THE MCKEE–FARRAR HIP ARTHROPLASTY

A LONG-TERM STUDY

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Between 1965 and 1973 a total of 808 McKee–Farrar metal-on-metal cemented total hip arthroplasties were performed in the Norfolk and Norwich Hospital. Of these, 230 surviving arthroplasties have been reviewed at average follow-up of 13.9 years.

There were good or excellent results in 49% of the arthroplasties as judged by the Harris hip score with 78% of these having little or no pain. A comprehensive radiographic analysis was undertaken and a survivorship study of 81% of the total number of prostheses is presented.

The introduction of polymethylmethacrylate cement in 1958 enabled prosthetic implants to be securely fixed to the skeleton in the short and medium term (Charnley 1961; McKee and Watson-Farrar 1966). The long term performance of metal-on-socket designs is well documented (Charnley and Cupic 1973; Cupic 1979; Olsson, Jernberger and Tryggö 1981; Salvati et al. 1981; Almby and Hierton 1982; Stauffer 1982) but there are few such studies of metal-on-metal prostheses (Dobbs 1980; Tillberg 1982).

The McKee–Farrar total hip arthroplasty, first used in 1960, had evolved to its standard design by 1965 (McKee 1970; McKee and Chen 1973). The cobalt-chrome-molybdenum (vitallium) cup had had studs both for fixation to the cement and also to ensure a minimum depth of cement. A flanged rim helped to retain the cement in the acetabulum as the cup was inserted. The vitallium femoral component had a collar and a curved stem, being modelled on the Thompson prosthesis (Thompson 1952). Radiolucent cement was inserted digitally into a vented femoral medullary canal and a cement restrictor was not used. The components were designed to allow polar bearing in order to minimise the frictional moment of the joint, which had been high in the original equatorial bearing design (Walker and Gold 1971).

The functional, radiographic and survivorship results of a series of McKee-Farrar total hip arthroplasties inserted at the Norfolk and Norwich Hospital between the years of 1965 and 1973 are presented.

METHOD

All of the hips were inserted using an anterolateral approach without trochanteric osteotomy (McKee and Watson-Farrar 1966). Antibiotics and anticoagulants were not used routinely.

The patients were evaluated using the Harris hip score system (Harris 1969). From a total of 100 points, 44 were allocated for pain, 47 for function, 5 for range of movement and 4 for absence of deformity. We recognise the drawbacks of all hip scoring systems, especially in the elderly, and consider this score as only a guide to the condition of the arthroplasty. Pain and mobility were separately assessed using visual analogue scales (Huskinson 1974).

All patients were reviewed and examined by the authors. A proforma was completed and a standard anteroposterior radiograph of the pelvis was taken. During the nine-year period under review 808 arthroplasties were performed: 255 were in patients who had died and a further 259 in patients who were untraceable but would probably have died by the time of the review. We have analysed from notes and radiographs 64 of the arthroplasties that had been revised during the period under review.

We have been able to review 230 unrevised hips in 175 patients with an average length of follow-up of 13.9 years (range 10 to 22 years). This represents a 28% follow-
up which is similar to the long-term review of Charnley (1979). Bilateral replacements had been performed in 55 of the patients (31.4%). The data, including radiographic measurements, were entered into a computer for statistical analysis.

At the time of the arthroplasty operation, the average age of the reviewed patients was 60.3 years, with a range of 24 to 78 years (Fig. 1). The average age at review was 72.7 years with a range of 38 to 95 years (Fig. 2), and a male to female ratio of 1:1.1. There were equal numbers of right and left replacements. The average age of the whole series of 808 arthroplasties at the time of operation was 61.5 years and the sex ratio was then equal. Our sample of this population is thus well matched for age and sex.

Previous hip surgery was uncommon (4.4%) and the pre-operative diagnosis was osteoarthritis in 87.5% (Table I). The operation was performed by a consultant in 72% of cases. The early complications in this group of patients have been reported previously (McKee and Chen 1973; Dandy and Theodorou 1975).

**Table I. Pre-operative diagnosis in 230 unrevised arthroplasties**

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osteoarthritis</td>
<td>87.5%</td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>6.5%</td>
</tr>
<tr>
<td>CDH</td>
<td>2.0%</td>
</tr>
<tr>
<td>Post-traumatic</td>
<td>2.0%</td>
</tr>
<tr>
<td>Other</td>
<td>2.0%</td>
</tr>
</tbody>
</table>

**RESULTS**

**Clinical findings**

**Hip score.** The Harris hip scores for the 230 unrevised hip arthroplasties were divided into excellent, good, fair and poor as shown in Table II. The mean hip score was 76.4 points (range 6 to 100 points), and 48.9% were good or excellent, while 78% of the arthroplasties were painless or only occasionally painful (Fig. 3). This is equivalent to Charnley's Grades 5 and 6 (Charnley 1972).

Over half of the patients (52.5%) could walk further than a mile and 26.8% could walk between half a mile and a mile. Only 36% regularly used a walking aid, though 10% needed the equivalent of two sticks and 19.5% were unable to walk out-doors. These figures are partly a reflection of the high average age of 72 years. The mean score for function was 64% (range 4% to 100%).
Subjective assessment. We have compared the patient's own assessment of pain and mobility before operation with that at review. Visual analogue scales 100 mm long were used, the absence of pain scoring 0 points whilst intolerable pain scored 100. Full mobility scored 0 points and total immobility scored 100. The mean scores before operation were 78 for pain and 74 for mobility; these had improved to 7 and 27 respectively at review. When asked their opinion of their operations, 90% of the patients were satisfied, 5.5% were indifferent and 4.5% dissatisfied.

Radiographic analysis

Methods. The measurements made on standard anteroposterior radiographs are shown in Figures 4 and 5, using the method of Sutherland et al. (1982). Signs of loosening of the femoral stem were recorded for the seven zones described by Gruen, McNeice and Amstutz (1979) and of the cup for three zones (DeLee and Charnley 1976). Loosening was defined as the presence of bone erosion adjacent to the components since, with radiolucent cement, signs such as lucent zones and cement fracture were absent. Despite this, loosening could be demonstrated around one or both components in 67.7% of the hips; this may be an underestimate in comparison with series using radio-opaque cement.

Femoral components. Loosening. The incidence of stem loosening was 50%, distributed in the seven zones as shown in Figure 6. Proximal zones showed more loosening than distal zones; 20% of the hips showed bony erosion in Zones 1 and 7 only, while 6% had calcar resorption only (Zone 7). Loosening in all zones was seen in 6%. The Harris hip score was shown to correlate very well with femoral component loosening (p<0.0001), a lower score being associated with increasing loosening.

Cortical hypertrophy of the femur at the level of the tip of the prosthesis also had a significant correlation (p = 0.001) with femoral component loosening. In six hips, the tip of the femoral prosthesis had eroded through the lateral femoral cortex.

Contrary to the findings of other authors we could not correlate loosening with femoral diameter, cortical width, medullary diameter, age at operation or sex of the patient (Beckenbaugh and Ilstrup 1978; McBeath, Schopler and Narechania 1980; Olsson et al. 1981).

Stem angle. The relative positions of the centre of the prosthetic head and the tip of the greater trochanter in the coronal plane did not affect the hip score or the incidence of loosening of either component. At the time of insertion the mean angle between the stem and the line of the femoral shaft was 24° varus, with a range of 8° valgus to 9° varus. At review the mean was 3.5° varus with a wider range of 20° valgus to 31° varus caused by the loosening of some prostheses. A number of prostheses had moved in a valgus direction as they loosened. No measurement of inclination in the sagittal plane was made.

In most cases the stem was within a few degrees of neutral at insertion; we were therefore unable to test the hyposthesis of McBeath et al. (1980), Coudane et al. (1981), and others that a varus position predisposes to loosening. However, there was no significant correlation between stem loosening and insertion in greater than 6° varus (29 hips), or a medial or lateral position of the tip of the prosthesis in the medullary canal.
Acetabular components. **Loosening.** Loosening was evident in 51.1% of the cups and the distribution by zones is shown in Figure 7. In 29% of the cups all three zones showed loosening.

The angle from the horizontal at which the cup was inserted is shown in Table III. Measurement of cup anteverision was not attempted. The mean angle of insertion was 38° which is within the range of 35° to 45° suggested by most authors, although originally an acetabular angle of 30° was recommended by McKee and Watson-Farrar (1966). When the cup rotated so that its face turned cephalad, we called the angle of change positive and when it turned caudally we called it negative. The mean change in the cup angle during follow-up was +0.9°, but some loose cups had rotated in each direction, the largest changes being −101° and +98°.

The proportion of the cup not covered laterally by the bony acetabulum on the postoperative radiographs correlated well with loosening at review (p = 0.001). In early cases, the uncovered portion of the cup was buttressed with cement which in turn was supported by two screws in the ilium (McKee 1974). Analysis shows that this made no difference to the incidence of loosening.

Unlike the results for the femoral stem, acetabular loosening correlated weakly with the hip score (p = 0.06) suggesting that a loose cup may not cause much pain or disability. The angle of insertion did not correlate with loosening of the cup at review.
Migration. Before operation 7.2% of the hips showed protrusio, as judged by the femoral head crossing Kohler’s line, K in Figure 4 (Hubbard 1969). Of these hips 38.5% were in patients with rheumatoid arthritis although only 6.5% of the total number of hips were in rheumatoid patients. At review 62.5% of the replacements for rheumatoid hips were in a protrusio position compared with only 4.4% of the previously osteoarthritic hips. The mean Harris hip score was significantly lower (p = 0.005) in those patients who had developed protrusio of the acetabular cup.

Migration of the cup was measured on the anteroposterior radiograph. There was migration of more than 5 mm in 92 cups; the direction of migration of these was recorded in the 30° sectors shown in Figure 8, and the largest number had moved in a superomedial direction, corresponding to the line of force transmission through the joint. In this direction the maximum migration was 34.6 mm with a mean of 13.8 mm. A few large migrations in lateral and superolateral directions were also seen, shifts of 31.1 mm and 49.2 mm being recorded.

Heterotopic bone. Heterotopic bone formation was recorded in four grades (Brooker et al. 1973) and the results are shown in Table IV. There was a significant correlation (p < 0.0001) with the Charnley range of movement score, confirming that movement is restricted in cases of heterotopic bone formation. There was, however, no significant correlation with the Harris hip score; this confirms Brooker’s finding that unless there was bony ankylosis, heterotopic bone formation did not affect the function score. There was no correlation between heterotopic bone formation and loosening.

Survivorship
Survivorship tables (Table V) were computed according to Smith, Putman and Gehan (1970). The end point of survival was taken as the time of removal of the prosthesis. This is the only possible end point in a retrospective review and can be criticised on the grounds that there are inevitably a number of “failed” prostheses which remained in situ. It therefore gives an underestimate of the real failure rate. Adequate data was available on 657 hips out of the total of 808 (81.3%).
Table V. Survivorship table based on removal of the prosthesis

<table>
<thead>
<tr>
<th>Interval since arthroplasty</th>
<th>Number at start of interval</th>
<th>Number of prostheses removed</th>
<th>Number of cases withdrawn from series</th>
<th>Number at risk</th>
<th>Annual percentage removed</th>
<th>Cumulative percentage surviving</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1</td>
<td>657</td>
<td>8</td>
<td>42</td>
<td>636.0</td>
<td>1.26</td>
<td>100.00</td>
</tr>
<tr>
<td>1-2</td>
<td>607</td>
<td>7</td>
<td>23</td>
<td>595.5</td>
<td>1.18</td>
<td>98.74</td>
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<tr>
<td>2-3</td>
<td>577</td>
<td>6</td>
<td>27</td>
<td>563.5</td>
<td>1.06</td>
<td>97.58</td>
</tr>
<tr>
<td>3-4</td>
<td>544</td>
<td>10</td>
<td>28</td>
<td>530.0</td>
<td>0.89</td>
<td>96.54</td>
</tr>
<tr>
<td>4-5</td>
<td>506</td>
<td>4</td>
<td>27</td>
<td>492.5</td>
<td>0.81</td>
<td>94.72</td>
</tr>
<tr>
<td>5-6</td>
<td>475</td>
<td>7</td>
<td>25</td>
<td>462.5</td>
<td>1.51</td>
<td>93.95</td>
</tr>
<tr>
<td>6-7</td>
<td>443</td>
<td>4</td>
<td>20</td>
<td>433.0</td>
<td>0.92</td>
<td>92.53</td>
</tr>
<tr>
<td>7-8</td>
<td>419</td>
<td>2</td>
<td>15</td>
<td>411.5</td>
<td>0.49</td>
<td>91.67</td>
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<tr>
<td>8-9</td>
<td>402</td>
<td>1</td>
<td>14</td>
<td>395.0</td>
<td>0.25</td>
<td>91.23</td>
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<tr>
<td>9-10</td>
<td>387</td>
<td>1</td>
<td>12</td>
<td>381.0</td>
<td>0.26</td>
<td>91.00</td>
</tr>
<tr>
<td>10-11</td>
<td>374</td>
<td>3</td>
<td>23</td>
<td>362.5</td>
<td>0.83</td>
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<td>320.5</td>
<td>1.25</td>
<td>90.01</td>
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<td>12-13</td>
<td>289</td>
<td>12</td>
<td>62</td>
<td>258.0</td>
<td>4.65</td>
<td>88.88</td>
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<td>13-14</td>
<td>215</td>
<td>1</td>
<td>39</td>
<td>195.5</td>
<td>0.51</td>
<td>84.75</td>
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<tr>
<td>14-15</td>
<td>175</td>
<td>15</td>
<td>38</td>
<td>156.0</td>
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<td>84.32</td>
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<td>9</td>
<td>39</td>
<td>102.5</td>
<td>8.78</td>
<td>76.21</td>
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<tr>
<td>16-17</td>
<td>74</td>
<td>6</td>
<td>18</td>
<td>65.0</td>
<td>9.23</td>
<td>69.52</td>
</tr>
<tr>
<td>17-18</td>
<td>50</td>
<td>7</td>
<td>12</td>
<td>44.0</td>
<td>15.91</td>
<td>63.10</td>
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<td>18-19</td>
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<td>11</td>
<td>25.5</td>
<td>7.84</td>
<td>53.06</td>
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<tr>
<td>19-20</td>
<td>18</td>
<td>7</td>
<td>4</td>
<td>16.0</td>
<td>43.75</td>
<td>48.90</td>
</tr>
<tr>
<td>20-</td>
<td>7</td>
<td>6</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>27.51</td>
</tr>
</tbody>
</table>

Those patients whose prosthesis had been removed during any given yearly time interval since operation were designated “removals”. Those who had died or became lost to follow-up during that period were designated “withdrawals” from the series. The number of prostheses “at risk” in any time interval was the number at the start of the interval minus half the “withdrawals”, assuming that these were equally spread through the time interval. The probability of removal during this time interval was then the number “at risk” divided by the “removals”.

These survival calculations, as pointed out by Armitage (1971, pp 408-14), are subject to two major assumptions, first that the withdrawals had the same probabilities of failure as the non-withdrawals and secondly that the survival probabilities for each time interval remained constant throughout the series. The first assumption is reasonable but the second is less reasonable as, apart from other and possibly unknown factors, the prosthesis was under development during the whole of the period under consideration.

The percentage of hips surviving in situ is plotted against time in Figure 9. It fell by an average of about 1% per year for the first 14 years after which it stood at 84.3%. After 14 years removal was more frequent and at 20 years only 27.5% survived in situ. Separate survival curves for the acetabular and the femoral components, as judged from the loosening reported at revision operations, showed approximately equal rates of loosening with time. Dobbs (1980) showed in his series of Stanmore metal-on-metal joints that the 50% survival time was 11.8 years and he predicted 33% survival after 20 years. We have shown a 50% survival of 18.7 years but 27.5% survival at 20 years, which is fairly close to Dobbs’ value. There are obviously factors due to the different types of prosthesis but the long term metal-on-metal survival figures seem to agree. This figure contrasts with Dobbs’ estimate that 50% of metal-on-plastic joints will survive for 34.5 years, with 74% survival at 20 years, but it remains to be seen what the future will show.

Revisions
We reviewed the notes and radiographs of 64 revision operations performed from 8 months to 20 years after the first insertion (mean, 7 years 11 months). The indications for revision are shown in Table VI. Replacement of one or both components was done in 75.8% of these operations, excision arthroplasty in 14.5% and other procedures in 9.7%. A defect in the acetabular floor was found at 27.8% of the revision operations.

![Cumulative percentage of 657 hips surviving in situ in relation to time in years. The bars represent standard errors.](image)
The level of physical activity reported by the patient one year after primary operation was graded as having been low, moderate or high. Of the revised hips 41% were in the high activity group; compared with only 25% of the unrevised hips. This suggests that high activity levels predispose to loosening (p = 0.03).

Table VI. Reasons for revision of 64 arthroplasties

<table>
<thead>
<tr>
<th>Reasons</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component loosening</td>
<td>78.0</td>
</tr>
<tr>
<td>Stem fracture</td>
<td>8.0</td>
</tr>
<tr>
<td>Femoral fracture</td>
<td>5.0</td>
</tr>
<tr>
<td>Secondary infection</td>
<td>3.2</td>
</tr>
<tr>
<td>Primary infection</td>
<td>1.6</td>
</tr>
<tr>
<td>Recurrent dislocation</td>
<td>1.2</td>
</tr>
<tr>
<td>Others</td>
<td>3.0</td>
</tr>
</tbody>
</table>

DISCUSSION

Studies of the long term results of hip arthroplasty are hampered by both the failure to locate and examine many of the living patients and also by deaths from unrelated causes (Charnley 1979; Stauffer 1982). Even when a large sample can be used, the assumption has to be made that the examined patients match the whole series.

The type of survivorship study we have used of necessity applies a less than ideal criterion of success and failure but it does give a view of the predictability of outcome of a given technique. In this study, the fact that more than three-quarters of the reviewed implants were painless or only occasionally painful, yet two-thirds were radiologically loose, must be seen in the context of a survival curve which declines steeply after thirteen years.

In vitro studies of metal-on-metal joints with large head sizes have led to criticism of their high frictional moments (Andersson, Freeman and Swanson 1972). Their wear rate, however, is much lower than that of metal-on-plastic joints (Walker and Erkman 1972; Walker, Salvati and Hotzler 1974); this observation has been supported by the examination of implants removed at revision operations. Surface wear of either component of a metal-on-metal joint after up to twenty years is minimal and cup deformation is not seen. In contrast, metal-to-high density polyethylene joints often show significant wear and cup deformation which both result in increased friction (Bradish, personal communication 1985).

Our results confirm that loosening is the main cause of failure and its incidence may well be under-estimated in this study because of the exclusive use of radiolucent bone cement. The pattern of acetabular loosening using bone erosion as the index is at variance with published data of the distribution of lucent lines in hips inserted with radio-opaque cement (DeLee and Charnley 1976). We have shown that radiological evidence of loosening was commonest in Zone III, but this may be due to the rigidity of the metal. Failure to centralise the socket, lack of lateral bone cover and placement in a "protrusio" position lead to early failure. Proximal failure of femoral cement has been a striking feature in our series, but our results do not support the notion that varus position of the stem contributes to loosening. We recognise that radiological errors introduced by rotation and the position of version of the femoral component may mask the truth in this matter.

Despite radiological deterioration, patient satisfaction remained high in the elderly group of patients with unrevised hip arthroplasties. Five per cent of the hips, however, showed gross loosening with loss of bone stock and a high risk of femoral fracture. These patients were referred for consideration of early revision operations. We believe that regular follow-up of replaced joints after ten years should be the rule, the more so because the survival curve shows such a dramatic deterioration after this time.

Early infection and technical error resulted in a relatively high probability of removal (1.3%) of the implant during each of the first five years after operation (Fig. 10), which is confirmed by the survival curve (Fig. 9). The second five-year period is one of success with a low probability of removal (0.5% per year). After eleven years the increasing rate of failure of metal-on-metal implants is largely due to loosening and therefore

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**Fig 10**

Percentage removal of the prosthesis. This is an estimate of the probability that a prosthesis that has survived for a given period will fail during the next interval of time. The bars represent standard errors.
failure of cement fixation. Although current prosthetic design and operative technique may have improved the results of total hip replacement, we see no reason to believe that cemented metal-on-plastic prostheses will show a different pattern of survival, though this may be spread over a longer time span. The need for revision procedures in cemented implants will remain, particularly when the operation is offered to the younger patient.

We are grateful to the designers of the prosthesis Mr G K. McKee and Mr J. Watson-Farrar and the other orthopaedic consultants at Norwich for permission to study their patients. We are indebted to Mr H. Phillips and Mr J. K. Tucker for their help and encouragement. Thanks are also due to Mrs. Palgrave-Moore and Mrs. Westaway for their administrative help. This study was supported by a grant from the East Anglian Regional Health Authority.

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