CEMENTLESS UNCOATED POLYETHYLENE ACETABULAR COMPONENTS IN TOTAL HIP REPLACEMENT

REVIEW OF FIVE- TO 10-YEAR RESULTS

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We reviewed the results of 545 consecutive total hip replacements using a cementless non-coated high-density polyethylene acetabular component combined with a cemented Müller stem at five to 10 years. In all, 421 patients (445 hips) were available for review, 118 by questionnaire and 303 by examination and radiography. Of these, 86% had a good or excellent result.

We found a high rate of radiological loosening of the cup after the sixth year, and a high rate of clinical loosening after the eighth year. Loosening was commoner in women, in younger patients and where a smaller size of acetabulum had been used. Calcar resorption was significantly related to loosening of the acetabulum.

Loosening appeared to be mainly due to polyethylene debris produced by micro-movement of the acetabulum against the bone, which had resulted in a giant cell foreign body reaction and subsequent bone erosion. We have abandoned the use of this prosthesis and suggest that direct contact between bone and polyethylene should be prevented by a coating of metal or some other material.

In 1973 a cementless polyacetal acetabular component was developed and used in Basle (Morscher and Mathys 1974), but excessive rates of wear were experienced, and therefore in 1977 a high-density polyethylene acetabular component (RM cup, Fig. 1) was developed for uncemented use, with the aim of achieving iso-elasticity. The cup is hemispherical and supported circumferentially by the original subchondral bone, giving more support to the implant, and avoiding excessive loss of bone stock during implantation.

Early results with this acetabular component were very encouraging (Morscher, Dick and Kernen 1982), and between 1977 and 1982 a total of 545 were implanted, combined with a cemented stem. Encouraging early results have also been reported by others using polyethylene acetabula in direct contact with bone (Bertin et al 1985; Nunn 1988), but to date the longest follow-up is seven years. Lord and Bancel (1983) have reported good results at up to seven years with a metal-backed uncemented prosthesis; there are other reports of good long-term results with similar metal-backed prostheses (Ring 1983; Andrew et al 1985).

Our experience of histological examination from retrieved acetabula early after hip replacement (Remagen and Morscher 1984), suggested that cementless non-
coated polyethylene acetabular replacements did not give such good long-term results as had originally been expected. We therefore undertook a review of all the patients treated at our clinic with this cup in combination with a cemented stem with a follow-up of more than five years.

PATIENTS AND METHODS
Between 1977 and 1982 a total of 545 RM high-density polyethylene acetabular components (Robert Mathys, CH 2544, Bettlach, Switzerland) were implanted in 516 patients together with a Müller cemented shaft, at the University of Basle Orthopaedic Department. The cup has two pegs which help to anchor it in the bone. The initial design included screw fixation, which was used in 63% of cases. Subsequently, dowels were designed to anchor the acetabulum, and these were used in 8% of cases. No extra fixation was used in the remaining 29%. Implantation of the cup is by a jig system which ensures accurate placement of the bone holes for the pegs and the acetabulum itself. Information was recorded prospectively on a standard form and included the age and sex of the patients, the aetiology of the arthritis, and details of the size of prosthesis, bone stock, and any difficulties encountered at the operation.

Various femoral components were used during this period including the original Müller curved prosthesis (14%), a collared stem with a 130° neck–shaft angle and a 130 mm wide stem (16%), and the Müller straight stem prosthesis either in a standard form (68%), or with a lateralised stem (2%). All the femoral components were cemented in place using polymethylmethacrylate cement. These replacements comprised about 75% of all the primary total hip arthroplasties we carried out during this period.

The patients were reviewed at one, three and 12 months, and at varying intervals thereafter, clinical information being recorded on standard forms. At the time of the study, 37 patients (40 hips) had been lost to follow-up, and 57 patients (60 hips) had died. The 210 patients (217 hips) who had not attended for review within the last two years were sent a questionnaire asking about pain, walking ability, mobility of the joint and their opinion of the result. They were invited to attend for review, and 92 of them (97 hips) were subsequently examined and radiographed. Thus 118 patients (120 hips) answered the questionnaire only, and a total of 303 patients had relatively recent examination and radiography.

Patients at review were asked about pain, walking ability, the use of walking aids, and the use of analgesics. The range of movement of the joint and the power of the abductors was assessed, and the patients were observed walking. The patients were given a hip score using the scale of Merle d'Aubigné (1970).

Radiological assessment. Radiographs taken three months postoperatively and at the time of the latest follow-up were compared by superimposition. Acetabular migration between the two radiographs was recorded as <2 mm, 2 to 5 mm or >5 mm. The bone stock around the acetabular component was assessed from the three-month radiograph, and given a score from 3 to 9, depending on the quality, type and position of bone sclerosis (Table I, Fig. 2).

The final radiograph was assessed for any lucency suggestive of osteolysis, which might suggest loosening. Cup wear on the inner side was assessed by measuring

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<th>Table 1. Scoring for bony sclerosis about the acetabulum (maximum 9 points)</th>
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<td><strong>Score for each feature</strong></td>
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Fig. 2
Three types of acetabular sclerosis. On the left, a sclerotic line is seen in all three zones, in the centre the sclerosis is diffuse, and on the right it is almost absent.
the distance between the tip of the femoral head and a line drawn through the centre of the metal ring surrounding the cup. Radiological loosening of the cup was defined as migration of more than 5 mm, or migration of more than 2 mm associated with evidence of bone lucency.

The femoral components were also assessed for loosening using the technique described by Gruen, McNeice and Amstutz (1979). Loosening of the femoral component was assumed where there was more than 2 mm movement of the prosthesis, or where there were radiolucent lines of more than 1 mm, in any zone, between the cement and bone. The amount of calcar resorption was measured in millimetres. Ectopic ossification was assessed on the three-month film according to the method of Arcq (1973).

**Statistics.** A survivorship curve was constructed for the acetabulum using the method described by Dobbs (1980). The results were stored on computer and analysed using the $t$-test and the chi-squared test where appropriate.

**RESULTS**

The average age of the patients was 65.2 (range 29 to 89), with the distribution shown in Figure 3. The average age of the women was significantly greater than that of the men (66.5 versus 64, $p = 0.0001$), but there were similar numbers of women and men (51.7% women, 48.3% men). The aetiology was osteoarthritis in 85% (of which 24% were secondary to hip dysplasia or slipped upper femoral epiphysis), rheumatoid arthritis in 5%, avascular necrosis in 7% and trauma in 3%. Figure 4 shows the distribution of the size of the cups in men and women. The average size was smaller in women. The clinical results were excellent or good in 86%, fair in 13%, and poor in 1%.

**Acetabular sclerosis.** In 54% of the patients there was sclerosis in zones I and II of the acetabulum, and 16% had this in zones I, II and III. There was sclerosis only in zone I in 21%, and no sclerosis at all in 9%. Of those with sclerosis, 77% had this in the form of a line and in 23% it was more diffuse. The degree of sclerosis was high in 22%, medium in 47% and low in 30%.

**Loosening.** Figure 5 shows the survivorship curves for radiological loosening and acetabular revision, as applied by Dobbs (1980), compared with the curve for cemented acetabular replacements (2 669 Müller cups implanted between 1970 and 1982, Morsch and Schmassmann 1983). It can be seen that up to six years the results of the cementless RM cup are good, but thereafter there are increasing numbers of radiological loosenings, and after eight years there are increasing numbers of revisions for loosening.

The pattern of loosening was either migration of the cup by more than 2 mm followed by lucency around the implant, or lucency around the acetabular pegs, followed by progression and migration (Fig. 6). These changes typically occurred quite rapidly (over a period of about
Loosening of a cementless cup. On the left, a satisfactory position at two months. In the centre early migration is seen at 17 months, while on the right there is established loosening with migration at 47 months, and bone lysis around both the cup and the calcar.

24 months) in what had apparently been a stable prosthesis without any signs of loosening. At the time of revision there were almost always abraded areas on the outer surface of the acetabulum (Fig. 7), where there had been contact and movement between bone and polyethylene. In many cases the pegs had broken off.

There were more cup revisions for aseptic loosening in women than in men (19 versus 13), and there was also a greater average migration of the acetabulum in women compared to men, but these differences were not statistically significant. Loosening was commoner in the younger age groups (p = 0.002); the average age of patients with loosening being 59.7 years as compared to 65.2 for those without loosening. A low cup score at three months (suggesting either poor remodelling of bone around the prosthesis and/or excessive reaming of the subchondral bone at surgery) was more likely to result in loosening of the prosthesis (p = 0.056). The most sensitive predictor of future loosening was the subjective assessment of the sclerosis around the prosthesis at three months.

The smaller the cup, the more likely was loosening (p = 0.036). The loosening rate was 8% for cups of 52 mm diameter and less, as against 5.4% for cups of 54 mm and greater. Radiological loosening of the acetabular prosthesis was more often associated with use of a straight standard femoral stem (which has a 135° neck–shaft angle), than with a 130° stem (which has a 130° neck–shaft angle). Radiological loosening was seen in 35% and in 7% respectively (p = 0.029).

Cup wear. In most patients there was very little cup wear; 80% had < 1 mm, 15% had 1 to 2 mm, and 5% had more than 2 mm. Wear on the inner surface of the acetabulum was greater in the presence of loosening (Fig. 8, p < 0.001). With decreasing age, cup wear increased (Fig. 9, p < 0.003). Despite the fact that there were more...
The variations (Sutherland et al 1983) have been used and 5% when they had not. Where the acetabulum had been fixed with screws, the presence or absence of screw breakage made no difference to the loosening rate.

**Calcaneal resorption.** Calcaneal resorption was more common in the presence of acetabular loosening (p < 0.001), and was significantly commoner with the collarless straight stem than with either of the other two-collared stems (p = 0.0005).

**DISCUSSION**

It has become apparent during the last few years that loosening of the acetabular component after cemented total hip replacement is one of the commonest causes of failure with increasing time (Stauffer 1982; Harris 1984). The incidence appears to follow an exponential course (Sutherland et al 1982; Morscher and Schmassmann 1983). Reported rates of loosening of cemented acetabula vary from 1% to 29% (Mjöberg 1986), but much of this variation depends on the way that loosening is defined, techniques of implantation and the time between implantation and follow-up.

The usual radiological signs of loosening are absent when a polyethylene cup is used without cement; other definitions of loosening must be established. Mjöberg (1986) considered that migration was the only definite sign of loosening in cemented hip replacement. If this definition is used, the loosening rate following cemented arthroplasty reported by Charnley (1979) at 12 to 15 years postoperatively was 11%, by Gudmundsson, Hedboe and Kjaer (1985) at 10 to 14 years was 10%, and by Andrew et al (1985) at five to 12 years after cementless ring arthroplasty was 7%. These are the rates of loosening with which our results must be compared.

Our earlier reviews showed no cases of loosening from six months to four years postoperatively (Morscher et al 1982); other reported results followed for up to seven years with non-metal-backed polyethylene cups have also been good (Ring 1983; Bertin et al 1985; Knahr et al 1987; Nunn 1988). However, our present results show an alarming increase in loosening after six years: the rates are 9% at seven years, 17% at eight years and 28% at nine years.

We were able to study the histology of 23 uncemented RM cups from patients who had died, and found that there was rarely bone integration into the grooves of the prosthesis (Remagen and Morscher 1984; Herren, Remagen and Schenk 1987). Conversely, we found that almost all the cups were surrounded by a layer of fibrous tissue, with bone pseudopodia supporting the cups at certain discrete points. The fibrous layer contained quiescent polyethylene debris. Theoretically, a thin membrane of fibrous tissue around a rigid prosthesis should help to distribute loads evenly, with less chance of subsequent loosening (Kozin, Johanson and Bullough 1986; Rapperport, Carter and Schurman 1987), but small movements of the acetabulum will take place under these circumstances.

Where there was evidence of frank loosening of the prosthesis at the time of post-mortem, we found evidence of granulomata with polyethylene debris. Charnley (1979) was one of the first to implicate polyethylene debris as a cause of loosening of total hip replacements. Wroblewski (1979) demonstrated that wear of polyethylene could result in bone resorption of massive proportions, and Goldring et al (1983) have demonstrated high levels of prostaglandin E2, which almost certainly causes bone resorption secondary to the foreign-body-type giant cell reaction. It has been suggested that polyethylene should never come in direct contact with bone (Wroblewski 1979; Remagen and Morscher 1984; Bertin et al 1985), and Wroblewski et al (1987) have subsequently shown that 32% of loose acetabular components have a deficient cement layer between the bone and cup, with direct contact and abrasion between polyethylene and bone.

The evidence we present supports the thesis of Wroblewski (1979) that polyethylene should never come into direct contact with bone in circumstances where movement may result in abrasion under load. A new model of the RM cup with a hydroxyapatite covering has since been introduced, but it is too early to confirm whether the long-term results will be better. Another solution to the problem is to implant a prosthesis which allows bony ingrowth; we have seen encouraging early results using a prosthesis with a firmly-fixed order-orientated titanium mesh (Morscher and Masar 1988).
Metal backing of the acetabular component increases its stiffness which may be an advantage in cemented acetabular replacement (Harris and White 1982; Harris 1984; Harris and Penenberg 1987). The metal backing helps to avoid peak stresses by spreading stress over a larger area (Crowninshield et al 1983), and it may be that this is also true for cementless hip replacement. However, it has been suggested that metal backing may lead to early migration of uncemented cups as measured by roentgenstereophotogrammetry (Freeman, personal communication 1987); the use of a titanium mesh backing preserves some elasticity which may prevent this (Morscher and Masar 1988).

We found that where there was poor remodelling of the bone, with little or no patchy sclerosis around the acetabular component at three months, loosening was more likely to follow. There is little doubt that the subchondral bone is of great importance in supporting the acetabulum and preventing migration (Huggler et al 1974; Jacob et al 1976; Lionberger, Walker and Granholm 1985; Cornell and Ranawat 1986) and that reaming of the subchondral bone weakens the acetabulum (Huiskes 1987), and encourages micro-movement. Thus, a low-profile hemispherical acetabular component which allows preservation of the bone is ideal. However, where the bone is reamed excessively in the course of implantation, as may have occurred in some of the cases reported here, the weight-bearing cortex of the acetabulum is destroyed; this may well lead to loosening and subsequent failure.

It has been suggested that the presence of osteoporosis may reduce osseointegration of implants (Linder et al 1988). It is possible that patients with relative osteoporosis also fail to remodel, and have poor bone formation around the prosthesis, allowing excessive migration and subsequent failure. We found an increased failure rate in women, possibly secondary to this factor, but increased acetabular failure rates have also been seen in women with cemented acetabular components (Morscher and Schmassmann 1983). The average acetabular size was smaller in women, and failure was more common in those with a smaller acetabulum, so this may be another factor in the difference between the sexes.

We found increased acetabular loosening in younger patients, contrary to the findings of Sutherland et al (1982). Previous authors have reported higher loosening rates in younger individuals, but this most commonly affects the femoral component (Chandler et al 1981; Dorr, Takei and Conaty 1983; Harris and Penenberg 1987), and is commoner in men (Morscher and Schmassmann 1983). We also found an increased rate of cup wear in younger individuals, probably related to increased activity levels.

The evidence from our study is that screw fixation makes no difference to failure rate, though it is generally agreed that primary stability is essential for the success of any cementless total joint replacement (Bertin et al 1985; Freeman and Railton 1987; Morscher 1987; Sportorno et al 1987; Unethum and Blomer 1987). However, it has been shown by roentgenstereophotogrammetry that almost all acetabula undergo some migration, amounting to 1 to 2 mm in the first two years (Baldursson et al 1980); this may not be recognised under normal circumstances (Russe et al 1986; Rapperport et al 1987). Some believe that adequate fixation can be achieved in uncemented hip replacement, without the use of bone screws or dowels, in the absence of bony ingrowth (Freeman, McLeod and Levai 1983), and indeed that bony ingrowth may not occur at all (Freeman and Railton 1987). Certainly screw fixation appears to be unnecessary, probably because any stability achieved with the screws is short lived, and does not affect the final stability of the implant. Indeed, screws may cause subsequent problems, such as impingement of the screws on the femoral head where there is migration of the acetabular component, loosening of the screws, and subsequent damage to the joint.

Calcar resorption was relatively common in our patients: 27% had 1 mm or more resorption of the femoral neck. This compares to rates of 71% reported by Cotterill, Hunter and Tile (1982) after Charnley–Müller hip replacement, 71% by Olsson (1987) with the CAP hip replacement in the absence of loosening, and 16% by Beckenbaugh and Istrup (1978). A number of authors have been unable to show any significant relationship between prosthetic loosening and calcar resorption following total hip replacement (Charnley 1979; Reikeras 1982; Stauffer 1982; Johnston and Crowninshield 1983). Other authors have demonstrated a relationship between femoral loosening and resorption of the calcar (Carlsson and Gentz 1980; Olsson, Jernberger and Tryggö 1981; Cotterill et al 1982; Andrew et al 1985), and between infection and calcar loss (Carlsson and Gentz 1980), but only Johnston and Crowninshield (1983) have suggested a relationship between acetabular loosening and calcar resorption. Our results show a very strong correlation between loosening of the acetabulum and calcar resorption, suggesting that calcar resorption is directly caused by the loosening. A simple explanation for the observed facts would seem to be that acetabular wear particles of polyethylene settle in the lowest part of the joint, where they excite a granulomatous reaction with erosion of the calcar.

Wear of the articulating surface of the cup has been minimal in the majority of our patients, as reported by other authors (Charnley 1979; Lord and Bancel 1982; Stauffer 1982), but in our series, wear was very marked where there was loosening of the acetabulum. There are three possible explanations for this: the first is that wear in the acetabulum produces particles which migrate between the acetabulum and the bone, causing a foreign body reaction and bone lysis, which leads eventually to loosening. A second possibility is that once the acetabulum is loose, deformation of the acetabulum is increased.
because of the loss of support by the subchondral bone plate due to bone destruction, and that as a result friction and wear are increased. A third possible explanation is that wear leads to eccentricity of the head in the socket, with an increase in the rotational moment and friction, and thus increased shear between the bone and the polyethylene (Mjöberg 1986).

The early hope that this type of implant would reduce long-term bone loss and loosening has not been fulfilled; it appears to offer no significant advantage when compared with cemented acetabular replacements (Charnley 1979; Morscher and Schmassmann 1983).

Indeed, we abandoned the use of this prosthesis in 1983. Histology and survivorship analysis suggest that newer designs of acetabular prosthesis which allow ingrowth of bone will give better long-term results. New designs of prosthesis should minimise acetabular wear and avoid any direct contact between bone and polyethylene.

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