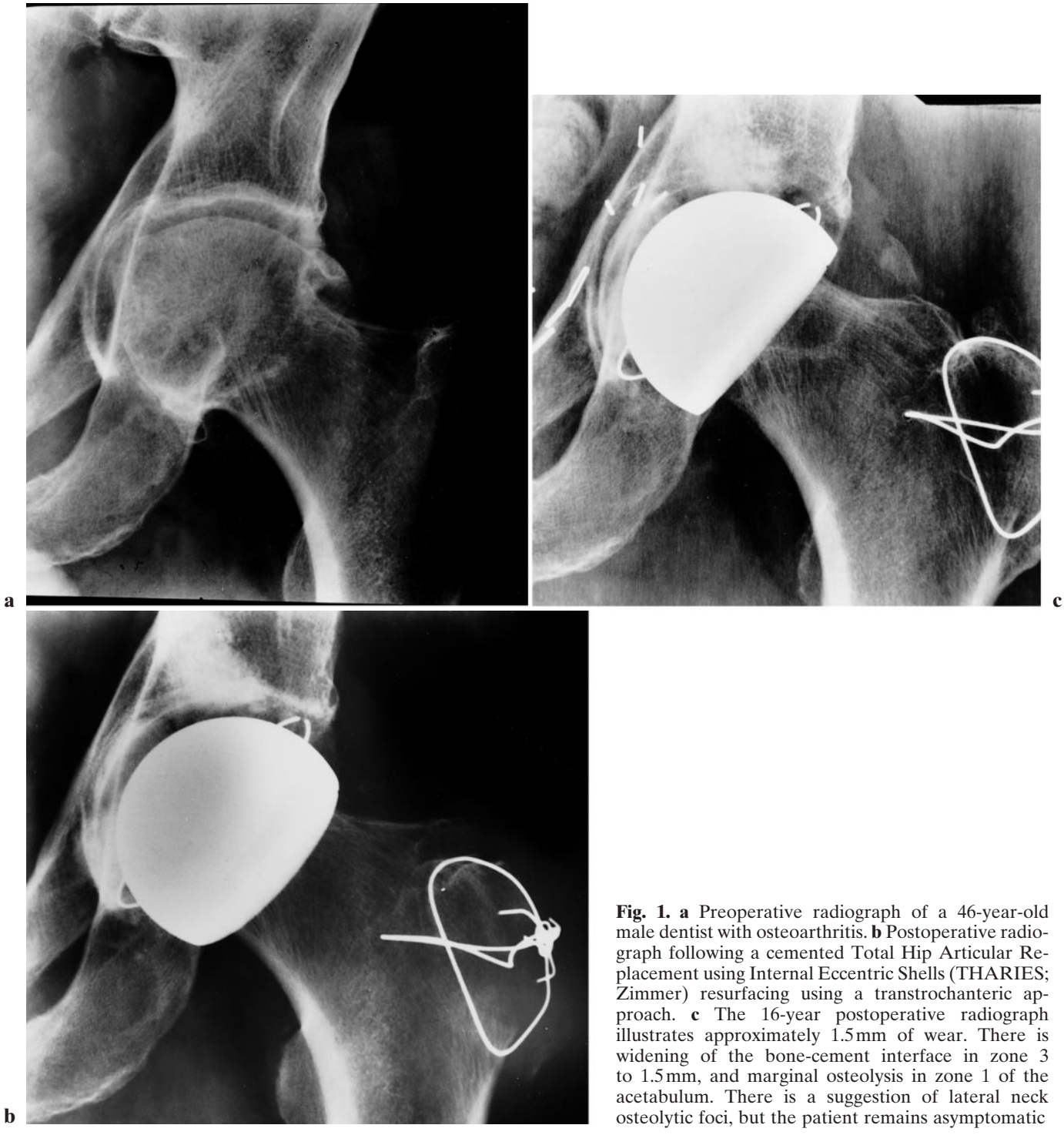


Fig. 1. a Preoperative radiograph of a 46-year-old male dentist with osteoarthritis. **b** Postoperative radiograph following a cemented Total Hip Articular Replacement using Internal Eccentric Shells (THARIES; Zimmer) resurfacing using a transtrochanteric approach. **c** The 16-year postoperative radiograph illustrates approximately 1.5 mm of wear. There is widening of the bone-cement interface in zone 3 to 1.5 mm, and marginal osteolysis in zone 1 of the acetabulum. There is a suggestion of lateral neck osteolytic foci, but the patient remains asymptomatic

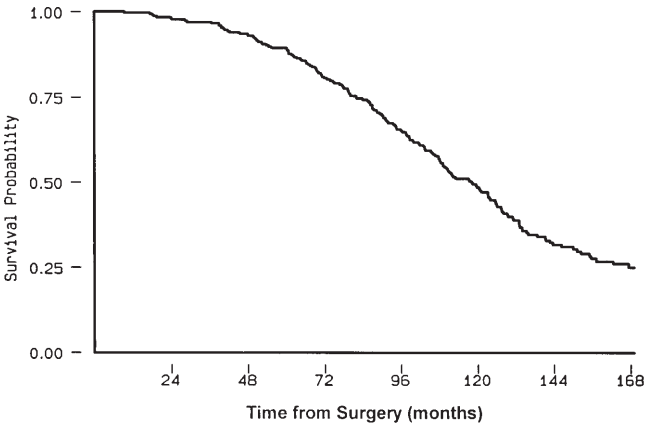


Fig. 2. Kaplan-Meier survivorship of all cemented THARIES (Zimmer)

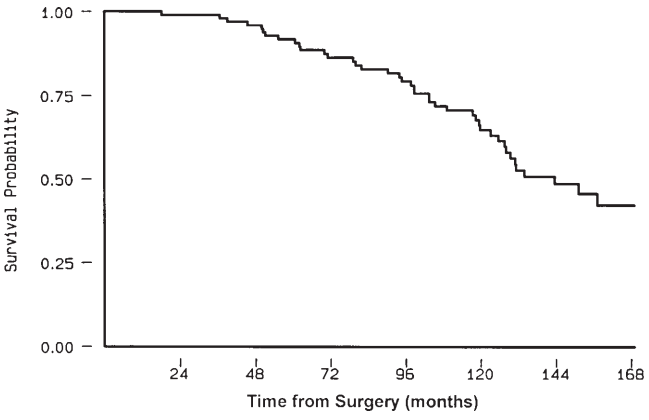


Fig. 3. THARIES survivorship curve of osteoarthritic males

Table 1. Percent survival based on date of revision, using the Kaplan Meier curves for various etiologies

	Any revision; years after surgery			Femoral failure; years after surgery			Acetabular failure; years after surgery		
Etiology	5	10	12	5	10	12	5	10	12
OA/PT	94	60	41	97	81	70	97	70	55
AVN	82	37	14	86	60	44	93	61	32
DDH	80	31	21	92	77	66	87	41	32
RA	90	49	31	90	71	61	95	62	45
Other	74	15	4	91	60	45	80	24	8

OA/PT, osteoarthritis/post-trauma; AVN, avascular necrosis; DDH, developmental dysplasia; RA, rheumatoid arthritis

a significant difference between the etiologies (P = 0.011 Log-rank test), and the 10-year estimated survivorships were: osteoarthritis, 51%; osteonecrosis, 33%; developmental dysplasia, 28%; rheumatoid disease, 50%; and other, 11% (which included failures of previous surface replacements).

Our experience has been that although most patients' THARIES prosthesis failed, when revision was required, they had gained an advantage over other comparable patients who had initially had conventional replacements, because they had a virgin femoral canal. The concept of resurfacing evolved into one of a conservative time-buying procedure that allowed the prospect of possibly increased durability after revision. It was anticipated that the surface replacement patients could benefit from newer and, we would hope, more advanced implants and simpler revisions. For example, beginning in 1983, cementless acetabular components, used either with a cemented or a cementless stem implanted into a virgin femoral canal, secured long-term function in these patients, some of whom were still young and active.

Cementless surface replacements

Because acrylic cement was thought to be the "weak link", cementless fixation was introduced into our surface replacement components in 1983, just as it was in conventional stem type devices. While acetabular durability improved considerably with the chamfered cylinder design (CCD), femoral osteolysis and/or fracture occurred with much greater frequency than in our cemented THARIES experience. These results are consistent with our current hypothesis, which states that the debris travels a path of least resistance. Because the CCD socket was securely interference-fitted at surgery into the acetabulum and subsequently circumferentially

secured by bone ingrowth, debris penetration deep into the pelvis was prevented, and as a result, the femoral head and neck or, in a few patients, the iliopsoas bursa became the most vulnerable sites. The subsequent osteolysis caused femoral loosening or fracture due to loss of structural integrity.

Although fixation of the chamfered cylinder cementless socket was excellent, it was technically difficult to insert. We therefore designed a cementless hemispherical socket which could be inserted after conventional hemispherical reaming and implantation techniques. When we changed to a hemispherical designed socket the initial fixation was secured with screws. The fixation of these components became secure in every patient with bone ingrowth. However, with wear of the polyethylene liner, we observed pelvic osteolysis in the dome; this had rarely been observed with the CCD. We hypothesize that the acetabulum became more vulnerable to debris because of the penetration of screws through the subchondral plate into the pelvis. The subchondral bone of the dome of the acetabulum often is relatively osteopenic and became susceptible to debris penetration under the fluid pressures of the joint.[40,41] The incidence of pelvic osteolysis was significantly reduced when screws were not used and the components were jammed in with an interference fit into an under-reamed cavity. However, the femoral neck became vulnerable to periprosthetic osteolysis.

On the femoral side, the cementless components, almost without exception, became fixed whether Ti alloy commercially-pure (CP) Ti mesh or porous beaded cobalt chrome components were used, but they were difficult to insert anatomically and often tilted during insertion, creating gaps between the bone and the component in some areas, which apparently added to the vulnerability to debris penetration.

The resultant effect of a very good acetabular component with a good seal and a poor one on the femoral side was a shortened durability of the femoral components in all etiologies, which was contrary to our experience with the all-cemented THARIES series (Fig. 4). We now believe that the cemented acetabular bone cement interface membrane was the path of least resistance and became a "storage reservoir" for debris. Ultimately this linear osteolysis did lead to loosening of the acetabular component, while the acrylic cement provided better protection for the femoral component bone interface. However, the reactive sclerotic bone at the interface on the acetabulum side acted as a debris barrier so that acetabular balloon osteolysis was rarely observed (only one patient, at 14 years). On the other hand, when cementless components become osseointegrated in the acetabulum, there is no sclerotic line (condensed bone), and the cancellous bone becomes more penetrable by the debris under pressure.

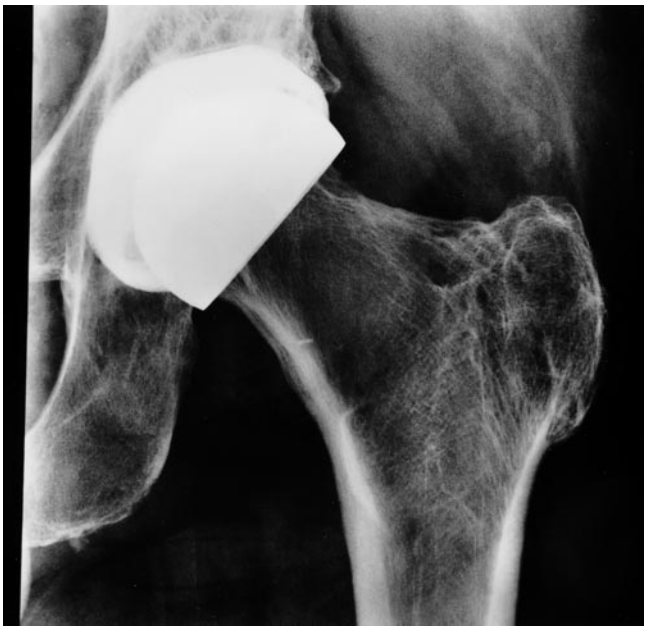
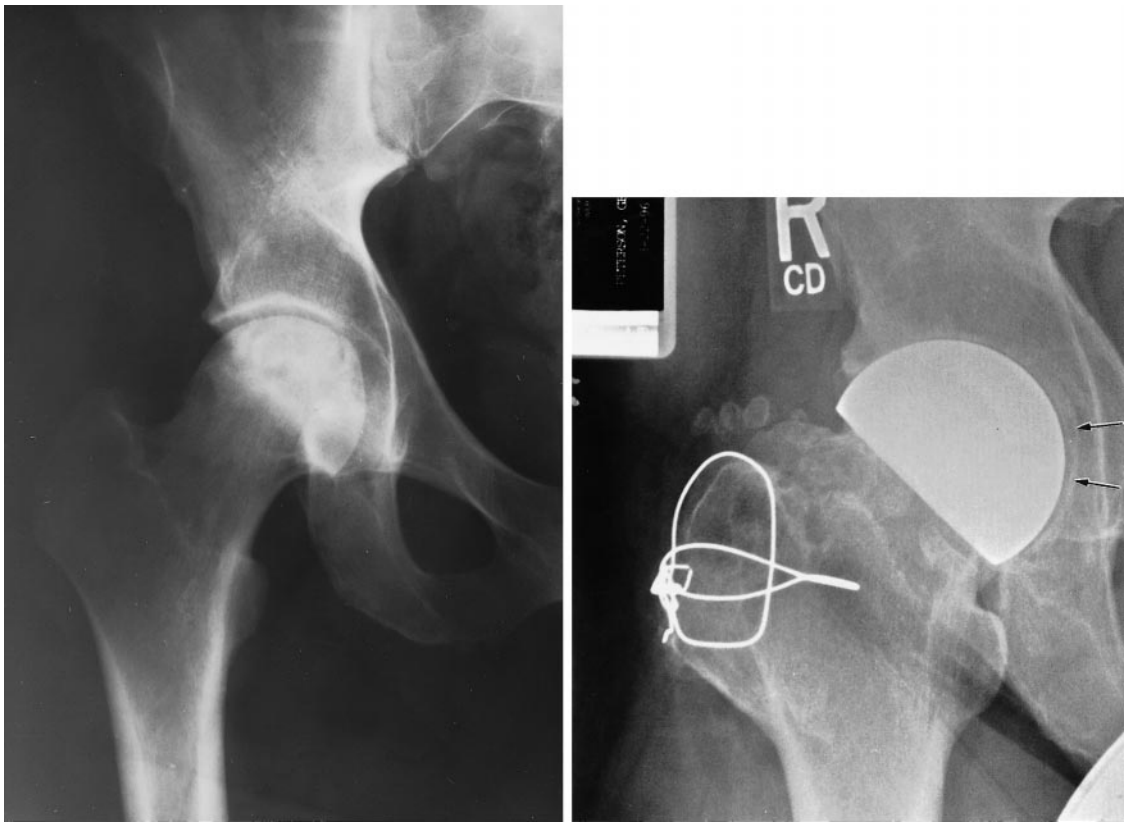


Fig. 4. Radiograph of a 46-year-old developer 12 years after cementless surface replacement with a chamfered cylinder design socket, Ti-alloy bearing and a commercially-pure (CP) titanium mesh. Note 1.5 mm of wear and marginal osteolytic erosion superiorly. He remains asymptomatic despite sustaining traumatic dislocation of both hips, normal and prosthetic, 8 years after the operation

All of the lessons of this early era were useful in the evolution of surface replacement design, but long-term durability is unlikely for young and active patients because of the limitation of polyethylene, especially since wear is increased due to the large ball size.

Hemisurface experience

The initiation of our precision-fit surface hemiarthroplasty experience began in 1980 because we were disappointed with the early results of full surface replacement (THARIES) as well as total hip replacement in young patients with osteonecrosis. Because the acetabulum is relatively normal in Ficat stage III and early stage IV osteonecrosis, the concept of hemiarthroplasty was appealing in order to defer total hip arthroplasty. Conventional stemmed hemiarthroplasty may fulfill this goal, but this procedure resects the femoral head and part of the neck and violates the femoral canal, and revision may require removal of the femoral stem, whereas precision fit surface hemiarthroplasty maximizes tissue conservation. By preserving proximal femoral bone, revision surgery is facilitated. We reported the medium-term results using custom Ti-alloy shells to precision-fit against the most preserved articu-



a b

Fig. 5. a Radiograph of a 35-year-old man who had bilateral osteonecrosis (ON) caused by alcoholism; Ficat stage III. **b** Fifteen years after Ti alloy custom hemi-surface. Note the new bone that has filled in the acetabular fossa (*arrows*). There is no evidence of femoral neck narrowing or erosion

lar cartilage in ten patients whose average age was 32 years in 1987[50] and subsequently the longer-term results in 1994.[8] Recently we reported on the results of 27 patients[10] in whom we used a variety of bearing materials, including cobalt chrome and ceramic, and the long-term results with the Ti-alloy components (Fig. 5a,b).

The morbidity has been minimal, with no sepsis, thromboembolic nerve palsy, or other complications. The quality of pain relief and range of motion has been good to excellent in all patients initially, and the results, although dependent on quality of acetabular cartilage, surprisingly durable. There have been no cases of prosthetic loosening, and the proximal bone is preserved and maintained (Fig. 6). The absence of osteolysis and loosening is due to the absence of a polyethylene bearing. The survivorship of the series performed in patients whose average age was 32 was 85% at 5 years, 67% at 10 years, and 42% still functioning at 16 years.[8,10,50]

Surface or cup hemiarthroplasty is appealing, and Hazelwood et al.[24] have confirmed that surface replacements provide a more normal transfer of stress to the

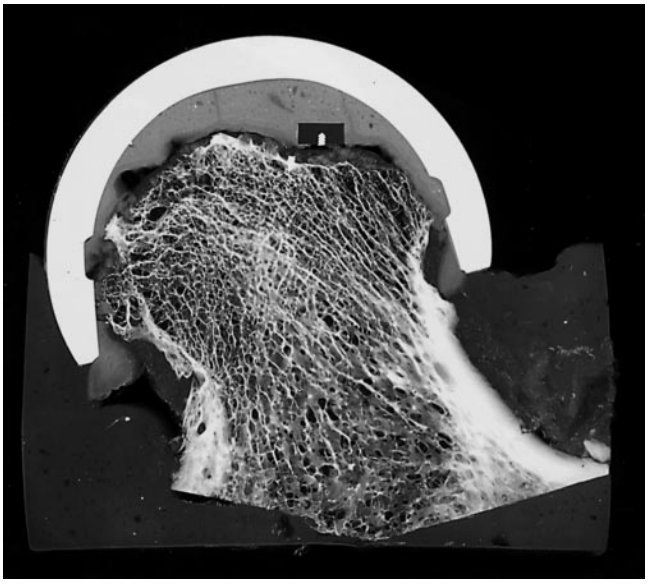


Fig. 6. Retrieved hemisurface specimen from a 34-year-old male with steroid-induced ON revised after 10 years because of pain associated with acetabular cartilage wear. Note the preservation of bone on the 3-mm slab section. There is a slight artifact at the bone/cement interface

proximal femur and may be expected to prevent proximal bone loss as a result of stress shielding. Sedel et al.[45] reported good results in 82% of hips at an average 7-year follow-up after Luck cup arthroplasty for osteonecrosis. Meulemeester and Rosing[34] reported only 8% failure at an average of 8 years with the Thomine cup. Scott et al.[44] reported a 13% revision rate at an average of 3 years in a series of total articular replacement arthroplasty (TARA; DePuy, Warsaw, IN, USA) surface hemiarthroplasties performed for Ficat stage III and IV osteonecrosis. Krackow et al.[30] reported 84% good or excellent results in nine hips with the TARA performed in patients with an average age of 41 years at an average of 3 years postoperatively. Wagner[51] reported no revisions at 4 years maximum follow-up in a series of ceramic surface hemiarthroplasties. Nelson,[37] using a hemispherical Ti alloy component for femoral head resurfacing, presented survivorship of 82% at 5 years in patients whose osteonecrosis was either idiopathic or caused by etiologies other than sickle cell disease.

Wear of the acetabular cartilage was the cause for revision in all of our patients. However, the histological response was very benign, with a few macrophages and some metallic debris scattered throughout a predominantly loose connective tissue, despite significant burnishing of the soft titanium alloy components. It is our belief that a harder bearing surface, such as cobalt chromium or aluminum, might produce even longer durability by minimizing the friction and metallic debris due to the soft titanium alloy component (Fig. 7a,b). However, it is also surprising how well the articular cartilage space has been preserved in some patients for more than 15 years, even though soft titanium alloy femoral components were used and even in the presence of rather advanced articular cartilage fibrillations in some areas of the acetabulum at surgery (Fig. 5b). We believe that the favorable survival was due to the "precision" fitting of these custom implants to the remaining normal acetabular cartilage.

For those requiring reoperation, revision to either full surface or total hip replacement was easy and much like a primary replacement because of bone stock preservation and intact intramedullary canals, and because there was no debris-induced granuloma. Since the quality of the articular cartilage once collapse has occurred is

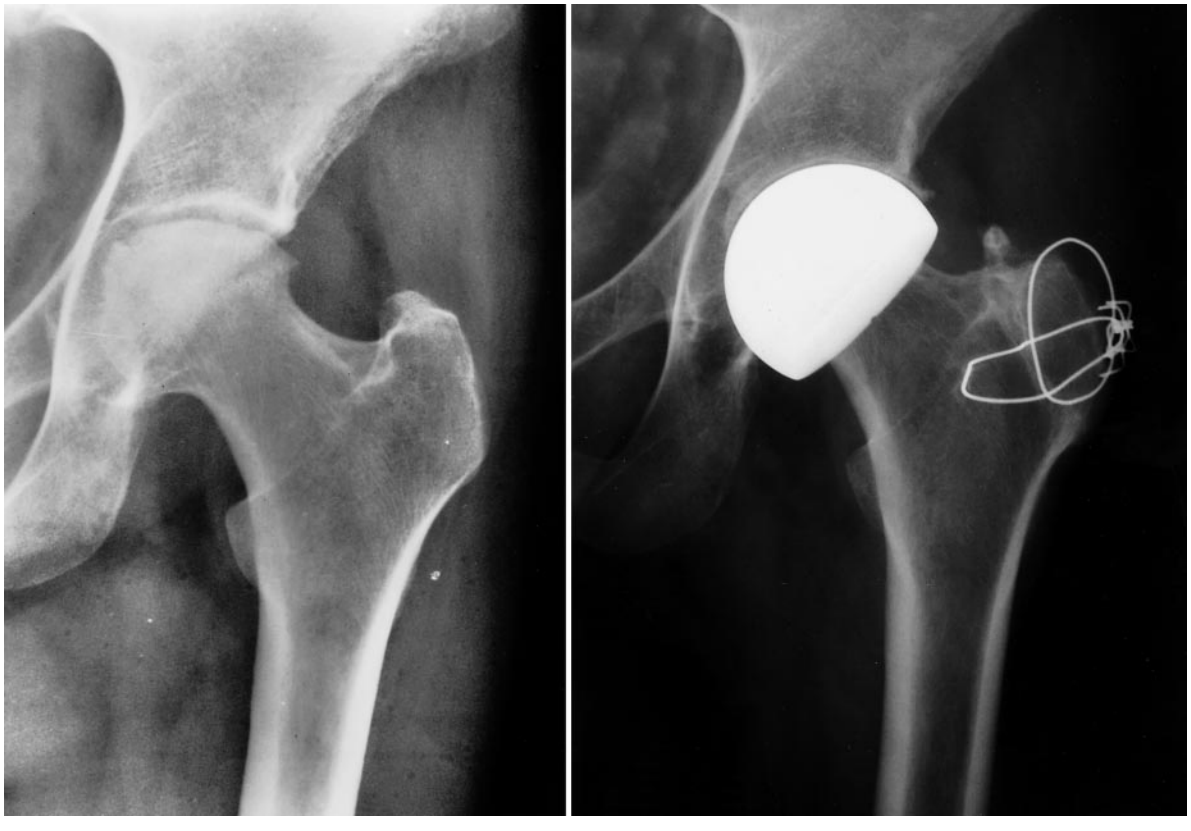


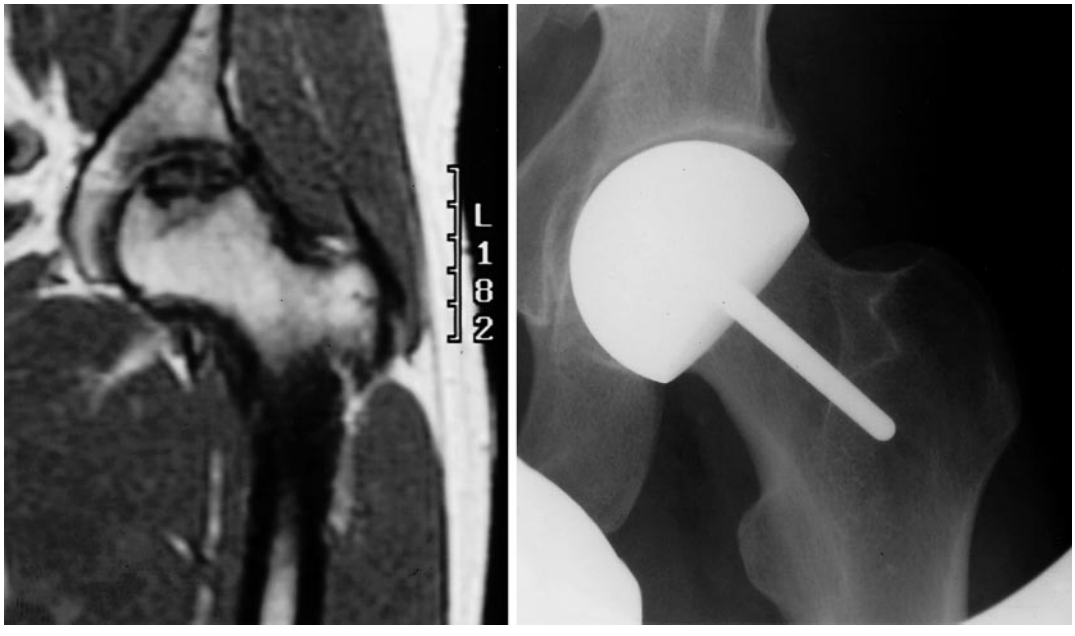
Fig. 7. a Radiograph of a 35-year-old woman with systemic lupus erythematosus and Ficat stage III ON; **b** 15.5 years postoperatively, a cobalt-chromium alloy hemisurface with preservation of thin articular cartilage. Note new bone in the acetabular fossa and preservation of proximal bone. The patient is essentially asymptomatic

related to long-term durability, we recommend nonweight bearing when stage III or early stage IV osteonecrosis has been identified in order to minimize secondary acetabular articular cartilage changes. Surgical delay caused by the need for custom components is now overcome by their routine availability in millimeter increments. The new femoral component (Conserve; Wright Medical Technology, Arlington, TN, USA[2]), available in millimeter increments, has greater than hemispherical coverage and incorporates a short stem to ensure accurate reaming and alignment of the component (Figs. 8, 9a,b).

The goal of management in patients with osteonecrosis is to preserve the femoral head rather than replace it, because the patient population tends to be younger. Precision-fit surface hemiarthroplasty offers an attractive, bone-preserving and "time-buying" alternative to selected patients with stage III or early stage IV osteonecrosis of the femoral head. This method should be considered as part of a lifetime treatment plan in the young patient, despite the potentially better initial performance of conventional total hip arthroplasties that will eventually require revision.

Unfortunately, if the osteonecrosis is far advanced and where both sides of the joint are arthritic, re-

Fig. 8. Wright Conserve — A new hemisurface femoral component that has greater hemispherical coverage and incorporates a short stem to ensure accurate reaming and alignment with a uniform cement mantle



a **b**

Fig. 9. **a** Magnetic resonance image from a 31-year-old cable pole climber with left Ficat stage III ON. Risk factors included steroids for ulcerative colitis, mild alcohol consumption, and trauma. **b** Postoperative hemisurface replacement with the Wright Conserve

placement or resurfacing of both sites of the bearing surfaces is necessary. Since conventional joint replacement with polyethylene is unlikely to produce lifetime durability for the young, alternative bearing materials with less wear and tissue reaction must be considered.

The new era of full surface replacement

The unsolved problem of treating young arthritic hips and the desire to increase the longevity of prosthetic reconstructions prompted a world-wide renewed interest in metal-on-metal articulations. The above studies and our accumulated experience suggest that in young and active patients who are most likely to outlive any type of hip reconstruction with polyethylene, a surface replacement with a low-wear bearing material is a prosthetic solution worth pursuing. It is probable that a reduction in volumetric wear debris will reduce the local inflammatory response to a level insufficient to cause interface destruction and prosthetic loosening. Several types of metal-on-metal prostheses were developed in the 1960s but by the mid 1970s they had been completely displaced by polyethylene bearings. These early metal systems fell out of favor as a result of high frictional torque which led to "seizing and loosening". Some of these joints are believed to have been prone to early failure because of bearing design flaws and manufacturing limitations of the bearing surface quality. By the late 1960s, the bearings had improved but metal tissue staining was noted at revision surgery and this was attributed solely to wear of the bearing surfaces.[7] Another likely cause of loosening was the poor head-neck diameter ratio, leading to prosthetic impingement, and adverse stem features, such as a curvaceous design with sharp edges introducing stress concentrations in the cement. Limitations of recommended implantation techniques at that time (resulting in unsupported cups) and early cementing methods also contributed to premature failures. Most of these factors have now either been improved or can be reinvestigated. However, despite the limitations, a significant number of these hips have survived for 25–30 years because of low wear rates and minimal osteolysis. The survivors had, often by chance, the necessary polar bearing, component orientation to avoid impingement, as well as good cementation, suggesting that with these systems the prosthesis could be extremely durable despite poor stem design and technique.[7]

Review of the metal-on-metal literature reveals no bearing seizures, and no significant bearing wear or metallosis in the post-1967 era, when most of the gross bearing design flaws had been eliminated.[7] Recent research suggests that the volumetric wear of cast cobalt chrome alloy bearings is 40–100 times less than that of the metal-no-polyethylene combination.[32,46] Studies of McKee-Farrar prostheses after more than 20 years of function indicate a volumetric wear at least 25 times less than that with polyethylene over comparable time and a volume of reactive periprosthetic tissue significantly less than that seen with polyethylene.[16,39,42] Furthermore, in pendulum tests, the 28-mm all-metal (Co-Cr-Mo forged alloy Protasul 21WF; Sulzer, Winterthur, Switzerland) bearings exhibit the same frictional torque values as their 32-mm metal-on-polyethylene counterparts.[48]

All types of metal-on-metal total hip arthroplasties (McKee-Farrar, Ring, Müller, and Huggler)[7] widely used in the past had large diameter heads similar to the sizes used in surface replacements. Three metal-on-metal surface replacements have been developed — two in Europe, by Wagner in Germany[52] and McMinn et al. in England.[33] Both systems were initially all-cementless. The Wagner design has a bearing surface of forged cobalt-chrome alloy (F799 with high carbon content) and has a grit-blasted, titanium alloy carrier with macro features for fixation to bone (Fig. 10). The initial

Fig. 10. The Wagner resurfacing components

McMinn surface replacement was cast cobalt-chrome alloy, with uncoated press-fit both on the femoral and acetabular side. The acetabular component was 160° in profile and had two fins for iliac fixation and a central stud for axial stability. The reaming for the femoral component was similar to that of the THARIES with a chamfered cylinder. The femoral component had peripheral antirotation ridges and a short central stem to assist in alignment and initial stability. Subsequently the femoral and socket components were altered for use with acrylic bone cement. The socket component had macro circular recessions and beads. McMinn then further modified the components for cementless fixation on the acetabular side, using a series of sharp fins and reintroducing hydroxyapatite coating.[33]

We began a pilot surface replacement program using the Wagner and McMinn components. The socket was customized by shortening the central stud and adding grooves and rounded depressions for better acrylic keying (Fig. 11a,b).[43]

We have previously reported on the assessment of technique, initial fixation, and early results of 21 hips with a short follow-up of 16 months (range, 10–25 months).[39] Our entire developmental experience included 50 hips in 46 patients (27 males and 19 females; average age, 45 years) with 5 socket designs, including 23 uncemented sockets. The follow-up in this group is 1–4 years (Fig. 12a,b).

All four of the patients with the uncemented Wagner components and those with uncemented sockets have radiographically fixed sockets with 6–48 month follow-up (Fig. 13a,b). The short-term radiographic analysis revealed radiolucencies in a large percentage of the original cemented McMinn sockets, with 6 of 13 revisions having been required for either socket cement disassociations or bone cement loosenings. None of the new style cemented components have loosened, but radiographic partial bone cement lucent lines strongly suggest that durable fixation of the acetabular component will require cementless fixation. Eight of the patients who have had the McMinn type metal-metal bearing have noted the presence of "clicks" on range of motion. In two, there was a racheting noise. We evaluated these devices using a coordinate measuring machine and found evidence that the sphericity and clearance of some of the retrieved devices may have been responsible for the clicks and may have been a factor in their loosening and the need for revision. Ultimately there was a recall of these devices in 1997; their status is uncertain at this time.

We began custom implantation with a new device, the Conserve Plus (Wright Medical Technology).[3] The components were designed to minimize wear and optimize fixation. The acetabular component is one-piece and has sintered beads (102 μm; average size, 50–200 μm; 38% porosity) on the outside dimension, designed for interference fitting to obtain initial stability even in the smaller diameter dysplastic acetabulum while bone ingrowth occurs (Fig. 14). The acetabular components are available in 2-mm increments. The femoral component is patterned after the THARIES chamfered cylindrical design but with a short stem to ensure precision reaming and a fixation with a uniform cement mantle. The component is similar to that used

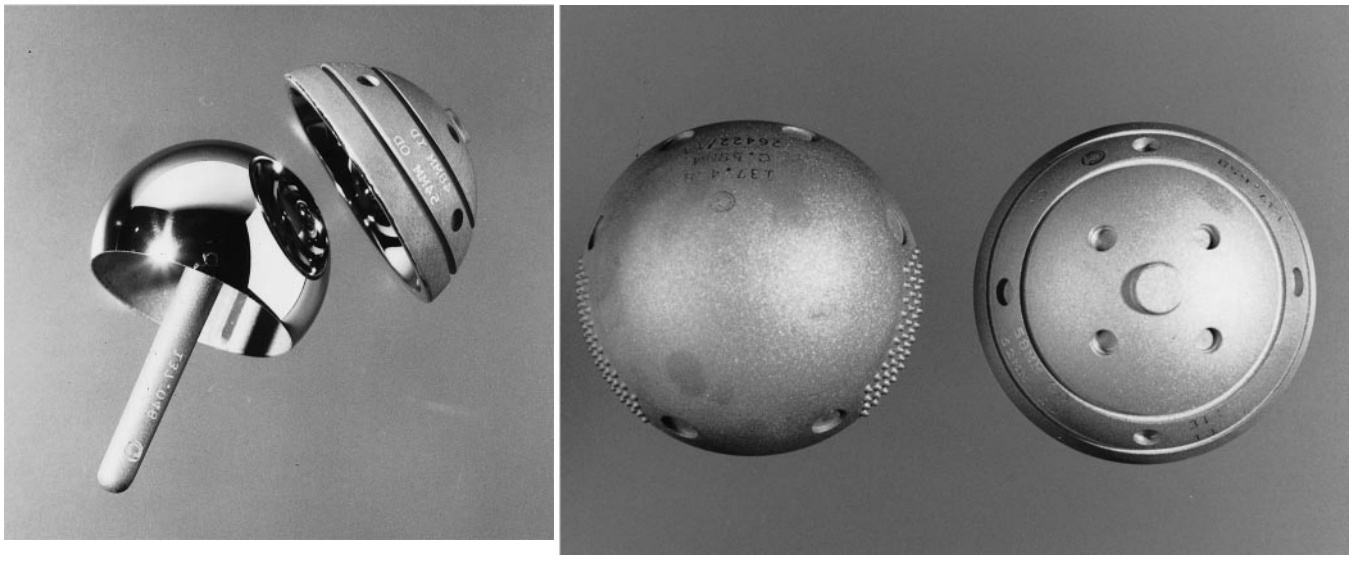
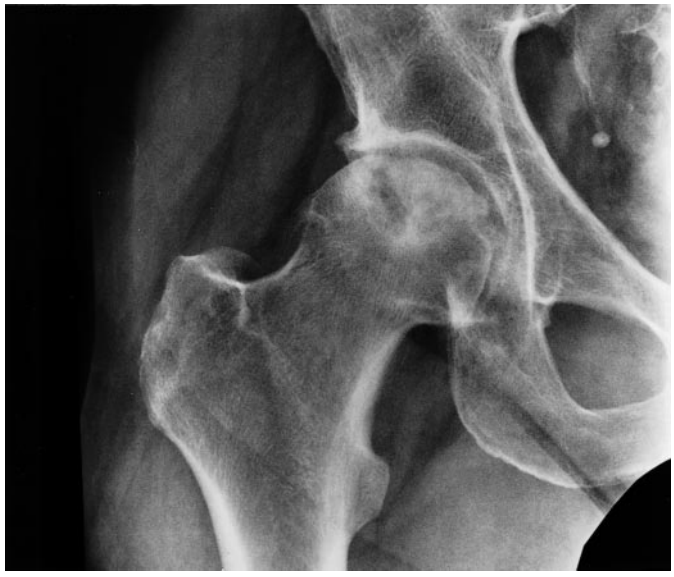


Fig. 11. a The McMinn resurfacing femoral component was modified for improved interlock with acrylic cement. **b** Original McMinn acetabular component design on the *left* and modified design for cementation on the *right*



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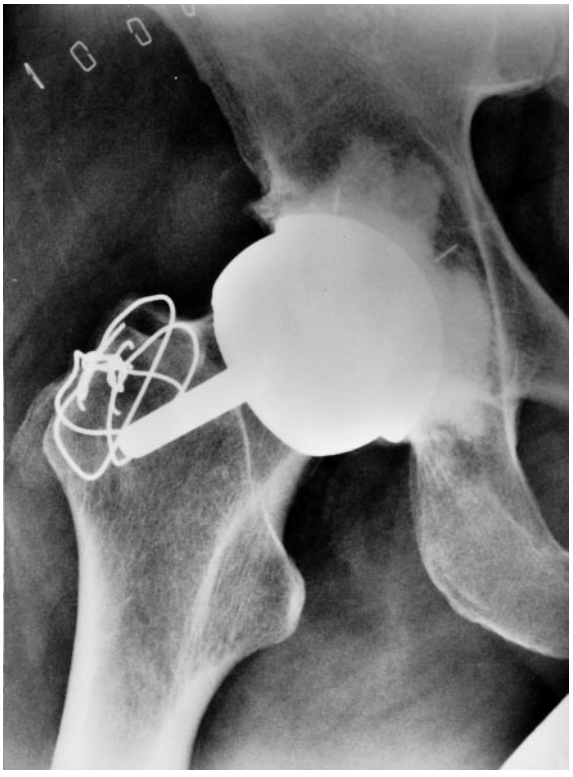


b

Fig. 12. **a** Preoperative radiograph of a 44-year-old male with Ficat stage IV ON of the femoral head. **b** The 3-year postoperative radiograph. There are no cement-bone radiolucencies and the patient has University of California Los Angeles (UCLA) ratings of pain, 10; walking, 10; function, 10; and activity, 8

for hemisurface replacement (the Conserve; Wright Medical Technology) but with improved sphericity, surface finish, and bearing clearance tolerances to minimize friction and wear. Forty have been implanted. The short-term (1-year) results are promising with no complications or clicks and there is apparent uniform osseointegration (absence of radiolucencies) of all acetabular components (Fig. 15).

The major advantage of surface replacement is its conservative nature. No "bridges are burned" now that the acetabular reconstruction is also very conservative and removes very little bone. There have been no infections in our series of patients. However, if infection should occur, it would be easier to manage because the femoral canal is not violated. Further, if a revision is ever required, it would be a relatively simple surgery to perform a total hip replacement, because the femoral intramedullary canal has not been violated.

We believe that the lessons learned about the design and technique of implantation of resurfacing components, combined with the modern precision manufacturing of metal-on-metal bearing surfaces, have ushered in a new era of surface replacement of the hip. Since the volumetric wear reduction is substantial, we anticipate greatly improved durability. It is inconceivable that metal-on-metal devices will wear out! There are some data suggesting increased metal levels in serum and urine in patients with metal-on-metal replaced hips, compared with patients with metal-on-polyethylene replacements and the population without implants.[28a] The clinical significance of these increased levels is not known and more information is needed regarding the long-term overall body response. However, there are increasing histological data[16a] to support the premise that the metallic wear debris is much better tolerated by the tissues around the implant than is the polyethylene.

In addition, there have been improvements to technique to minimize the risk of nerve injury, and an anti-inflammatory (indomethacin) has been effective in reducing heterotopic ossification (bone formation) where it is not wanted. Although avascularity of the femoral head has been reported by some following surface replacement,[28] it has never been identified as a factor in any of our patients. Although the technique modifications have enabled this technically demanding surgery to be performed more easily, it remains more difficult than that of stem-type devices.

Current indications for surface replacement

Surface replacement should especially be considered for patients who might in their lifetime require a revision and a second replacement. This includes the young and/or active, slightly older patients who want to par-

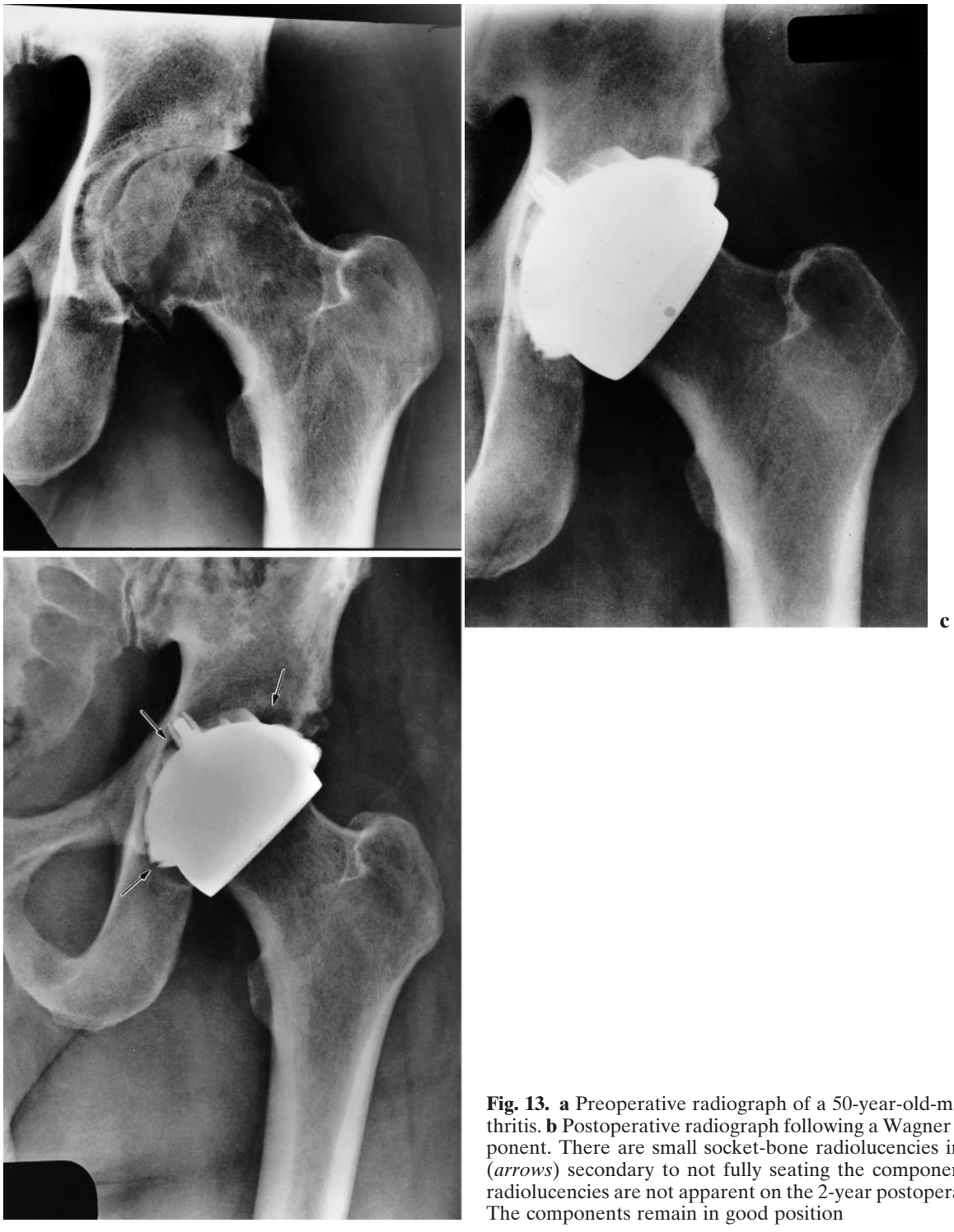


Fig. 13. **a** Preoperative radiograph of a 50-year-old-male with osteoarthritis. **b** Postoperative radiograph following a Wagner resurfacing component. There are small socket-bone radiolucencies in all three zones (*arrows*) secondary to not fully seating the component. **c** The diffuse radiolucencies are not apparent on the 2-year postoperative radiograph. The components remain in good position

ticipate in activities which are generally predicted to shorten the durability of replacements. There are several especially good indications for this surgery which should be considered at any age. These include patients who have some deformity of the proximal femur which would make a stem-type replacement either impossible or extremely difficult technically, or could adversely affect the result. Further, these indications include patients who are at high sepsis risk either because of previous infection in the hip region or because of a high susceptibility due to disease and/or drug therapy with steroids or other immunosuppressives. In addition, pa-

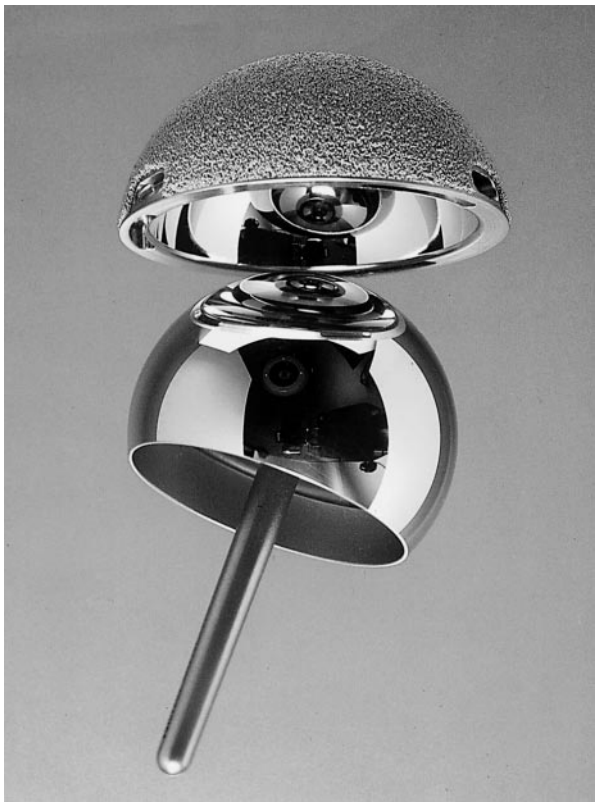
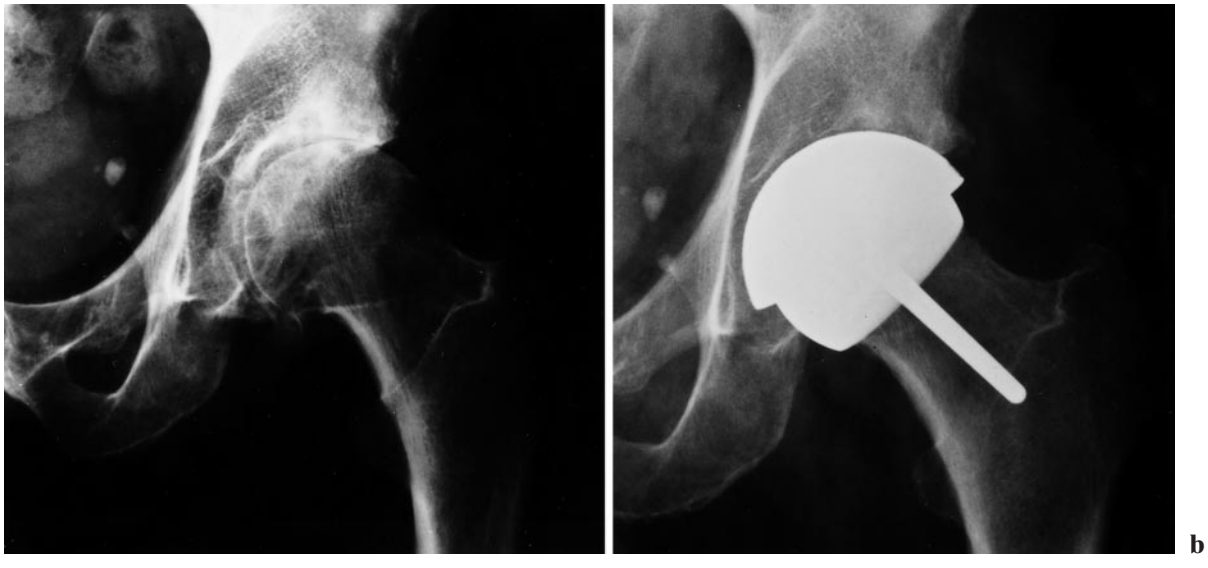


Fig. 14. Metal/metal surface replacement (Wright Medical Technology)

tients who have some neuromuscular disorder should be considered for resurfacing. The large diameter ball of the surface replacement will produce additional stability for the replacement and minimize the risk of dislocation.

Generally, surface replacement candidates are in the 40- to 65-year-old age range. Slightly older patients are included if there are varying combinations such as heavy build, potentially high activity level (either in sports or in heavy-duty labor), and other physiologic factors which are known to contribute to loosening or other complications from conventional replacement. We also consider the procedure for patients under 40 who are required to do heavy work, if there is no suitable alternative (such as osteotomy, coring, or hemiarthroplasty for osteonecrosis; osteotomy for early osteoarthritis or dysplasia; or arthrodesis). We include those individuals who developed osteoarthritis secondary to slipped capital femoral epiphysis, those with congenital hip dysplasia, dwarfism, coxa vara, or Legg-Calvé-Perthes disease, or post-trauma patients with significant symptoms and functional loss; patients with traumatic or non-traumatic osteonecrosis, who often have bilateral disease as young or middle-aged adults; patients with multiple joint arthropathy, such as those with juvenile rheumatoid arthritis; and patients who have an increased risk of postoperative sepsis, caused by steroids or other immunosuppressive drugs, and general debility.



a **b**

Fig. 15. **a** Radiograph of a 60-year-old developer and active sportsman with osteoarthritis. **b** Four-month postoperative X-ray of left metal-metal surface replacement. Acetabular component fixation is by bone ingrowth

Surgical technique for hemisurface (Conserve) and full surface replacements (Conserve Plus)

Preoperative planning is helpful in assessing the approximate size and orientation of the hemi-surface replacement (Fig. 16). Using a caliper and/or the scaled X-ray templates provided, the dimension of the femoral neck, the center of the femoral head, and the approximate size of the hemi-surface replacement are assessed. However, the magnification of hip radiographs is dependent on the distance between the X-ray tube and the joint and the radiograph plate (20% ± 6% for a 40-inch tube-to-radiograph distance). The magnification is greater in large patients and less in thin patients, so that final determination of prosthetic size is made at surgery. The diameter of the femoral neck in its widest plane is observed in the medial/lateral perspective. For hemi-surface replacement there should never be a need to notch the neck. A "Johnson lateral (shoot-through or cross table lateral)" X-ray assists in assessing anteversion.

The best surgical exposure is the one the surgeon knows best. We prefer the posterior approach because of the ability to completely visualize the entire acetabulum as well as the circumference of the femoral head and neck. This view enables an accurate assessment of the articular cartilage and optimizes precision fitting to the cartilage which is best preserved, whether it is central or around the periphery. Moreover, the option is available to remove the greater trochanter, to improve visualization or to advance the trochanter to tighten the abductors when necessary.[9] We recommend sectioning the gluteus maximus tendon at the point where it inserts into the linea aspera. Next, divide the short rotators, including pyriformis tendon and the quadratus femoris. The pyriformis tendon should be tagged for later repair.

To mobilize the femoral head, the ligamentum teres is sectioned with a ligamentum teres sectioner and the capsulotomy completed. The entire capsule must be released circumferentially to have adequate visualization of the acetabulum. Moreover, the release will facilitate the placement of the pin down the central axis of the neck. The entire capsule can be safely removed to improve visualization. The hip can now be rotated internally and the femoral head delivered for inspection and central pin placement.

Trochanteric osteotomy may be used in heavily built patients or in patients with severely contracted hips. It is performed with a Gigli saw that is passed extracapsularly between the gluteus medius and minimus tendons, ensuring that the amount of trochanter removed is relatively small. The osteotomy should extend distally to the vastus tubercle so that the vastus lateralis tendon can be safely repaired after the trochanteric fixation. The extended posterolateral approach includes routine detachment of the tendinous insertion of the gluteus maximus into the linear aspera so that the femur can be fully mobilized. After the hip is dislocated, a circumferential capsulectomy is performed. The position is checked by rotating the hip internally and externally and sighting from several directions. Osteophytes that, on rare occasions, prevent proper seating can be excised using a rongeur or a high-speed burr.

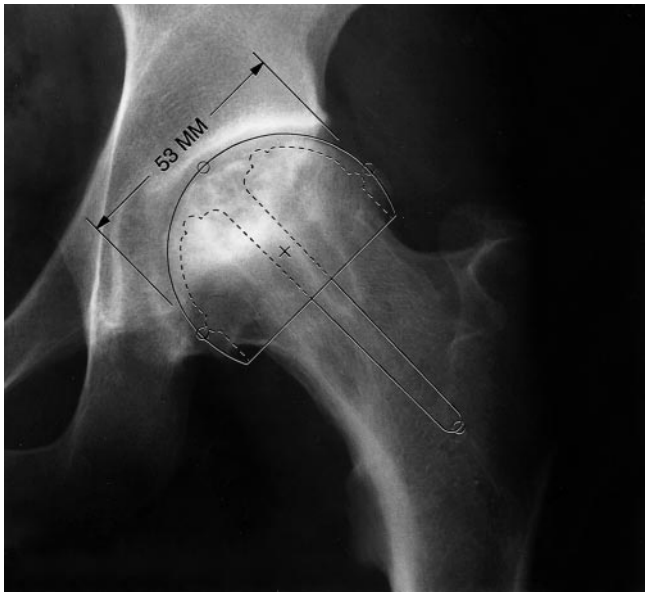


Fig. 16. Radiograph of a 26-year-old patient with Ficat stage IV ON with template for hemisurface replacement superimposed

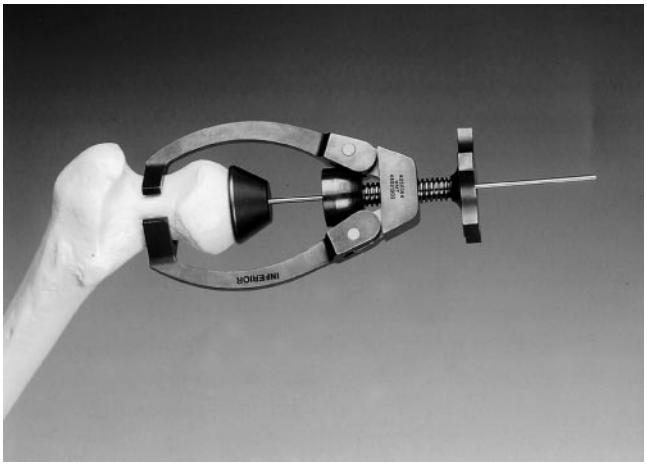


Fig. 17. Pin-centering guide is used to help with pin placement down the central axis of the femoral neck. This pin guides the cylindrical reamers

Apply the pin-centering guide (PCG; Wright Medical Technology) around the femoral neck and turn the knob clockwise until the two guide arms are tight (Fig. 17). The wide jaw is positioned inferiorly. While holding the PCG, insert a 3.2-mm Steinmann pin through the PCG to a depth of approximately 10–20 mm. Visually assess in two planes that the pin is aligned in the axis of the femoral neck. With the posterior approach, the PCG often must be forced anteriorly to correct against the tendency to retrovert the pin. Once pin alignment is verified, fully insert the pin until slight endosteal cortical purchase is obtained in the lateral aspect of the metaphyseal region of the femur. Loosen the locking knob and remove the PCG, leaving the Steinmann pin in place. Correct positioning is checked using the cylindrical reamer gauge. Its rotating pin confirms that there is equal clearance around the femoral neck and verifies that the pin is in the central axis of the neck. If the tip of the rotating pin impinges against the femoral neck, the central guide pin has to be repositioned, or a larger component size has to be selected. If the pin is malpositioned it may be removed and the guide reset for proper placement. If the correction is less than the width of the pin, it is preferable to leave the initial pin in situ. A new pin can then be inserted in the proper orientation without fear of inserting it down the original hole.

Proper pin placement and use of the reamer gauge should prevent the selection of a reamer that is smaller than the femoral neck and will also prevent displacement of the femoral reamer from the neck axis, which would result in notching of the neck during the reaming process. Before reaming, it is recommended that a polyethylene sheet be placed over the head and onto the base of the neck to collect debris.

An oversized reamer (generally two sizes more than necessary; see below) is selected initially to remove a small amount of bone. Attach the initial reamer to the power source and advance it over the Steinmann pin, taking care to clear debris and to stop reaming at the femoral head/neck juncture (Fig. 18).

It is necessary to check, both visually and by palpation, that there are no positioning errors and that the reamer will not invade the neck as it is advanced. As the cylindrical reamer advances, the surgeon should use his/her free hand to palpate the location of the vibrations of the cylindrical reamer at its exit point. This action will further help prevent notching the neck. Successive reamings are made with appropriate, smaller size reamers until the final reamed head diameter is reached. Each reamer has an intrinsic dome stop so that the cutting teeth do not penetrate the bone of the intertrochanteric area. These stops were anthropometrically designed to prevent a dangerous notch of the femoral neck and will be effective when the largest cylindrical reamer used is no more than two sizes over the anticipated final reamer size (based on templating neck dimensions of the contralateral normal neck or measurement of the abnormal neck). However, as the reamers advance, regular visual inspection and finger palpation is advisable to avoid neck invasion.

The cutoff guide is then used to assess the dome resection of the femoral head (Fig. 19). It is positioned so that its inferior margin covers the reamed portion of the head and the head-neck junction. The dome of the

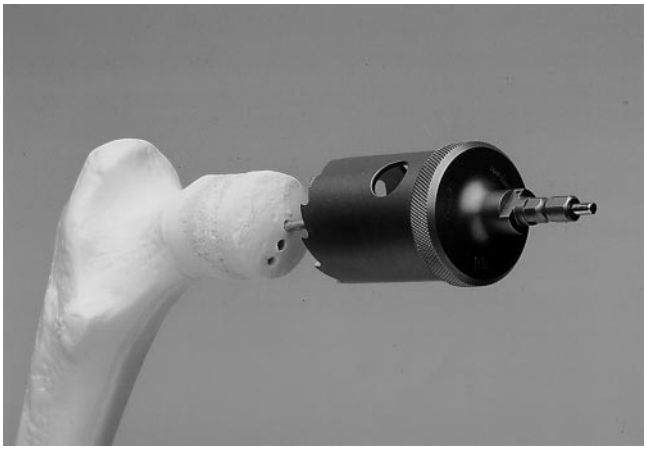


Fig. 18. Cylindrical reamer guided by a Steinman pin

Fig. 19. Saw cutoff guide covering the reamed surface of the head. A saber or oscillating saw is used to remove the femoral head dome

femoral head is then resected with a saber or oscillating saw. The hole for the short neck stem is made at this time by attaching the tower guide assembly. A tapered stem reamer is used to prepare a hole in the head and neck to the appropriate level for the stem using the tower alignment guide.

The chamfer guide is inserted to guide the chamfer reamer of the appropriate size to give the femoral head its final shape (Fig. 20). The chamfer reamers significantly increase the available fixation area at the femoral head. The size of the femoral head is confirmed with the femoral template which matches the internal dimensions of the femoral component. By rotating the template, the uniformity of the cement mantle can be assessed. The femoral head bone preoperation is schematically summarized in Fig. 21. The bone at the distal tip of the template is marked to indicate complete seating of the femoral component during impaction. Additional fixation holes may be made with a 1/8-inch drill if the bone is dense. Remaining cysts are curetted out and the bone is cleaned with saline, using pulsatile lavage. The translucent head protector is applied.

A pocket for the head is created anteriorly and superiorly using a periosteal elevator after all of the capsule is removed. The femur is brought to a neutral position and displaced anteriorly to allow visualization of the acetabulum.

If a trochanteric osteotomy has been performed, the extremity is flexed, externally rotated, and adducted to allow for acetabular visualization. Alternatively, if a posterior approach has been used, the femoral head is displaced anteriorly, using a blunt right-angle Hohmann or Cobra retractor as a lever. Insert the translucent acetabular gauges (available in 1-mm increments) into the acetabulum and press against the acetabular cartilage to visualize the contact areas. In order to optimize contact with the best remaining cartilage, apply several trials with larger or smaller opaque acetabular gauges. The final size will ultimately be dictated by the location and quality of the acetabular cartilage. This procedure will then dictate the correct femoral component size and final head preparation for a cement mantle of 1 mm.

The Conserve (Wright Medical Technology) surgical system utilizes instrument groupings to prepare the femoral head (inner diameter of the definitive implant) to accommodate more than one size outside/dimension (OD) femoral implant (e.g. size 42/43 reamer gauge, cylindrical reamer, chamfer cutter, etc. prepare the femoral head to accept either the size 42-mm OD or 43-mm OD implant).

Before cement is applied, the areas are thoroughly cleaned with pulsatile lavage to make certain all bone fragments and soft tissue have been removed. In addition, the entire area is thoroughly irrigated and soaked with duo-biotic (polymycin + bacitracin solution). A trial reduction can be performed with the press-fit component, and the range of motion can be checked.

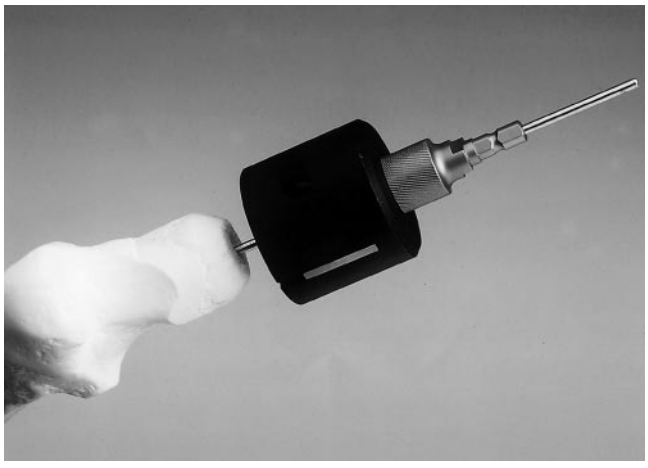


Fig. 20. Chamfered reamer

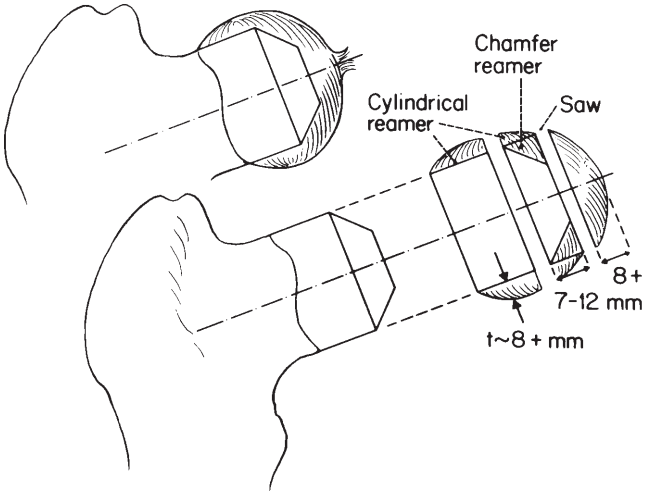


Fig. 21. Femoral head bone preparation

The timing of the application of the acrylic bone cement into the femoral head depends on the bone density. If the bone is very compact and dense, apply the cement in a less viscous state, and apply later if the area is osteopenic.

It is our preference, where there is good bone quality, to avoid cementing the stem of the implant by reinserting the chamfer guide into the dome hole for the stem during initial application, and by finger pressurization of bone cement into the cancellous bone, especially of the cylindrically reamed bone. The femoral component containing the doughy cement is pressed onto the prepared femoral surface and held until the bone cement has cured. The hip is reduced and the gluteus

maximus tendon reattached. The wound is then closed with one or more suture drains.

For the full surface replacement, the head is downsized to the femoral neck size, using the same instrumentation; the acetabulum is then prepared, with increasing diameter hemispherical reamers, to remove soft tissue and cartilage from the floor of the cotyloid foramen, exposing cancellous bone. Reaming is commenced several sizes smaller than the final size and is recommended to be no less than 1 mm undersize or more than 2 mm undersize. The socket is 170° and is 10 mm larger than the OD of the ball. Use the opaque acetabular gauges to assess the size, roundness, and depth of the reamed cavity. The acetabular component holder is attached using the bayonet couplers and is tightened. The outriggers are set for 40° lateral and 15° anteverted. The component is impacted into place using landmarks identified and marked previously with the acetabular gauges. A check X-ray may be taken to verify that the socket is fully seated. Once the acetabular component insertion has been completed, attention is again turned to the femur. The exposed trabecular bone is further cleaned with pulse lavage and dried. Acrylic cement in the low viscosity state is poured into the component above the circumferential recess. Medium viscous cement is applied to the reamed surface and the femoral component which is impacted and rigidly held until polymerization is completed, and the hip is then reduced. Check the range of motion for stability. The greater trochanter, if osteotomized, is reattached using a three-wire interlocking technique.[9] Prophylactic cephazolin is administered for 2–3 days depending on removal of the urinary catheter. All patients are commenced on an adjusted dose of warfarin on the night of surgery.[6] Male and high-risk female patients are given a 5-day course of indomethacin for prevention of heterotopic bone formation. Ambulation begins on the first postoperative day, allowing 20% weight-bearing, which progresses to full weight-bearing by 8 weeks. Sports are permitted at 4 months postoperatively.

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