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Metal on Metal Surface Replacement of the Hip Experience of the McMinn Prosthesis

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The historical failure of surface replacement has been due to the production of wear debris with subsequent bone resorption, loosening, and failure. To avoid these problems, a surface replacement using a metal on metal bearing allowing thin components and femoral design and instrumentation to avoid varus alignment has been designed. Two hundred thirty-five joints have been resurfaced with this prosthesis in almost 5 years. There have been no femoral neck fractures and no dislocations. There have been 4 designs differing in the method of fixation. In the press fit group, 6 of 70 hips had to be revised for aseptic loosening. In the cemented group, debonding of the cup occurred in 3 of 43 cases. Six patients had hydroxyapatite coated components and have had excellent clinical outcomes. The current design uses a peripherally expanded hydroxyapatite coated cup and a cemented metal head; 116 of his design have been implanted during a 19-month period with excellent outcome. Despite short follow-up the authors are hopeful that the combination of a polar metal on metal bearing with appropriate fixation will yield a method of preserving bone stock in the younger patient requiring arthroplasty.

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Conservative hip arthroplasty with resurfacing of the acetabulum and femoral head is an attractive concept particularly in young patients. Nonviolation of the upper femur, retention of upper femoral bone stock, and the reduction of stress shielding in the proximal femoral shaft are unique advantages. In the authors' hands decreased operative time, diminished blood loss, and reduced volume of implanted material are achieved in comparison with that experienced in total hip arthroplasty.

Sir John Charnley performed the first hip resurfacing in the early 1950s using thin cups of Teflon.[6,7] Rapid wear of the Teflon occurred and the wear debris caused an intense tissue reaction and subsequent clinical failure. Resurfacing hip arthroplasty using a polyethylene cup and a metal head shell had gained popularity in the 1970s and by 1978 several systems were in clinical use.[2,5,11,13,14-20] By 1982, however, reports of high failure rates resulted in the procedure being abandoned by many surgeons and the reader is referred to an extensive review of the subject by Amstutz.[1] The importance of precise surgical technique was brought to light by the early experience of surface replacement. Notching of the femoral neck and varus placement of the femoral component are particularly deleterious regarding causation of fracture of the femoral neck.[10] The overwhelming difficulty of resurfacing using a polyethylene component, however, relates to the inevitable use of a large diameter femoral shell and the associated high production of polyethylene debris.[3]

It was the current authors' view that polyethylene could not be used in resurfacing hip arthroplasty with any expectation of success and consideration was given to the use of other materials.

Development of this resurfacing arthroplasty began in 1989 and the following features were considered essential:
(1) thin components to avoid undue resection of the femoral head or acetabular bone stock;
(2) the articulation of a large diameter head femoral component against a socket without excessive production of wear debris;
(3) use of materials and design criteria with a known track record in clinical use; and
(4) technique and instrumentation to avoid femoral neck notching and varus placement of the femoral component.

Published results showed that a metal on metal articulation using CoCr could satisfy the material requirements. Low revision rates of the Ring implant have been published with 95% success at 15 to 16 years.'[7] The Ring metal on metal implant had a 40-mm head articulating in a metal socket with a polar bearing geometry. Development of the authors' prosthesis was undertaken in collaboration with Corin Medical Ltd, Cirencester, United Kingdom, whose engineers had experience in the manufacture of the Ring metal on metal hip replacement.

MATERIALS AND METHODS

A pilot study was undertaken with the first resurfacing arthroplasty being performed in February 1991. The first type of resurfacing was an uncemented, uncoated, press fit type on the acetabular and femoral sides. The acetabular design was based on the Freeman superolateral fins acetabular component.[12] This design theoretically gave axial and rotational stability without the use of cement or additional screws (Fig 1A). The femoral component was of a chamfered cylinder design with the addition of a short stem into the femoral neck. The purpose of the stem was to ensure correct alignment of the implant and to bridge the head/neck junction, an area considered to be vulnerable to fracture. This first type of replacement was implanted between February 1991 and February 1992 in 70 hips.
The second design of resurfacing differed in that the femoral and acetabular components had the addition of hydroxyapatite coating to the shells. This second design was implanted between February 1992 and March 1992 in 6 hips.

The third design of resurfacing in the pilot series was a cemented design on the acetabular and femoral sides. This acetabular type had no pegs or wings; shallow pits were incorporated for cement keying. The technique used on the acetabular side was minimal acetabular reaming trying where possible to retain the subchondral plate, multiple small keyholes, medium viscosity cement, and the use of an acetabular cement pressurizer. This was implanted between March 1992 and December 1993 in 43 hips.
On the basis of experience with the pilot series, a definitive type of resurfacing design was decided on with a completely redesigned acetabular component (Fig 1B). This acetabular component is designed for cementless fixation and is fully coated with hydroxyapatite on its outer surface. It presents a central peg for axial stability and 2 sets of peripheral splines for fixation into the region of the pubis and ischium assisting with rotational stability. In addition, the outer configuration of the cup is of a larger radius at its equator than the pole, giving a tight fix in the reamed acetabulum. The outer surface of the cup subtends an arc of 180°. The articular surface of the cup is highly polished and subtends an arc of 160°, thus allowing a good range of movement before impingement. The cup has 2 peripheral holes for locking of a cup introducer. The femoral component is unchanged from the pilot series design and is fixed with cement. Acetabular components are available in 4 sizes: 46, 50, 54, and 58 mm. Femoral components are available in 4 sizes: 40, 44,

48, and 52 mm. Each femoral component is used with the corresponding size of acetabular component. Between March 1994 and October 1995, 116 hips were treated with this hybrid system.

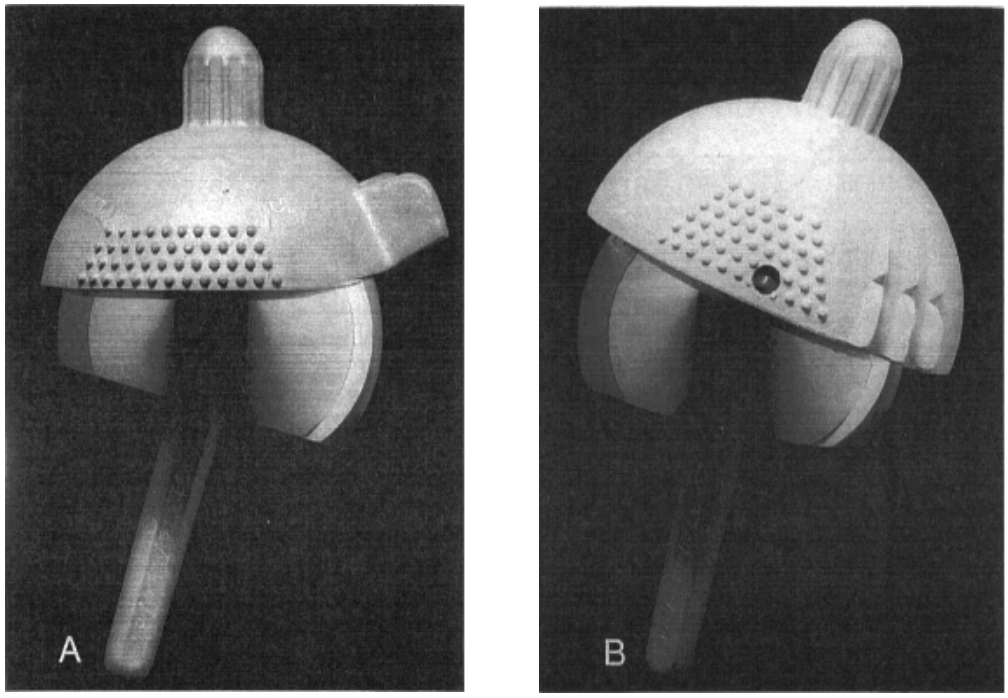

Fig 1A-B. (A) Press fit femoral component and press fit acetabular component with superolateral fins. (B) Hybrid design with femoral component for cemented use and hydroxyapatite coated acetabular component.

Technique

Preoperatively, the radiograph is templated and the size of components to be used is determined. In addition, the desired position of the femoral component is determined by measuring from the tip of the greater trochanter to the lateral femoral cortex. This measurement is used later for insertion of a temporary pin. The authors prefer to insert the resurfacing hip replacement through an extended posterior approach, although a Smith-Peterson, Freeman, or Trochanteric osteotomy approach can be used. The acetabulum is reamed to the desired diameter allowing insertion of the acetabular sizer. The acetabular component is 2 mm greater in diameter at its equator than the sizer so under reaming of the acetabulum must not be carried out. The acetabular sizer is placed in an anatomic position and a drill passed through its superomedial hole. Any cysts are curetted and bone grafted. The cup is offered up to the acetabulum on its introducer so that the anti-rotation splines are opposite the ischium and pubis and the cup impacted into position. Protruding acetabular osteophytes are resected flush with the cup edge. On the femoral side, a temporary pin is inserted into the lateral femoral cortex at a predetermined distance down from the greater trochanter tip.

A centering jig is located over this pin, thus ensuring correct varus/valgus alignment (Fig 2A). Proximally the jig is adjusted to ensure centralization on the femoral neck, checks for centralization being made by rotating the adjustable probe around the neck. A long guide wire is advanced into the femoral head and neck through the centering jig. The guide wire is over-drilled with a cannulated drill and a centering rod is introduced. An appropriately sized cylindrical head cutter is advanced over the rod taking care to stop at the head/neck junction (Fig 2B). The head sleeve is placed over the prepared surface down to the head/neck junction and the top of the femoral head is then resected. A chamfer cutter is advanced, the femoral head is brushed and lavaged, cement keyholes are drilled and cysts are curetted and bone grafted. The

femoral component containing low viscosity cement is impacted into position (Fig 2C). Patients are mobilized on the second postoperative day initially using a frame. They are then allowed to bear full weight and walk using crutches or sticks and they are weaned off the sticks when comfort allows. Patients are given *25* mg of indomethacin 3 times daily for 5 days as prophylaxis against heterotopic ossification and low dose warfarin as prophylaxis against thromboembolism during their inpatient stay.

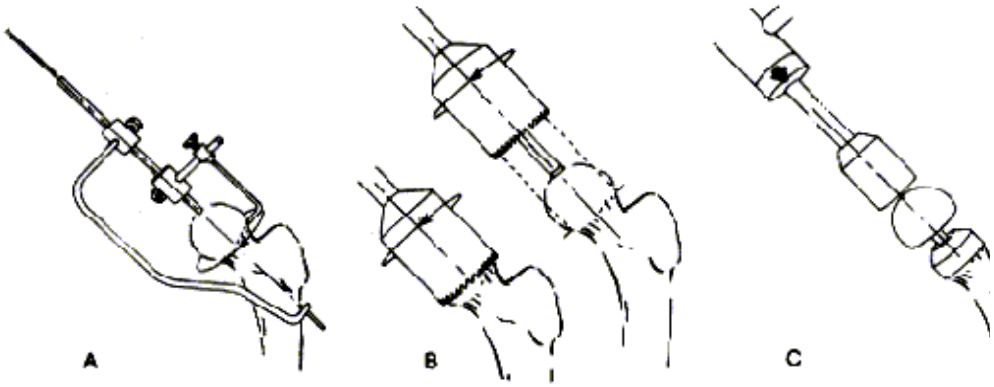

Fig 2A-C. (A) A guide wire is passed using a centering jig to avoid femoral neck notching. (B) A cylindric femoral head cutter is passed as far as the head/neck junction. (C) After further femoral head preparation with a chamfered reamer, the femoral component containing cement is impacted into position.

Follow-up and radiographs occur at 2 months and 1 year postoperatively and yearly thereafter.
Indications for this resurfacing arthroplasty have included young patients with hip arthrosis giving enough pain and functional impairment to justify arthroplasty when there was enough bone stock available to insert this implant. Some older patients active enough such that they would be expected to outlive a standard total hip replacement have also been treated. In the *235* hips treated with this resurfacing arthroplasty the average age at surgery was 48.7 years, and the largest age group was between 50 and 60 years (Fig 3). There were 125 hips in men and 110 hips in women, and there were 16 bilateral procedures.
The primary diagnosis leading to the resurfacing arthroplasty is shown in Figure 4. The clinical scoring method was the Merle d'Aubigne and Postel Score.[8] Serial radiographs were assessed for component position, femoral neck thinning, radiolucencies around the femoral component stem, and, with cemented cups, radiolucencies at the bone cement interface.[9] An assessment was made for osteolysis and heterotopic bone formation.[4] Femoral component migration and acetabular component migration was measured.[16]

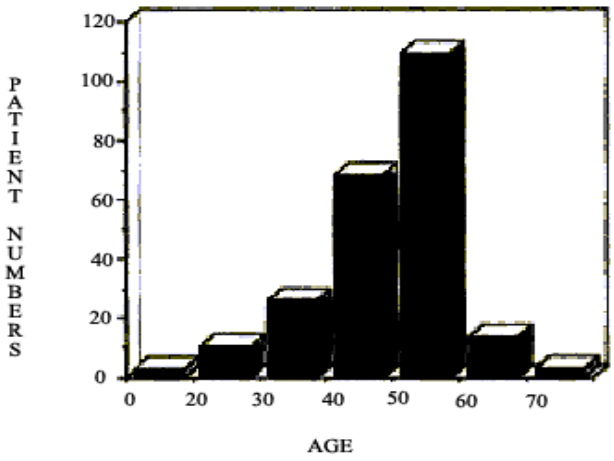

Fig 3. Age distribution of all patients treated with metal on metal resurfacing at time of operation

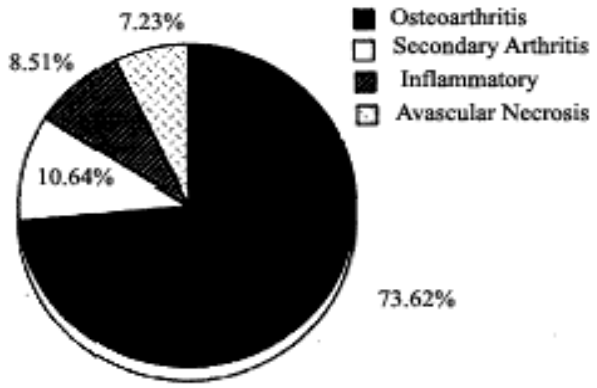

Fig 4.Distribution of patients by diagnosis who were treated with metal on metal resurfacing.

CLINICAL RESULTS: PILOT STUDY

For the 70 hips (66 patients) in the press fit group, the average follow-up was 50.2 months (range, 44-54 months). Two patients in whom infection developed (3 hips) have had revision surgery. One of these patients had bilateral infected hips from hematogenous infection. Six other patients have had unsatisfactory pain relief and have had revision surgery (8.6% aseptic revisions). In these patients both components were confirmed to be loose at re-operation, there was no macroscopic metallosis and the remaining femoral head bone was viable on visual inspection and at histology. There was no osteolysis and revision was easily carried out to a total hip replacement in *5* cases and a cemented resurfacing in 1 case. Of the 61 patients whose hip remains in situ, the functional results are satisfactory (Fig 5). Many of the patients have returned to active work (Fig 6). Of the 6 patients in the hydroxyapatite group all have excellent outcomes (Fig 7). There have been no revisions at an average follow-up of 40.2 months (range, 38-42 months). Of the 43 hips (39 patients) in the Cemented group, 1 patient has undergone revision surgery for infection and 3 patients have had revision surgery for break out of the acetabular component from the cement mantle

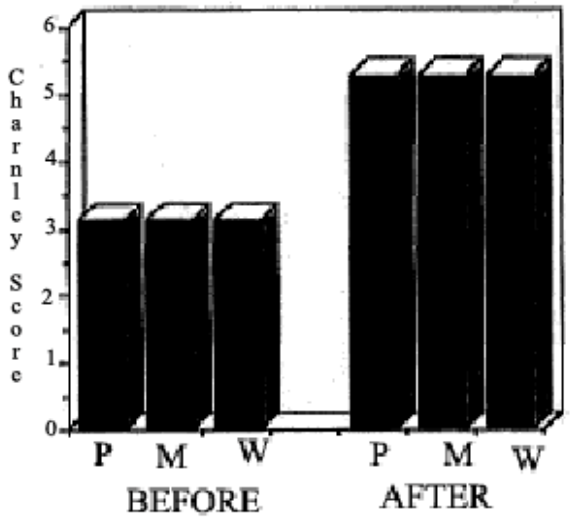

Fig 5. Functional scores for pain (p), mobility (m), and walking (w) in the press fit group.

These 3 patients have had their acetabular components revised to a hydroxyapatite coated uncemented component. The femoral components were not damaged, were well fixed, and were left in situ. The remainder of the patients in this group had satisfactory results (Fig 8). The average follow-up in this cemented group is 33.2 months (range, 23-38 months).

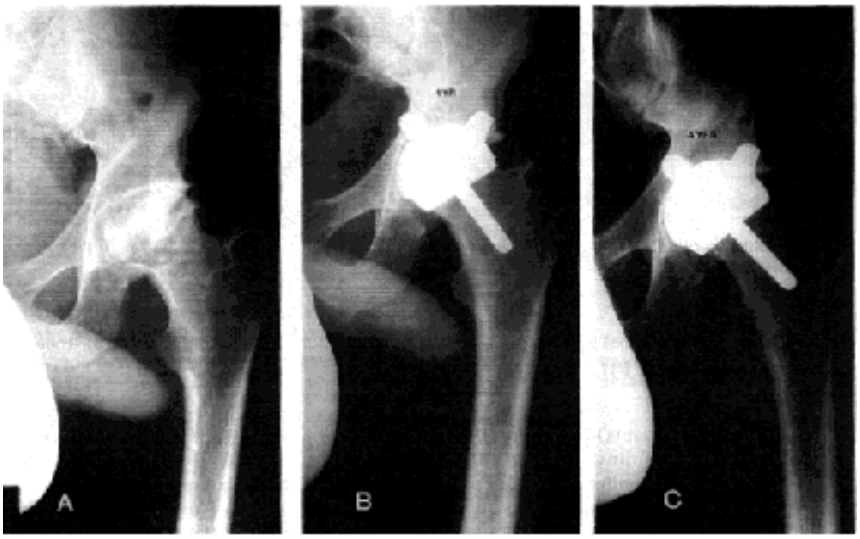

Fig 6A-C. (A) Preoperative, (B) 1-year postoperative, and (C) 4-year postoperative radiographs of a 25-year-old man with avascular necrosis who continued to work as a heavy manual laborer after press fit resurfacing.

HYBRID SERIES

One hundred sixteen hips (109 patients) have been treated with this hybrid design of resurfacing implant between March 1994 and October 1995. The average follow-up was 8.3 months (range, 1-19 months). The clinical outcomes in this group have been excellent and no patient has required revision surgery. In the 60 patients who have had greater than 6 months of follow-up (average, 15 months) the clinical scores are shown in Figure 9. These patients have made a much more rapid recovery than the patients in the press fit series and most patients have a normal gait and have abandoned using canes by the 2-month postoperative review (Fig 10). Many of the patients are young and returned to recreational sporting activity. Although the initial outcome of this hybrid series has been excellent, the ultimate success of this implant can only be judged by the passage of more time. In the total series of 235 hips treated with this resurfacing arthroplasty there have been no femoral neck fractures. Avascular necrosis has not occurred in any patients either as judged clinically or histologically. In 1 patient with bilateral infected press fit hips, both femoral heads had disappeared at revision surgery, but this was likely a result of the infection and not simply avascular necrosis. There have been no dislocations in these 235 operations. Three patients have had a nonfatal pulmonary embolism. There have been no deaths. There has been 1 sciatic nerve palsy that has partially recovered. All patients who have had revision surgery, including revisions for infection, had satisfactory outcomes.

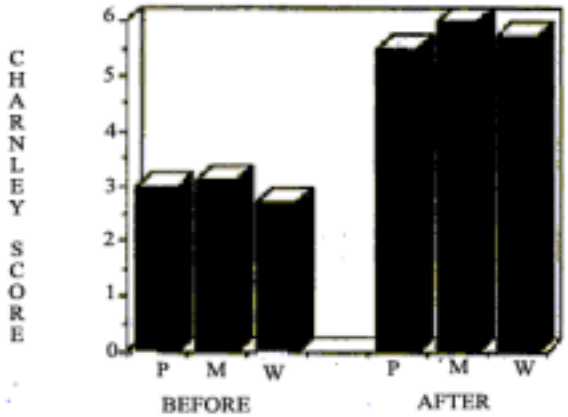

Fig 7. Functional scores for pain (p), mobility (m), and walking (w) in the hydroxyapatite group.

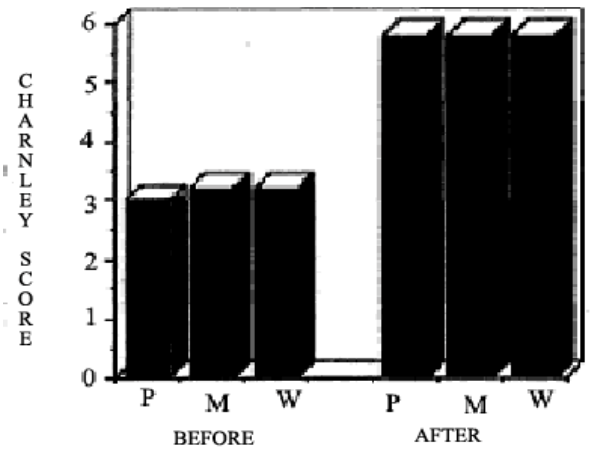

Fig 8. Functional scores for pain (p), mobility (m), and walking (w) in the cemented group.

RADIOGRAPHIC RESULTS

Eighty-six percent of patients had no heterotopic bone formation, 11% had Brooker Grade I ossification, 1.5% had Brooker Grade II ossification, 1.5% had Brooker Grade III ossification, and no patients had Grade IV ossification. Of the cemented cups, 25% had a bone cement interface radiolucency in I or 2 zones on the postoperative radiograph; none had complete 3 zone radiolucent lines. At 1 year *50%* had a radiolucent line and 11%, complete. At 2 years *59%* had a radiolucent line and 22%, complete. At 3 years 88% had a radiolucent line and 67%, complete. There was no association between thickness of the cement mantle and the presence or absence of a radiolucent line. The mean vertical migration at 3 years postoperative for cement fixed cups was *0.25* mm, for hydroxyapatite cups was 1.25 mm, and for press fit cups was 2.3 mm. There was no statistical difference in the vertical migration at 3 years between cups fixed by the 3 different methods.

All patients had satisfactory alignment of their components as judged on the anteroposterior (AP) projection. Ninety-five percent of the femoral components had neutral alignment and *5%* had valgus alignment. No patient had varus positioning of the femoral component confirming the efficacy of the authors' femoral component jig. In the early stages of the development of this implant true lateral radiographs were taken, but the stem of the femoral components was so reliably positioned down the neck of the femur that the authors thought it was not justified to carry out further lateral radiographs and for the rest of this series true lateral radiographs were not routinely performed.

At 3 years, 26% of femoral component stems had a surrounding radiolucent line; there was no difference between the 3 types of femoral component shell fixation with respect to the presence or absence of a stem radiolucency at 3 years.

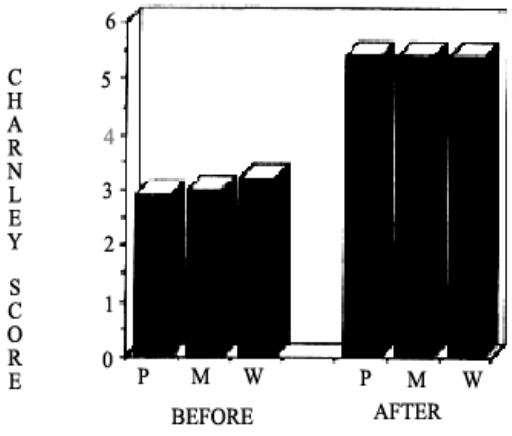

Fig 9. Functional scores for pain (p), mobility (m), and walking (W) in the hybrid group with greater than 6 months follow-up.

Femoral neck thinning was measured from annual AP radiographs by comparing the femoral neck diameter with the initial postoperative radiograph. The mean femoral neck thinning at 3 years was 1.47 mm, there being no difference in the 3 types of femoral component fixation. At 3 years 40% of hips had less than 1 mm of femoral neck thinning, 16% had between 1 mm and 2 mm of femoral neck thinning, and 44% had more than 2 mm of femoral neck thinning. There was no association between neck thinning and the presence or absence of a radiolucent line around the femoral component stem. There was no association between neck thinning and femoral component alignment in either neutral or valgus positions. The mean vertical migration of femoral components at 3 years was 1.27 mm for cement fixation, 1.49 mm for hydroxyapatite, and 1.67 mm for press fit, there being no statistical difference between the 3 groups ($p = 0.9$).

Retrieved cups and heads were subjected to surface scan profilometry to determine the surface roughness in accordance with International Standards Organization 468. The surface roughness average ranged from 0.02 to 0.05 μm. These values are within the standard requirement as defined by International Standards Organization 7206- 2, which specifies a roughness average value not greater than 0.05 μm for the spheric bearing surface of stainless steel or CoCr femoral head bearings. The measurements were performed with a cutoff length of .08 mm, *5* cutoffs were used to determine the surface roughness. The generation of metal particles from the backs of these components, however, was not great enough to cause metallosis visible to the naked eye.

Light microscopy was carried out on decalcified, paraffin embedded, hematoxylin and eosin stained material. On histology, generally only small numbers of metal particles were present. There was no evidence histologically of a hypersensitivity reaction, the main histologic feature from soft tissue around these loose implants being fibrosis.

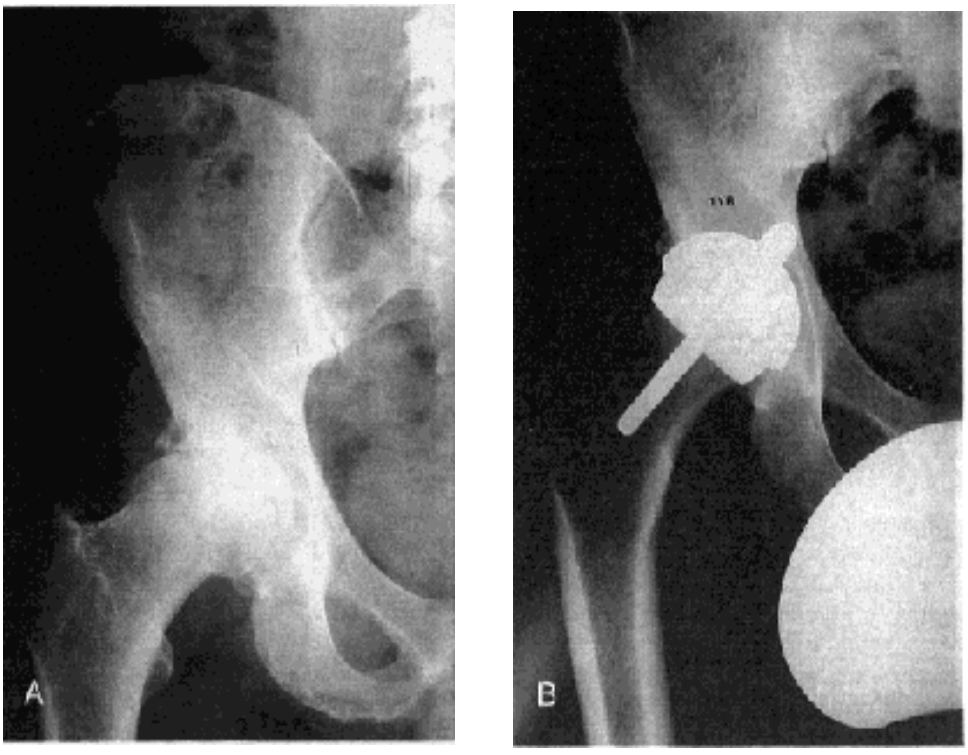

Fig 10A-B. (A) Preoperative and (B) 1 year postoperative radiographs of a 42-year-old man with osteoarthritis who returned to office work 2 weeks after hybrid resurfacing.

DISCUSSION

This study supports the premise that resurfacing hip arthroplasty is a practical and potentially useful treatment method. Fractures of the femoral neck did not occur in this series. This is attributed first to precise surgical technique, in particular the use of a centering jig to avoid varus placement of the femoral component and to avoid notching of the femoral neck. The short stem on the femoral component may also help by bridging the head/neck junction, an area considered to be vulnerable to fracture. Thinning of the fern-oral neck has occurred in some patients but it has not presented any clinical problems and the authors are unsure at present of its significance. There is no evidence to suggest that thinning of the femoral neck is related to the presence of a short stem on the femoral component. In the non-infected cases, avascular necrosis of the femoral head has not occurred.

Experience indicates that this resurfacing hip arthroplasty needs to be securely fixed to bone if a satisfactory outcome is to be reliably achieved. The particular requirements of surface replacement arthroplasty demand a large diameter femoral component and thin components on the femoral and acetabular sides to avoid resection of excessive bone stock. Experience has shown that metal on polyethylene designs generate large volumes of polyethylene debris. The brittleness of ceramics have meant that thick components have had to be used for ceramic on ceramic resurfacing articulations resulting in sacrifice of acetabular bone stock. The authors' experience with ceramic on polyethylene articulations for resurfacing arthroplasty has shown that large volumes of polyethylene debris are produced and the failure rate is identical to the same design of metal on polyethylene resurfacing arthroplasty. A metal on metal resurfacing arthroplasty has the advantages of using a bearing of established long term track record and the shells can be made thin, thus conserving femoral and acetabular bone stock. Revision of these press fit components confirmed that they were loose and burnishing of the backs of the components showed that metal had been removed by abrasion against bone. Inspection of the articular surfaces showed no visual sign of wear with polishing of both articular surfaces.

Cement fixation of the acetabular components has not been satisfactory. Break out of the components from the cement mantle could be addressed by additional features on the cup for keying into the cement, but this was not done in view of the unsatisfactory bone cement interface radiology. The authors think that with radiolucent lines already present at the bone cement interface, clinical failure will inevitably occur, and this method of acetabular component fixation has been abandoned. Similar problems of early loosening and breakout of components from the cement mantle have been seen with metal backed polyethylene cemented ace-tabular total hip replacement cups. Hydroxyapatite coated acetabular components have given excellent clinical and radiographic outcomes and this is currently the authors' preferred method for acetabular component fixation. Porous coated components have not been tried for fear of beads or mesh dislodging and causing 3-body wear of the bearing.

The small series of hydroxyapatite coated femoral components have done well, but cement fixed femoral components have been excellent. The authors prefer this method of fixation because it gives much more versatility in treating patients with misshapen femoral heads, large bone cysts, or avascular necrosis. Patients have endured the misery of some poorly fixed components in the pilot study, but at revision surgery it was confirmed that the femoral heads are viable and the metal on metal bearing is behaving well as predicted from 35 years of use of metal on metal bearings.

The authors' current metal on metal resurfacing hip replacement with hydroxyapatite fixed acetabular component and cement fixed femoral component is performing well at short follow-up. The future is approached with cautious optimism.

Acknowledgments
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