RADIOGRAPHIC SIGN OF PERSISTENT SOFT-TISSUE IMBALANCE AFTER KNEE REPLACEMENT

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We report on the radiological findings in a series of 871 consecutive primary condylar knee replacements followed up for an average of four years.

A new radiological sign has been identified, consisting of a smoothly tapering wedge of cement visible beneath the horizontal portion of the tibial component on the anteroposterior radiograph. This was found in 25.4% of our cases and appears to indicate a persistent soft-tissue imbalance following condylar arthroplasty of the knee.

The cement-wedge sign was associated with a highly significant increase in radiolucent lines at the tibial cement–bone interface.

Condylar knee replacement is an operation requiring an accurate operative technique. It is important to make exact bone cuts and to perform any necessary soft-tissue release to allow the joint surfaces to assume their proper anatomical alignment (Freeman, Sculco and Todd 1977). The underlying principles of bone and soft-tissue realignment were detailed by pioneers in the field (Insall, Scott and Ranawat 1979), but the relative importance of these two elements is still controversial (Engelbrecht 1981; Moreland 1988).

The accuracy with which the bone cuts have been made can be readily observed on the postoperative radiograph and, on this basis, elaborate methods of assessment have been put forward to measure technical success (Ducheyne, Kagan and Lacey 1978; Laskin and Rieger 1989; Vince, Insall and Kelly 1989). Perhaps for these reasons most recent instrument systems have elaborate jigs for ensuring the accuracy of the bone cuts.

In contrast there has been no method put forward for the postoperative assessment of the adequacy of soft-tissue balancing, nor are suitable instruments available to allow its satisfactory assessment during the operation.

We report a radiological sign which may give such information and describe its relationship to component failure.

METHODS

Between 1979 and 1987, 871 primary condylar total knee replacements were performed on 679 patients at Derby hospitals. Some were under regular review, but to improve the completeness of follow-up all were recalled to be seen in special review clinics between May 1988 and November 1989 and clinical and radiological assessments were performed by two of the authors not involved in the original operations (TJW and AS).

Between 1979 and 1983, 120 arthroplasties of the original total condylar type with all-plastic tibial components (Howmedica International Inc, Staines, England) were performed. The remaining 751 arthroplasties were of the Kinematic design (Howmedica) and were inserted between 1982 and 1987. The mean length of follow-up was four years.

In all, 731 knees were seen at review; 86 patients (109 knees) had died. Only 31 (4%) of the arthroplasties were otherwise lost to follow-up, several of the patients had emigrated. Thirty-one patients (40 knees) had to be visited and only their current clinical status could be assessed, no radiograph was obtained. The radiographs of some of the dead patients had been destroyed so that the total number of knees with adequate radiographs was 732.

The radiographs were long-leg films (43 cm) taken by a standard projection with the patient standing.
Assessment was based on the method of the American Knee Society (Ewald, Hsu and Walker 1989) including measurement of the overall alignment, the alignment of each component in the sagittal and coronal planes, and the presence and width of radiolucent lines at the cement–bone interfaces.

We also noted the presence, size and position of cement-filled bone defects, and in particular the thickness and three-dimensional distribution of the cement beneath the tibial tray.

The method used to assess the coronal attitude of the components is shown in Figure 1. In addition to the angle $\beta$, which reflects the coronal alignment of the tibial component, the angle (T) of the tibial cut relative to the tibial shaft was also measured where this differed from the angle $\beta$ (Fig. 2).

An important feature of our operative technique was that the femoral and tibial components were implanted simultaneously and the cement was allowed to cure with the leg lying on the operating table under its own weight. The posterior cruciate ligament was routinely excised whichever prosthesis was used even though, with the Kinematic prosthesis, 'cruciate-sparing' tibial components were used.

The clinical assessment was performed according to the original Hospital for Special Surgery scoring system and additional information, suggested in the British Orthopaedic Association knee assessment form, was also collected. There were two observers and, to minimise inter-observer differences, a uniform method of assessment was determined during a preliminary investigation. The radiological assessment of the first 300 knees was performed by these two observers, following which slight modifications to the data being collected proved desirable. Because of this, all the radiographs were reassessed by a single observer (AS). Where the two observers disagreed, or where the first assessment
disagreed with the second and no agreement could subsequently be reached in discussion, the knee was classified in the group ‘radiographs not of sufficient quality for accurate assessment’ (vide infra).

All the data were entered on an IBM-compatible microcomputer and the results were analysed using the SPSS.PC suite of statistical software. The data were analysed as a whole and then a specific subset of varus osteoarthritic knees was used to elucidate particular features of soft-tissue imbalance.

**The radiological cement-wedge sign.** An unequal thickness of cement was seen beneath the horizontal portion of the tibial component on the anteroposterior radiographs in a number of cases and was then specifically sought in every case. This inequality was not irregular, but consisted of a smoothly tapering wedge of cement between the tibial tray and the cut surface of the tibia (Fig. 2).

### Table 1. Diagnosis, alignment and component position related to presence or absence of the cement-wedge sign. Mean angle in degrees (SEM)

<table>
<thead>
<tr>
<th>Diagnosis (per cent)</th>
<th>Cement wedge</th>
<th>Laterally-based</th>
<th>None</th>
<th>Medially-based</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All</td>
<td>Group 1 (n = 165)</td>
<td>Group 2 (n = 265)</td>
<td>Group 3 (n = 21)</td>
</tr>
<tr>
<td>Osteoarthritis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>71</td>
<td>88</td>
<td>68</td>
<td>86</td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>27</td>
<td>11</td>
<td>31</td>
<td>14</td>
</tr>
<tr>
<td>Pre-operative alignment</td>
<td></td>
<td>Valgus 1.7</td>
<td>Valgus 3.6</td>
<td>Valgus 18.6*</td>
</tr>
<tr>
<td></td>
<td>(0.49)</td>
<td>(0.65)</td>
<td>(1.76)</td>
<td></td>
</tr>
<tr>
<td>Post-operative alignment</td>
<td></td>
<td>Valgus 4.9</td>
<td>Valgus 5.4</td>
<td>Valgus 8.0*</td>
</tr>
<tr>
<td></td>
<td>(0.25)</td>
<td>(0.22)</td>
<td>(0.50)</td>
<td></td>
</tr>
<tr>
<td>Angle α</td>
<td>97.2</td>
<td>96.9</td>
<td>97.4</td>
<td>98.1</td>
</tr>
<tr>
<td></td>
<td>(0.21)</td>
<td>(0.19)</td>
<td>(0.74)</td>
<td></td>
</tr>
<tr>
<td>Angle β</td>
<td>87.5</td>
<td>86.8*</td>
<td>88.0</td>
<td>89.0*</td>
</tr>
<tr>
<td></td>
<td>(0.18)</td>
<td>(0.15)</td>
<td>(0.45)</td>
<td></td>
</tr>
<tr>
<td>Angle T</td>
<td>87.9</td>
<td>88.3</td>
<td>88.0</td>
<td>88.3</td>
</tr>
<tr>
<td></td>
<td>(0.18)</td>
<td>(0.15)</td>
<td>(0.51)</td>
<td></td>
</tr>
</tbody>
</table>

*significance of difference with group 2 (Student's t-test), p < 0.0005

The cement was usually thickest beneath the lateral part of the tray and thinnest medially, producing the appearance of a laterally based wedge. This was regularly found in knees which had had a varus deformity pre-operatively (Table 1), in which any pre-existing bony defect would be expected to be on the medial tibial plateau. Furthermore, where such bone defects did cause inequalities of cement thickness they tended to be confined to the most medial part of the medial tibial plateau (Fig. 3), in complete contrast to the laterally based cement wedge described above in similarly varus knees. The laterally based wedges cannot therefore be attributed to cement filling a pre-existing bony defect.

Less frequently, we found a similar smoothly tapering wedge of cement but based medially, and with the thinner cement beneath the lateral part of the tibial tray. This was found in association with knees with a valgus pre-operative deformity (Table 1).

A final variant was found in some knees which had been in varus. In these there was not only a pre-operative medial bony defect, but also a laterally based cement wedge. In this case a composite cement wedge was found as shown in Figure 4.

These wedges of cement were only visible when the X-ray beams had been well-aligned to the plane of the horizontal portion of the tibial component.
Table II. Component position in 232 varus* osteoarthritic knees related to the presence or absence of the cement-wedge sign. Mean angles in degrees (SEM)

<table>
<thead>
<tr>
<th>Cement wedge</th>
<th>Present n = 127</th>
<th>Absent n = 105</th>
<th>Significance† of difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle α</td>
<td>96.7 (0.232)</td>
<td>96.8 (0.240)</td>
<td>NS</td>
</tr>
<tr>
<td>Angle β</td>
<td>86.5 (0.204)</td>
<td>87.7 (0.223)</td>
<td>p &lt; 0.0005</td>
</tr>
<tr>
<td>Angle T</td>
<td>88.1 (0.202)</td>
<td>87.7 (0.223)</td>
<td>NS</td>
</tr>
</tbody>
</table>

*varus defined as a pre-operative tibiofemoral angle of 3° valgus or less, on weight-bearing radiographs
†significance by Student’s t-test

RESULTS

Of the 732 knees which were radiologically assessed, 186 (25.4%) showed a cement-wedge sign of one of the above varieties. In 265 knees (36.2%) there was no wedge of cement visible. In 281 knees (38.4%) the radiographs, while adequate for assessing the overall alignment of the limb and components, were taken at such an angle to the plane of the tibial tray that the cement thickness could not be measured. In such cases the cement-wedge sign was not diagnosed, even when it seemed likely that better radiographs would have proved positive. Since these 281 knees did not differ significantly in other parameters from the rest, the sign would probably have been found in the same proportion (186:265) if perfectly aligned radiographs had been available.

Table I shows the results for the whole series related to the diagnosis, alignment and component position and for the subgroups with and without the cement-wedge sign. Knees with a laterally based wedge (group 1) were found to have been more frequently in varus pre-operatively than those with no such wedge (group 2) (p < 0.0005), while those with a medially based wedge (group 3) were more frequently in valgus pre-operatively (p < 0.0005). Both groups 1 and 3 contained a higher proportion with osteoarthritis than would be expected from the proportions in the whole study, but this difference was only significant for the group with the laterally based wedge (p < 0.001 by the chi-squared test).

Knees in group 1 showed a tendency still to be in more varus alignment postoperatively than those in group 2 (p < 0.0005), although their final alignment still represented a greater correction towards normal than was found in those with no wedge. Those in group 3 were left at a more valgus angle than those without a cement ‘wedge’ (p < 0.0005).

In order to eliminate some of the variables a subgroup of 232 varus osteoarthritic knees (with pre-operative tibiofemoral angles of ≤ 3° valgus on weight-bearing radiographs) was analysed separately. This was the largest subgroup and was thought to contain those knees most likely to have fixed pre-operative soft-tissue contracture. The alignment of these knees is shown in Table II according to whether they demonstrated a cement wedge or not. The alignment of the femoral components was the same in the two groups. The mean alignment of the tibial components differed significantly (p < 0.0005) between groups while the true tibial cut had an almost identical angle. This suggests that the actual bone cuts caused no significant difference in alignment in the two groups, and that a small but significant tilting of the tibial component occurred during cementing in those with a cement wedge, consistently in the direction of the pre-operative deformity.

The relationship between the presence of a cement wedge and the subsequent development of radiolucent lines is shown in Figures 5 and 6. At review, a highly significant association was found between the presence of such radiolucencies and the presence of a cement wedge on the postoperative radiograph (Z = -11.99, p < 0.0005; Mann-Whitney U test). This applied to the very common, thin (< 1 mm), lucent lines beneath the horizontal part of the tray, to the much less common radiolucencies of 1 to 2 mm thickness and also to the rare radiolucencies around the keel of the component (chi-squared test, significance varies with threshold score for radiolucencies).

DISCUSSION

In condylar knee replacements where both components are cemented in place at the same time (Sledge and Walker 1984), a large proportion have demonstrated unequal thickness of cement beneath the tibial component. The ‘wedge’ of cement was consistently found to point towards the side of maximum pre-operative bone loss, that is, towards the ‘tight’ side of a deformed knee. Inequalities of cement thickness could occur in a
number of ways. First, a pre-existing bony defect may be incompletely resected, as recommended by Insall (1984), and then filled with cement. We found this in a number of our cases whether they demonstrated a cement-wedge sign or not. Cement-filled defects appeared consistently on the side of the knee opposite to the base of any cement wedge. They can be related to the pre-operative radiograph, and the two phenomena often coexist (Fig. 4).

Irregular or stepped saw-cuts also give rise to irregular cement thickness and this was occasionally seen in our series. Such errors cannot account for the cement wedge, however, since the cement would not then be smoothly tapering, and its consistent relationship to the side of the pre-operative deformity would remain unexplained.

The most obvious cause of a smoothly tapering cement wedge would be an error in the angle of the bone cut which is then compensated for by having more cement on the side from which too much bone has been resected. In such a case one would expect the final tibiofemoral alignment and the alignment of the tibial component to the tibial shaft (β) to be as intended, while the angle of the tibial bone cut (T) would be less than ideal in the direction of, and to the extent of the 'wedge' of cement.

In practise, however, those cases with a cement wedge were found to have a more varus overall alignment and a more varus tibial component alignment (β angle) but an identical true tibial cut angle (T) when compared with those without a cement wedge. Errors in the angle of the bone cut cannot therefore explain these findings.

We believe that the cause of this phenomenon is a disparity between the alignment of the limb as determined by the bony cuts, and the soft-tissue 'alignment' at the time of cementing. If this situation exists and the two components are cemented simultaneously with the leg lying freely on the table with no varus or valgus force applied by the surgeon, the unequal tension in the collateral ligaments will squeeze more cement out of one side of the knee than the other. The final tibiofemoral alignment in the case of a varus knee would then be slightly more varus than that intended by the bony cuts.

The wedge of cement is in no way a quantitative phenomenon since the variability of the components' thickness means that, in the presence of a given amount of soft-tissue imbalance, the use of a thicker component will squeeze more cement from both sides of the knee giving rise to a smaller cement wedge than with a thinner component.

The reason why this kind of cement wedge is associated with such a high incidence of radiolucent lines is not clear. Certainly the tibial components were marginally more varus than those without a wedge, but the difference was small and the mean for both groups was very close to the "ideal" 87° that has been suggested by Hungerford and Kenna (1983). An alternative explanation is that the cement is less well pressurised on the side of the knee on which it is thicker and may therefore offer less resistance to micromotion. One might then expect the lucencies to occur predominantly on the side of the component with thicker cement but we found no evidence of such a distribution (Fig. 6).

It seems likely that the difference in tension between the two sides of the knee is in fact only partially alleviated by the recoil into varus that we suggest occurs during cementing. This would then give rise to continuing deforming forces as recognised by Scott, Scuderi and Stillwell (1987). In that case, any persisting differences in tension could lead to differential loading of the two compartments of the arthroplasty. Such asymmetrical loading could cause micromotion and result in radiolucent lines, and it would be difficult to predict whether such lines would occur predominantly on one side of the knee or in the wider distribution that we found.
The cement-wedge sign could be eliminated either by cementing the components separately, or by the application of corrective varus or valgus stress while the cement is setting. However, this manoeuvre would simply eliminate the evidence of soft-tissue imbalance while doing nothing to correct it. It might even make it worse.

The appearance of a cement wedge suggests persistent soft-tissue imbalance following total knee replacement and is associated with the development of radiolucent lines during follow-up. We believe that more extensive ligamentous release is necessary in a large proportion of knee replacements, and that the performance of such releases along the lines described by Insall (1984) should improve the overall alignment of the limbs and lessen the incidence of radiolucent lines. It is possible that such occult soft-tissue imbalance may be the 'important cause of failure' in total knee replacements alluded to by Tew and Waugh (1985), who suggested that a large proportion of failures were not attributable solely to malalignment of the bones.

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REFERENCES


