FRACTURE OF THE METAL TIBIAL TRAY AFTER KINEMATIC TOTAL KNEE REPLACEMENT
A COMMON CAUSE OF EARLY ASEPTIC FAILURE

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We reviewed 1567 elective knee replacements performed between 1980 and 1990, using either the Total Condylar prosthesis with an all-plastic tibial component, or the Kinematic prosthesis which has a metal tibial tray. The ten-year probability of survival was 92.1% for the Total Condylar design and 87.9% for the Kinematic. The difference was mainly due to 16 revisions required in the Kinematic series for fracture of the metal base-plate. This was the most common cause of aseptic failure in this group.

These fractures were strongly associated with a preoperative varus deformity (hazard ratio (HR) 8.8) and there was a slightly increased risk in males (HR 1.9) and in osteoarthritic knees (HR 1.8). In the nine fractures which occurred within four years of primary implantation (group 1), failure to correct adequately a preoperative varus deformity and the use of a bone graft to correct such a deformity were both strongly associated with fracture (HR 13.9 and 15.8, respectively). In eight fractures which occurred more than five years after primary replacement (group 2) we could detect no significant risk factors.

Early complications occurred in two patients after the 16 revision procedures for tray fracture. One had a deep infection and the other refraction of the tray.

Since the introduction of metal-backed tibial components, fracture of the base-plate has been recognised as an occasional complication, but long-term follow-up suggests that this is rare (Ewald et al 1984; Knutson, Lindstrand and Lidgren 1986; Wright et al 1990); less than 20 cases have been reported. The factors which have been implicated include poor design of the prosthesis (Ranawat et al 1986; Morrey and Chao 1988; Flivik, Ljung and Rydholm 1990) malalignment of the component (Scott, Ewald and Walker 1984), obesity, a high activity level and poor proximal tibial bone stock (Mendes et al 1984; Scott et al 1984; Gradisar, Hoffman and Askew 1989).

In 1983, after reports of the high incidence of deformation in all-plastic tibial components (Scott and Tria 1982), we began to use the Kinematic Condylar prosthesis, with its metal-backed tibial component, as our standard primary implant instead of the Total Condylar prosthesis. We have compared our experience with these two designs to assess the influence of the use of a metal-backed tibial component on implant survival, to examine the factors which may influence fracture of the metal tibial tray, and to evaluate the results of revision surgery.

PATIENTS AND METHODS

We studied the clinical records and radiographs of all primary knee replacements carried out between 1980 and 1990 at the Princess Margaret Rose Orthopaedic Hospital. The Total Condylar replacement (Howmedica International Ltd, London, UK) had been used in 550 patients between 1980 and 1983 and the Kinematic prosthesis (Howmedica International Ltd) in 1017 patients between 1983 and 1990 (Table I). Of these, 58 patients with Total Condylar replacements and 62 with Kinematic replacements had died. The radiographs were inadequate for 72 Total Condylar and 102 Kinematic replacements; these cases were excluded for subsequent survivorship analyses which required radiological evaluation. We used the Kaplan-Meier technique for univariate analysis of survival (Kaplan and Meier 1958). Death of the patient and discharge or loss from follow-up were recorded as withdrawals; none of these patients had revision operations in our centre, which is the only hospital within the Lothian Region in which elective knee arthro-
plasty is carried out.

We identified 16 patients who had revision for fracture of the metal tibial tray (Table I) and one elderly, infirm woman with a fracture which had been managed conservatively.

Operative technique. The original operation had been carried out or supervised by a consultant surgeon using standard Kinematic components in all cases and the Universal jig system. Varus deformity had required a medial release in 15 patients. In three of these loss of bone at the medial tibial plateau had required augmentation using an allograft or autograft. A Kinematic Stabiliser component had been used in one patient. The thickness of the plastic insert used had been selected by the trial size which produced the best soft-tissue balance and stability. Patellar resurfacing had been carried out in 15 patients.

After fracture of the metal tray, revision was performed for pain or progressive varus deformity within 3.5 months of diagnosis with the exception of the one elderly, immobile patient who was managed conservatively in a brace.

At the revision operation, considerable wear of the plastic insert was always seen on the medial side, often with a marked synovial reaction to the resultant plastic debris. In all cases fracture of the base-plate had occurred close to the central stem on the medial side passing forwards from the cut-out in the tray for the posterior cruciate ligament. This resulted either in a sagittal split close to the central stem with a second coronal fracture of the posteromedial part of the plate (Fig. 1a) or a single oblique fracture (Fig. 1c). In the case in which the Stabiliser component had been used, the fracture propagated forwards as a solitary split (Fig. 1b). Extraction of the femoral prosthesis was easily achieved in all cases, but removal of the tibial stem and the remaining lateral base-plate was difficult due to rigid cement fixation. The stem could often be dislodged only by circumferential excision of its enveloping cement mantle followed by removal with an extraction device. It was sometimes difficult to clamp adequately the remains of the broken plate, and this usually resulted in the loss of further metaphyseal bone.

After removal of the components, further bone cuts and soft-tissue rebalancing were required to correct the varus deformity. In all cases there was marked tibial metaphyseal bone loss, especially on the medial side, usually caused by sinking of the fractured portion of the base-plate or by non-incorporation of the bone graft used at the primary operation. The resulting defects were augmented using structural allograft bone secured by screws with cancellous cavities packed with morsellised graft. In three patients a medial metal wedge was used for augmentation, in 12 long-stemmed tibial components were used and in four the revision tibial component was of the posterior stabilised type. All components were cemented. Due to the bone loss, a thicker plastic insert was necessary to restore adequate soft-tissue balance.

We compared the patients who sustained a fracture with all the others in terms of age, gender, weight, height, diagnosis, previous surgery, knee alignment before and after primary replacement and the use of bone grafts. The statistical significance of potential risk factors was assessed using log-rank tests.

Table I. Comparison of the Total Condylar with the Kinematic prosthesis

<table>
<thead>
<tr>
<th></th>
<th>Total Condylar</th>
<th>Kinematic</th>
</tr>
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<tbody>
<tr>
<td>Years of use</td>
<td>1980-3</td>
<td>1983-90</td>
</tr>
<tr>
<td>Number of replacements</td>
<td>550</td>
<td>1017</td>
</tr>
<tr>
<td>Mean age of patients in years</td>
<td>67.2</td>
<td>64.9</td>
</tr>
<tr>
<td>Male:female</td>
<td>1:1.2</td>
<td>1:1.1</td>
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<tr>
<td>Failed arthroplasty requiring revision (rate per 1000 patient years)</td>
<td></td>
<td></td>
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<tr>
<td>Infection</td>
<td>11 (2.04)</td>
<td>14 (2.03)</td>
</tr>
<tr>
<td>Loosening</td>
<td>2 (0.37)</td>
<td>4 (0.58)</td>
</tr>
<tr>
<td>Fracture of tibial component</td>
<td>0</td>
<td>16* (2.51)</td>
</tr>
<tr>
<td>Deformation/wear of plastic insert</td>
<td>2 (0.37)</td>
<td>0</td>
</tr>
<tr>
<td>Knee instability</td>
<td>1 (0.19)</td>
<td>3 (0.43)</td>
</tr>
<tr>
<td>Patellar replacement</td>
<td>0</td>
<td>6 (0.87)</td>
</tr>
<tr>
<td>Others</td>
<td>1 (0.19)</td>
<td>5 (0.72)</td>
</tr>
<tr>
<td>Total</td>
<td>17 (3.16)</td>
<td>48 (6.94)</td>
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* 17 fractures, one patient was treated conservatively.
RESULTS

Figure 2 gives overall survivorship curves for the two prostheses with failure defined as revision for any reason. The estimated five-year and ten-year survival values for the Kinematic replacement (94% and 88%) compare unfavourably with those for the Total Condylar replacement (97% and 92%). The main reason for the difference in survival curves between the two implants was fracture of the metal tibial tray (Table I and Fig. 3).

Details of the patients with and without fractures are shown in Table II. Fracture of the tray was diagnosed at a mean of 54 months after the primary operation (23 to 105). The mode of presentation varied: three patients had an acute onset of severe localised medial pain while walking and 11 developed mild aching discomfort over some months, with progressive instability and recurrence of varus deformity. Three had no symptoms; the fractures were diagnosed incidentally at routine follow-up. Radiographs showed that all the affected knees had varus angulation since the fractures always occurred on the medial side.

The age distribution in the two groups was similar but the fracture group contained a higher proportion of men (hazard ratio [HR] = 1.9, 95% CI 0.5 to 2.8, p not significant) and more osteoarthritic than rheumatoid knees (HR = 1.8, 95% CI 0.7 to 4.4, p not significant). Weight and height were not routinely assessed in the main group but patients with fracture of the prosthesis were within two standard deviations of normal values on weight/height charts and none had had operations on the knee before the replacement.

Risk factors for fracture included preoperative varus deformity (HR = 8.6, 95% CI 2.0 to 13.4, p < 0.001), failure to correct such deformity beyond neutral (HR = 5.2,
Standing radiographs of the left knee of a 52-year-old man with osteoarthritis (a) preoperatively, (b) six weeks after Kinematic replacement; there is a residual varus bow, with displacement of the mechanical axis to the medial side of the knee, (c) 42 months after primary replacement; the varus angulation has increased and the fracture of the medial tibial tray is clearly seen, and (d) six weeks after revision to a Kinemax prosthesis with morsellised medial tibial allograft; the knee is now in satisfactory alignment (the black or white lines show the knee mechanical axis, drawn from the centre of the hip to the centre of the ankle.)

Standing radiographs of the left knee of a 78-year-old woman with rheumatoid arthritis (a) preoperatively; there is marked varus deformity with considerable medial tibial bone loss, (b) six weeks after Kinematic replacement with structural allograft to augment the medial tibial plateau; the varus deformity has been corrected and the mechanical axis is through the centre of the knee, and (c) 36 months after primary replacement; the knee has fallen back into varus with fracture of the medial tibial base-plate. There were minimal symptoms and the patient declined revision surgery and was effectively managed in a knee brace (the black and white lines show the knee mechanical axis drawn from the centre of the hip to the centre of the ankle.)
95% CI 1.5 to 12.6, p = 0.02) and the use of a bone graft to correct varus deformity (HR = 11.3, 95% CI 2.9 to 52.8, p < 0.001). Patients who sustained a fracture of the base-plate had more severe varus deformities compared with the subgroup of the historical cohort with preoperative varus deformities (p < 0.05).

The two groups were well matched for the use of the four different sizes of femoral component, the three widths of tibial component and the four thicknesses of plastic tibial spacers (log rank for trend, p not significant).

We have identified two groups of patients with base-plate fractures determined by the time of their presentation.

**Group 1.** In nine patients the fracture occurred within the first four years (mean 29 months; 23 to 48). All had a preoperative varus deformity which had been fully corrected in only three, who had all had a structural bone graft. Fracture within the first four years was strongly associated either with failure to correct a preoperative varus deformity (HR = 13.9, 95% CI 4.2 to 51.4, p < 0.001) or the use of bone graft to obtain correction (HR = 15.8, 95% CI 2.8 to 71.9, p < 0.001). Follow-up radiographs showed an increase in varus due to progressive deformity of the medial tibial tray and collapse of the bone graft when this had been used (Figs 4 and 5). There were no radiological signs of prior loosening of the tibial component in these patients.

**Group 2.** In eight patients, the fracture occurred at over five years after the operation (mean 84 months; 68 to 105). Six of these knees had a preoperative varus deformity, but all had correction to at least 4° of valgus, with the mechanical axis passing through the centre of the knee. Bone grafts had not been used (Fig. 6). The slightly increased risk for fracture associated with this preoperative varus deformity did not reach significance, and there were no other obvious risk factors (Fig. 6). Sequential radiographs showed a gradual shift of the knee into varus and in six of the patients some patchy osteoporosis developed before fracture and was seen only in the medial tibial table in zone 1 (Ewald et al 1984).

After the 16 revisions, the mean postoperative alignment was 4° of valgus (10° varus to 9° valgus). One patient subsequently developed a deep infection which required an arthrodesis. Another refractured the base-plate two years after revision. The varus deformity after the first fracture had been inadequately corrected using medial bone allograft which had collapsed before the refracture occurred. After the second revision this patient developed loosening and subsidence of the tibial component and required revision to a PFC modular prosthesis with a long-stemmed tibial component. There have been no other early complications, but the mean follow-up of the revisions is only 37.6 months (11 to 90).

**DISCUSSION**

We have found that fracture of the metal tibial base-plate was the most common early cause of aseptic failure requiring revision after Kinematic Condylar knee replacement.

Standing radiographs of the right knee of a 64-year-old man with osteoarthritis (a) preoperatively, (b) eight weeks after Kinematic replacement; the preoperative normal valgus alignment has been maintained after replacement, with the mechanical axis displaced slightly to the lateral side of the knee, (c) 84 months after primary replacement; the knee has now fallen into varus with fracture of the medial tibial tray, and (d) six weeks after revision to a Kinemax prosthesis with a long-stemmed tibial component and using morsellised medial tibial allograft; there is now satisfactory alignment of the mechanical axis.
This was largely responsible for the poor survivorship at five and ten years in comparison with that for the Total Condylar replacement with an all-plastic tibial component (Table I).

The early and late subgroups of patients, with fracture before and after five years, appeared to have different risk factors. The latest Kinematic prosthesis was implanted five years ago and it is likely that most of the early fractures have occurred. All the late presentations had primary arthroplasty between 1983 and 1985, with a mean time to fracture of seven years and we will therefore probably encounter more group-2 fractures in the future.

In group 1 the likely mechanism of fracture was the displacement of the mechanical axis to the medial side of the knee. This places abnormal bending moments on the medial plate around the fulcrum of the central tibial post. The failures after bone grafting had been used with adequate correction of varus suggest that lack of buttressing under the plate due to graft failure was a contributory factor. At revision it was apparent that the bone had not incorporated and had failed to provide structural support to the plate. Histological examination of this bone showed no evidence of ingrowth of new bone. In view of the high rate of failure of structural bone grafts we now favour the use of longer-stemmed prostheses in young individuals to bypass the grafts mechanically and the use of metal wedges for the defects in elderly patients.

In group 1, early failure is predictable and therefore preventable, but in group 2 all the patients had satisfactory correction of the knee axis after primary operation. Johnson, Leitl and Waugh (1980) and Harrington (1983) have shown that during normal gait, despite an apparently neutral or even valgus anatomical axis, the centre of loading shifts to the medial compartment for most of the stance phase which is the period of maximum load transmission. This may explain why fracture of the base-plate always occurred on the medial side of the knee despite apparently normal mechanical axes.

The presence of progressive patchy osteoporosis beneath the medial part of the plate before fracture supports the idea that there may be stress shielding of the tibial metaphyseal bone, as has been suggested experimentally (Lewis, Askew and Jaycox 1982; Reilly et al 1982). At present, late fracture in an apparently satisfactory replacement is neither predictable nor preventable.

Scott et al (1984) have suggested that heavy, active males are most at risk of base-plate fracture. In our series, however, six of the 17 patients were female, all were of average weight and height, and six had severe polyarticular rheumatoid arthritis which restricted activity. We found no relation to the size of femoral or tibial implant used or to the use of thinner plastic tibial inserts.

The revision procedures were technically difficult with problems in removal of the tibial component, restoration of tibiofemoral valgus and augmentation of metaphyseal deficiency. It is too early to comment on the results of our revision procedures, but our early postoperative radiographs, despite the emphasis on restoring the normal axis, showed that we had failed in three cases because of severe varus deformity and bone loss. One of these revisions has already failed with re-fracture of the base-plate; the other two must have poor long-term prospects.

In the last five years we have used the Kinemax system which has a thicker and stronger tibial base-plate. The theoretical risk of fatigue fracture persists if there is eccentric loading; the important precaution is the restoration of the normal mechanical axis of the knee.

Our experience of 13 years suggests that the incidence of deformation in the all-plastic tibial component of the Tibial Condylar knee replacement (Table I) has not been as high as was initially suspected (Scott and Tria 1982). We have seen no fatigue fractures of the tibial component in patients with this implant, and despite the longer follow-up our revision rate for aseptic complications has been lower than that after Kinematic arthroplasty. We are now conducting a randomised prospective trial to compare all-plastic with metal-backed designs.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

REFERENCES


