Many designs of unicondylar knee replacement show early and mid-term failure due to polyethylene wear. We studied the wear rate of congruent polyethylene meniscal bearings retrieved from failed Oxford unicondylar knee replacements.

We examined 16 bearings, 0.8 to 12.8 years after implantation, measuring their thickness and comparing it with that of 14 unused bearings. The mean rate of penetration, which included the effects of wear at both upper and lower surfaces, was 0.036 mm per year (maximum 0.08). Bearings as thin as 3.5 mm wore no faster than thicker models, but ten with evidence of impingement had greater wear. The six bearings with no impingement showed a mean rate of penetration of 0.01 mm per year.

In unicondylar knee replacement, careful implantation of fully congruous meniscal bearings can avoid failure due to polyethylene wear.

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In unicondylar knee replacement, polyethylene wear is an important long-term problem causing over half the failures of some designs of prosthesis. The cumulative failure rate of such replacements at ten years is reported to be higher than that for modern total replacements and consequently unicondylar replacement is being used less often. However, unicondylar replacement in selected patients has potential advantages, including quicker rehabilitation, lower morbidity and more physiological function. In addition, there is less soft-tissue and bone damage, less blood loss and the implant is cheaper.

Most designs of unicondylar replacement use incongruous bearing surfaces, like those of the normal joint but without an equivalent of the natural meniscus. They give very small areas of contact and therefore sustain high contact stresses. Conservative resection of bone allows only a thin polyethylene layer, and preservation of the cruciate ligaments causes the femoral component to roll as well as slide on the polyethylene. These three factors combine to cause rapid wear. A vicious circle may develop in which wear of a medial component causes an increasing varus deformity, since 1 mm of wear produces about 1° change in angulation. In turn, this further increases the load on the medial side.

The Oxford meniscal-bearing unicondylar replacement (Biomet Ltd, Bridgend, UK) differs fundamentally from other designs. The femoral component is spherical and the tibial component flat (Fig. 1). The meniscal bearing provides fully congruous contact of about 5.7 cm² at each surface in all positions. This minimises contact stresses and, because the meniscal bearing is free to slide, the
femoral component does not roll on the polyethylene. These factors minimise wear, but there are two bearing surfaces in the joint and the polyethylene at the centre of the concavity has to be thin.

Very low penetration rates have been reported for Oxford meniscal bearings retrieved from failed bicompartmental arthroplasties. We aimed to determine the penetration rates of similar bearings used in medial unicompartmental replacement.

Materials and Methods

We retrieved 16 ultra-high-molecular-weight polyethylene bearings at revision operations on 16 patients in whom Oxford medial unicompartmental arthroplasty had been performed by several surgeons between 1983 and 1993 (Table I). Machined polyethylene had been in use before 1986, and moulded after 1986. Sterilisation was by gamma irradiation. In four knees revision was for pain due to progression of arthritis in the lateral compartment, in three for loosening of the tibial component, and in one each for loosening of both components, loosening of the femoral component with dislocation of the bearing, and dislocation. Six revisions were for pain, for which there was no definite cause; four of these were traced and three had no improvement after revision.

We used a modification of the dial-gauge technique reported by Argenson and O’Connor, to determine the minimum thickness of each bearing. Their method of clamping the gauge above a flat surface on which the bearing rested was inaccurate for deformed bearings. We therefore supported each bearing on a disc 1 cm in diameter and used a modified probe with a spherical end of the same radius of curvature as the femoral component (Fig. 2).

<table>
<thead>
<tr>
<th>Size*</th>
<th>Autoclaved</th>
<th>Side</th>
<th>Findings at revision</th>
<th>Patients* age (yr)</th>
<th>Duration in situ (yr)</th>
<th>Impingement</th>
<th>Pitting (grade)</th>
<th>Nominal thickness (mm)</th>
<th>Retrieved thickness (mm)</th>
<th>Estimated penetration (mm)</th>
<th>Penetration rate (mm/yr)</th>
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<td>3</td>
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<td>R</td>
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<td>3.82</td>
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<td>0.11</td>
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<td>Gross anterior</td>
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<td>6.61</td>
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* in 1 mm steps from 0 (3.5 mm) to 8 (11.5 mm)
† osteoarthritis

Table I. Details of the patients and the 16 retrieved bearings arranged in order of their penetration rates

Fig. 2

The gauge used for measuring the thickness of retrieved bearings.
For each retrieved bearing, one observer made three independent measurements of minimum thickness, and took the mean value. To establish the range of variation in thickness before implantation we measured the minimum thickness of 14 unused medial bearings, manufactured over a period similar to that of the retrieved components, to allow for possible changes over time.

Nine of ten used bearings, autoclaved after retrieval, were thicker than their nominal thickness at the time of implantation (Table I). We therefore autoclaved the 14 unused bearings and remeasured them. The measurements before autoclaving had been made on 12 bearings using only the original dial gauge, but we used these results because there was no significant difference between the two methods for unused bearings which had not been autoclaved.

We calculated penetration by subtracting the mean thickness of the used bearing from its estimated thickness at the time of implantation, using the mean thickness of autoclaved or non-autoclaved unused bearings, whichever was appropriate. The penetration measurements included the effects of wear at both upper- and lower-bearing surfaces as well as any creep in the polyethylene. We calculated the ‘average penetration rate’ using linear regression, with the regression line constrained to pass through zero. We report the regression coefficient, and used Student’s $t$-test to compare regression coefficients and means.

**Results**

The nominal minimum thickness of the bearings varied in eight 1 mm steps from 3.5 to 11.5 mm (sizes 0 to 8), and the measured thickness was subtracted from the appropriate nominal thickness to standardise results (Fig. 3).

The mean thickness of non-autoclaved unused bearings was 0.060 mm (SD 0.063) greater than their nominal thickness; we used the corrected value as the thickness at implantation of non-autoclaved retrieved specimens. Autoclaving unused bearings increased their mean thickness by 0.32 mm (SD 0.06, p < 0.0001), and this was not significantly influenced by the nominal thickness of the bearing (p = 0.3). The mean thickness of the autoclaved unused bearings was 0.379 mm (SD 0.068) greater than their nominal thickness; again, we used the corrected value as the
thickness at implantation of the autoclaved retrieved specimens.

Figure 4 shows the penetration for the retrieved bearings against the number of years in use. For each bearing, the possible errors were those in measuring the thickness at retrieval, and the uncertainty of the thickness at implantation. The second factor is substantially larger and is quantified by the standard deviation (SD) of the measurements of the thickness of the unused bearings, represented on the graph by error bars. We found no significant difference ($p = 0.14$) between the mean rates of penetration for autoclaved and non-autoclaved groups of bearings. This implies that the method used to calculate penetration of the autoclaved bearings was appropriate. The mean penetration for all 16 used bearings was 0.036 mm per year (95% confidence limit (CI) 0.022 to 0.049). The highest penetration rate in any bearing was 0.083 mm per year.

On examination, ten bearings showed erosion of their non-articulating surfaces, caused by impingement against bone or cement (Table I). The most common site was anterior produced by impingement against bone in front of the femoral component in extension (Fig. 5). We graded damage to the articulating surfaces as: 0, undamaged; 1, roughened; 2, occasional pits of over 1 mm across; and 3, severely pitted. Four bearings showed severe pitting (Fig. 5) and six had no obvious surface damage (Fig. 6).

The bearings with evidence of impingement all had higher rates of penetration (Table I; Fig. 7) with a mean for the ten specimens of 0.054 mm per year (95% CI 0.045 to 0.063), as against 0.010 mm per year (95% CI 0.003 to 0.018) for the six with no impingement ($p < 0.0001$). We also found a correlation between articular surface damage and rate of penetration (Fig. 8); bearings with smooth articulating surfaces had lower wear rates than those with many pits ($p = 0.02$).

There was also a relationship between the reason for revision and the rate of penetration which was generally lower in the six revisions for pain for which no cause was found than in those in which an abnormality was seen. Nine of the ten knees in which a cause of failure was identified showed evidence of impingement and five of the six knees with unexplained pain showed no impingement (chi-squared test with Yates’ correction, $p = 0.02$).

In Figure 9, the rate of penetration is plotted against the nominal bearing thickness, with error bars as explained above. We found no significant increase in the rate of penetration in the thinner bearings ($p = 0.87$), and linear regression results suggest no relationship to the thickness.
Discussion

The non-articulating surfaces of a normally functioning Oxford medial unicompartmental arthroplasty should not impinge against bone or cement. The mean rate of penetration of such bearings was 0.01 mm per year, and even this may be an overestimate. It is known that hip replacements retrieved at post-mortem show substantially less wear than those retrieved at revision operations. A rate of penetration as low as 0.01 mm per year will not cause an appreciable alteration in alignment; it would take about 100 years for the varus angle to increase by 1°, and 350 years to wear through the thinnest bearing. Even at the highest rate of penetration in the series, 0.08 mm per year, it would take 12 years to alter the alignment by 1°.

There have been no comparable studies of other uni-
compartmental knees. Blunn et al\textsuperscript{13} described wear tracks in 103 retrieved components of PCA, St Georg and Marmor design but made no measurements of the depth of wear. Witvoet, Peyrache and Nizard\textsuperscript{1} followed 121 replacements for a mean of 4.6 years; they attributed ten of the 16 failures from aseptic loosening to gross polyethylene wear and found radiologically measurable wear of 1 to 7 mm in 33 implants which had not been revised. The wearing through of unicompartmental implants has been frequently reported,\textsuperscript{3,6} but not for the Oxford meniscal bearing. The Swedish knee register showed that of 50 failures of Oxford knees, none was caused by wear.\textsuperscript{14}

Argenson and O’Connor\textsuperscript{11} reported a mean rate of penetration of 0.026 mm per year in 23 Oxford bearings retrieved from failed bicompartamental replacements. Plante-Bordeneuve and Freeman\textsuperscript{3} also found a low rate of penetration, at 0.025 mm per year, for the retrieved polyethylene components of a total knee replacement with congruent cylindrical articulating surfaces, suggesting that is this congruence which allows the transmission of high loads with little wear, rather than the meniscal design. Meniscal knee prostheses with polycentric rather than spherical femoral components can be fully congruous in only one position of the joint; it is likely that the very low rates of penetration which we report can be achieved only in completely congruous designs.

It is suggested that the small particles generated by wear at congruous surfaces cause osteolysis and aseptic loosening. Calculations of the volume of wear debris produced by the Oxford unicompartmental meniscal knee, assuming that there is no creep so that the measured penetration results entirely from wear, give a mean volumetric wear rate of 6 mm\textsuperscript{3} per year for bearings showing no impingement, with a maximum of 10 mm\textsuperscript{3} per year. The results for bearings with impingement were 31 and 47 mm\textsuperscript{3} per year, respectively, from the articulating surfaces. However, additional polyethylene debris is released from the area of impingement. No comparable data are available for other knee replacements, but for various designs of total hip replacement, which also have congruous surfaces, the mean volumetric rates of wear assessed in vivo, vary from 26 to 89 mm\textsuperscript{3} per year.\textsuperscript{16} There is some evidence, from acetabular components retrieved at revision, that the tissues around the hip are able to tolerate a mean of 600 mm\textsuperscript{3} of polyethylene debris before there is enough bone resorption to need revision.\textsuperscript{17} It is therefore unlikely that wear particles from normally functioning meniscal bearings will cause problems, but in the presence of impingement and accelerated wear, particles may cause osteolysis in the long term. It seems that impingement, or the loosening that may follow from it, releases debris which then acts as a third body and speeds up the wear rate. This also explains our observation that pitting of the articular surfaces is associated with a higher rate of wear.

We used a modified dial gauge to avoid errors from surface damage and distortion of the bearings, and took into account the effects of autoclaving the bearing after retrieval. The earlier study,\textsuperscript{11} which used a standard dial gauge, did not consider the effects of autoclaving and calculated the mean rate of penetration by a different technique. We therefore repeated the measurements on our retrieved bearings using the old method. The mean rate of penetration of 0.023 mm per year (95% CI -0.008 to 0.055), was not significantly different, but with wider confidence limits which suggest that the new method is more precise.

There was a strong association between impingement and the particular conditions of the implant seen at revision. Assuming that impingement occurred before failure, we suggest that technical error at implantation was an important factor in the subsequent loosening. Shock loads due to impingement may have caused both loosening and abnormal loads in the lateral compartment leading to arthritis. The lateral compartment would also be damaged by debris from impingement.

Of the four patients whom we traced after revision of a unicompartmental implant for pain with no evidence of mechanical failure, three had no benefit. This supports the concept that surgeons may perform the relatively simple operation of revision to a total arthroplasty on less than adequate evidence. If there is no clear evidence of mechanical failure of the implant or progression of the arthritis, pain in the knee is unlikely to be relieved by such a conversion. Such revisions are undertaken more readily after unicompartmental than after total replacement, and survival analyses using revision as the endpoint are therefore biased against the less invasive procedure.

Conclusions

In unicompartmental arthroplasty using congruent meniscal bearings, linear polyethylene wear is negligible, and is not influenced by the thickness of the polyethylene from 3.5 to 11.5 mm. Great care is needed at implantation to avoid impingement of the bearing against bone or cement, since this leads to accelerated wear and may contribute to failure.

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References


