The length of the patellar tendon after unicompartimental and total knee replacement

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Patella infera may occur after reconstruction of the anterior cruciate ligament (ACL), high tibial osteotomy and total knee replacement (TKR). Restriction of movement of the knee and pain may result. Our aim was to compare the incidence and to assess the effects of patella infera after TKR and unicompartimental knee replacement (UKR).

We reviewed radiographs of the knees of 84 patients who had had either TKR or UKR as part of a randomised, controlled trial. The length of the patellar tendon was measured on serial radiographs taken before, at eight months and at five years after operation.

There was no significant change in the length of the patellar tendon after UKR, but a significant reduction was observed after TKR. Five years after the operation, the shortening of the tendon had increased to a mean of 3.5 mm. Of the knees with TKR reviewed at five years, 34% developed patella infera, defined as 10% or more of shortening, compared with 5% of those with UKR. Shortening was greatest in those knees which had required a lateral release; in this subgroup the mean shortening was 7.2 mm. Shortening correlated with restriction of movement and pain in the knee.

Our study has shown that patella infera develops in most patients after TKR with lateral release, and in approximately 25% of patients after TKR without this additional procedure. Patella infera rarely occurs after UKR. It is associated with restriction of movement and pain in the knee. It may be an effect of the more extensive exposure required to perform TKR and may, in part, explain the better clinical results of UKR.

Received 26 October 1998; Accepted after revision 18 March 1999
ology and clinical results of this group has been published elsewhere.18

After arthrotomy 102 knees were randomised to receive either a UKR or a TKR. Two UKRs and one TKR required revision at five years. All patients were assessed before and at eight months and at five years after operation by physiotherapists who recorded a global knee score (Bristol knee score) which included a pain score with a possible maximum of 40 points (Table I). The range of knee movement was measured by a goniometer. At the same time, standard radiographs were taken, including a lateral view of the knee.

At five years 11 patients were unavailable for review because of death or loss to follow-up (Table II). Clinical details were available for the remaining 88 knees. Serial radiographs were reviewed in 84 knees since four sets had been lost.

**Measurements.** We measured and recorded the apparent length of the patellar tendon on the lateral radiographs taken before and after operation (Fig. 1). Since it is difficult to define precisely the point of origin and insertion of the tendon, and since the shape of the patella changes at operation because of resurfacing and removal of osteophytes, the three radiographs for each patient were reviewed simultaneously. The same points were identified on each and measurements were made between a point on the inferior pole of the patella and the tibial tuberosity. They were repeated for each series of radiographs on a separate occasion. Changes in the apparent length of the tendon were calculated both as an absolute evaluation and as a percentage of the original length. Patella infera has been defined as a decrease of 10% in the length of the tendon.20,21

To ensure that there was no variation in magnification between the different sets of radiographs, the apparent diameter of the femoral shaft was measured on all films 8 cm proximal to the junction of the shaft with the femoral condyles.

An estimate of the accuracy of the measurement of the length of the patellar tendon was made by comparison of the length on pairs of radiographs of ten knees which had been taken within six months of each other for clinical purposes. The same method was used as in the main study. Pairs of radiographs were only used if they had both been taken either before operation or more than four years after.

**Statistical analysis.** Statistical analysis of changes in the length of the tendon and the diameter of the femoral shaft was made using Student’s paired *t*-test within groups, and Student’s unpaired *t*-test between groups. The incidence of changes was compared using the chi-squared test with Yates’ correction. Linear regression analysis of the data was performed to determine variables statistically associated with changes in the length of the patellar tendon.

**Results**

There was no significant change in the diameter of the femoral shaft at any stage indicating that the magnification of the radiographs did not change.

The variation (1 sd) in the length of the patellar tendon measured on pairs of films viewed simultaneously and taken within six months of each other was 2.4 mm. The accuracy (2 sd) of the measurement of the patellar tendon

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**Table I.** The scoring system for pain

<table>
<thead>
<tr>
<th>Pain on activity</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>25</td>
</tr>
<tr>
<td>Slight</td>
<td>20</td>
</tr>
<tr>
<td>Moderate</td>
<td>10</td>
</tr>
<tr>
<td>Severe</td>
<td>0</td>
</tr>
</tbody>
</table>

**Table II.** Details of the 102 patients and of the radiographs

<table>
<thead>
<tr>
<th></th>
<th>UKR</th>
<th>TKR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of knees</td>
<td>50</td>
<td>52</td>
</tr>
<tr>
<td>Mean age at operation in years (range)</td>
<td>69.6 (53 to 89)</td>
<td>69.8 (47 to 85)</td>
</tr>
<tr>
<td>Male:female</td>
<td>17:28</td>
<td>21:28</td>
</tr>
<tr>
<td>Varus:valgus</td>
<td>46:4</td>
<td>44:8</td>
</tr>
<tr>
<td>Died</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Revised</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Lost to follow-up</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Radiographs missing/unsuitable</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Clinical review at five years</td>
<td>43</td>
<td>45</td>
</tr>
<tr>
<td>Radiographs reviewed</td>
<td>43</td>
<td>41</td>
</tr>
</tbody>
</table>

**Fig. 1**

Measurement of patellar tendon (PT) length.
was therefore taken to be 4.8 mm, which is approximately 10% of its length. If a change in length was estimated to be 10% or more, we considered it to be a definite change. When repeated measurement of the length was made on a single radiograph viewed on different occasions the accuracy (2 SD) was 8.6 mm.

There was a highly significant reduction in the length of the patellar tendon in the TKR group at eight months after operation (p < 0.001; Table III). By five years after operation, the shortening had increased by a mean of 3.5 mm. The further increase in shortening was not significant (p = 0.06). No significant change in the length of the patellar tendon was identified after UKR (Fig. 2).

Five years after TKR, the patellar tendon had shortened by a mean of 7.2% (0% to 23.9% shorter); at the same time, there had been no significant change in length after UKR

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**Table III.** The mean length (mm; sd) of the patellar tendon and diameter of the femoral shaft in both groups

<table>
<thead>
<tr>
<th></th>
<th>Preoperative</th>
<th>8 mth</th>
<th>5 yr</th>
<th>p value preop → 8 months postop</th>
<th>p value preop → 5 years postop</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UKR</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patellar tendon length</td>
<td>45.8 (5.5)</td>
<td>46.2 (5.3)</td>
<td>46.3 (5.8)</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Femoral shaft diameter</td>
<td>31.9 (4.0)</td>
<td>31.6 (3.9)</td>
<td>31.4 (3.6)</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td><strong>TKR</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patellar tendon length</td>
<td>48.4 (6.9)</td>
<td>45.7 (7.3)</td>
<td>44.9 (7.0)</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Femoral shaft diameter</td>
<td>32.5 (3.4)</td>
<td>32.6 (3.8)</td>
<td>32.6 (4.1)</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

Fig. 2
The mean change in the length of the patellar tendon after UKR and TKR with time after operation.

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**Fig. 3**
Proportionate change in the length of the patellar tendon five years after operation.
Fourteen of 41 TKRs (34%) had shortening of more than 10% at five years compared with only two of 43 UKRs (5%) (p < 0.05). The proportionate change in the length of the patellar tendon five years after surgery is illustrated in Figure 3.

The mean range of movement was significantly greater after UKR than after TKR (p< 0.001). When all knees were considered together, it was found that five years after operation shortening of the patellar tendon showed a significant negative correlation with the range of movement (p = 0.006; R = -0.3; Fig. 4). On average, 1 mm of shortening was associated with 0.95° of decreased flexion. When this analysis was repeated with TKR and UKR considered separately, no significant correlation was found between shortening of the patellar tendon and the range of movement (p = 0.6; R = -0.07; and p = 0.04, R = -0.1, respectively).

The mean pain score was marginally greater (less pain) after UKR than TKR, but the difference was not significant (p = 0.17) (Table IV). When all knees were considered, there was found to be a significant negative correlation between shortening of the patellar tendon and the pain score (p = 0.007; R = -0.3; Fig. 5); 9 mm of shortening was associated with a decrease in pain score of one grade or of five points. When TKR and UKR were considered separately, there was a significant correlation between short-
ening of the patellar tendon and the pain score for TKR (p = 0.002, R = -0.5), but there was no correlation between these variables for UKR (p = 0.3, R = -0.17).

Seven of the patients undergoing TKR required a lateral release. In this subgroup, the mean shortening of the patellar tendon was 7.2 mm (SD 4.8) after five years, compared with 2.8 mm (SD 2.8 mm) in those in which a lateral release was not required. Lateral release was found to cause a mean reduction in length of the tendon of 4.4 mm which was highly statistically significant (p = 0.002; Fig. 2). In the subgroup without lateral release there was significant shortening at eight months (p < 0.001) and five years (p < 0.001) after operation. This shortening was significantly greater than that in the UKR group (p < 0.001). Six of the seven knees (86%) requiring lateral release developed patella infera compared with eight of 34 (24%) of those which did not.

Discussion

Our study has shown that patella infera, defined as shortening of the patellar tendon of 10% or more, develops in most patients undergoing TKR with lateral release, and in about 25% of patients having this procedure without lateral release. It occurs rarely after UKR. Patella infera is associated with restriction of movement and pain in the knee. In a series of 94 TKRs performed for both osteoarthritis and rheumatoid disease, Koshino et al. found shortening of 10% or more in 61. In our series the incidence of patella infera after TKR was approximately half that of the earlier Japanese study. There are no reported studies of patella infera after UKR.

When assessing the length of the patellar tendon, a ratio of length to some other measurement on the radiograph is usually used to correct for changes resulting from magnification and projection. The widely used Insall-Salvati ratio may be affected by changes in patellar morphology. Resection of a part of the proximal or distal pole of the patella at the time of resurfacing may alter the shape in the sagittal plane rendering measurement of the Insall-Salvati ratio unreliable. Similar technical objections arise in the use of other indices of length of the patellar tendon. In our study, in which all the radiographs were taken in a standard fashion, we analysed the length of the tendon as measured on the radiograph and did not make any correction for magnification or projection. Measurement of the diameter of the femoral shaft at a point where it is roughly cylindrical, confirmed that errors from projection or magnification were negligible. Blind and randomised measurement of the length of patellar tendon would have been the ideal. We found, however, that with this approach there were large errors of measurement (8.6 mm) because of uncertainty regarding the position of bony landmarks. Simultaneous examination of sequential radiographs of each knee minimised such error (4.8 mm) because it was possible to identify the same bony landmarks on a series of radiographs.

The idea that the patellar tendon shortens is not readily accepted, despite evidence which shows that it does. Although the causes of patella infera are variable, both intrinsic and extrinsic mechanisms may be involved. Extrinsic influences such as dysfunction of the quadriceps muscle secondary to pain or joint effusion can initiate the process and intrinsic factors involving the response of collagen to injury are also involved. Dandy and Desai found that surgical exposure alone in patients undergoing prosthetic reconstruction of the ACL, can produce shortening of the tendon and suggested that it is caused by injury to or ischaemia of the tendon. Our study lends support to that theory. Shortening was greatest in those knees in which a lateral release had been performed, but even in the TKR subgroup in which lateral release was not required, there was significantly greater shortening of the patellar tendon than in the UKR group. The dissection and exposure required to perform a TKR are greater than those required for a UKR. Radical excision of the fat pad to increase exposure necessary to perform TKR, patellar osteotomy, lateral release and incisions for medial arthroplasty placed within 1 cm of the patellar margin independently cause ischaemia of the patella and its tendon.

Some authors have cited the importance of early mobilisation in the prevention of development of postsurgical patella infera. Patients undergoing UKR in our study regained knee movement more rapidly and were discharged sooner than those having TKR.

Lengthening of the patellar tendon of 10% or more was identified in approximately 14% of knees undergoing UKR in our series. Dandy and Desai observed lengthening of the tendon of up to 8% in their patients who had reconstruction of the ACL; errors of measurement could explain changes of this magnitude. Tria, Alicea and Cody described lengthening of the patellar tendon of more than 10% in 7% of knees undergoing reconstruction of the ACL and stated that they were unable to provide an explanation for the observation. Similarly, lengthening of the tendon of 10% or more has been described in 2% of cases after TKR. We do not have a satisfactory explanation for the lengthening in our study. Affected patients achieved high knee scores and lengthening was associated exclusively with UKR. A possible explanation is that because of preoperative pain and disability, resulting from the degenerative process, there was shortening of the patellar tendon and that this corrected when the function improved after operation. Shortening of the tendon is associated with restriction of movement after high tibial osteotomy and can be prevented by early mobilisation.

Functional knee scores, range of movement, patellar-femoral pain, and mechanical symptoms have been shown to correlate independently with the length of the patellar tendon after TKR. Our study has confirmed that shortening of the tendon is associated with a decreased range of movement and increased pain. Biomechanical studies give an explanation for these associations. There is a complex relationship
between the patellar articulation and the wrapping of the distal quadriceps around the femur. The length of the patellar tendon has a profound effect on the mechanics of the patellofemoral joint. Patellofemoral contact force changes by 3% per millimetre of alteration in length of the tendon. Patella infera significantly affects the mechanics of retropatellar contact. The areas of contact migrate proximally on the patella and decrease in size with progressive severity of patella infera. Therefore, the contact pressures probably increase. The pain associated with patella infera may be caused by these local mechanical factors.

Mechanical factors may also explain the association between patella infera and the restriction of the range of movement. Reduction in the length of the extensor apparatus inevitably reduces the range of flexion. In a geometrical model of the knee it has been shown that when there is a short patellar tendon, it contacts the femur at a smaller angle of flexion than occurs when it is of normal length. The length of the lever arm of the patellar tendon is about 50 mm. Therefore 1 mm of shortening would be expected to cause loss of flexion of about 1°. In our study, we found that 1 mm of shortening was associated with loss of flexion of 1° suggesting that loss of flexion may be one direct consequence of shortening of the extensor apparatus. The correlations between shortening of the patellar tendon, range of knee movement and pain score were highly significant when UKR and TKR were considered together. They were not significant, however, when the groups were analysed separately. This may be because the numbers were too small or that there were no correlations within the subgroups. We believe that the former explanation is correct since there seems to be a good biomechanical explanation for the correlations.

Our study has shown that patella infera is rare after UKR, but develops in approximately 25% of patients undergoing TKR without lateral release, and in most patients having TKR with the latter procedure. It is associated with pain and restriction of movement of the knee. We suspect that it is due to the more extensive surgical exposure required to perform TKR compared with UKR and the longer rehabilitation associated with TKR. It may, in part, explain the better clinical results of UKR.

The authors have received financial assistance from one of the manufacturers for provision of secretarial help to the unit.

References