The effect of the design of the femoral component on the conformity of the patellofemoral joint in total knee replacement

H.-M. Ma,
Y.-C. Lu,
T.-G. Kwok,
F.-Y. Ho,
C.-Y. Huang,
C.-H. Huang

From the Mackay Memorial Hospital,
Taipei, Taiwan

One of the most controversial issues in total knee replacement is whether or not to resurface the patella. In order to determine the effects of different designs of femoral component on the conformity of the patellofemoral joint, five different knee prostheses were investigated. These were Low Contact Stress, the Miller-Galante II, the NexGen, the Porous-Coated Anatomic, and the Total Condylar prostheses. Three-dimensional models of the prostheses and a native patella were developed and assessed by computer. The conformity of the curvature of the five different prosthetic femoral components to their corresponding patellar implants and to the native patella at different angles of flexion was assessed by measuring the angles of intersection of tangential lines.

The Total Condylar prosthesis had the lowest conformity with the native patella (mean 8.58˚; 0.14˚ to 29.9˚) and with its own patellar component (mean 11.36˚; 0.55˚ to 39.19˚). In the other four prostheses, the conformity was better (mean 2.25˚; 0.02˚ to 10.52˚) when articulated with the corresponding patellar component. The Porous-Coated Anatomic femoral component showed better conformity (mean 6.51˚; 0.07˚ to 9.89˚) than the Miller-Galante II prosthesis (mean 11.20˚; 5.80˚ to 16.72˚) when tested with the native patella. Although the Nexgen prosthesis had less conformity with the native patella at a low angle of flexion, this improved at mid (mean 3.57˚; 1.40˚ to 4.56˚) or high angles of flexion (mean 4.54˚; 0.91˚ to 9.39˚), respectively. The Low Contact Stress femoral component had the best conformity with the native patella (mean 2.39˚; 0.04˚ to 4.56˚). There was no significant difference (p > 0.208) between the conformity when tested with the native patella or its own patellar component at any angle of flexion.

The geometry of the anterior flange of a femoral component affects the conformity of the patellofemoral joint when articulating with the native patella. A more anatomical design of femoral component is preferable if the surgeon decides not to resurface the patella at the time of operation.

One of the most controversial issues in total knee replacement (TKR) is whether or not to resurface the patella. Many authors have advocated that it should always be resurfaced because of a low rate of complications and less post-operative anterior knee pain.1-4 Picetti et al2 recommended routine resurfacing of the patella in TKR. Wood et al3 observed that in patients treated with the Miller-Galante II TKR, those without a resurfaced patella had worse clinical results in regard to anterior knee pain and descent of stairs.

In contrast, other authors have stated that the clinical results of not resurfacing the patella are similar to those of resurfacing.5-8 Complications have been reported after patellar resurfacing,9-15 including post-operative anterior knee pain, patellar fracture, osteonecrosis, loosening of the component, instability, breakage, wear of polyethylene, the patellar clunk syndrome and problems with the extensor mechanism. Many of these are associated with early designs of TKR and advocates of patellar resurfacing state1-3 that with improvements in techniques of patellofemoral resurfacing and designs of TKR, complications associated with resurfacing have been minimised. The concept of selective resurfacing of the patella was developed to offer resurfacing to those most likely to benefit from it,2,7,16,17 but it is often difficult to decide which patients may do so. Several recent studies5,10,17,18 have failed to identify clearly those patients needing patellar resurfacing on the basis of body-weight, quality of the patellar cartilage and anterior knee pain before operation. In a prospective, randomised, double-blind study of 118 knees,
Barrack et al. found that obesity, the degree of chondromalacia of the patella and the presence of pre-operative anterior knee pain were not predictive of post-operative clinical scores or anterior knee pain. Burnett and Bourne and Soudry et al. noted that the quality of patellar cartilage assessed intraoperatively was also a poor predictor of outcome. Kim et al. found no correlation between post-operative anterior knee pain and factors examined before operation including patellofemoral joint space, the presence of patellar sclerosis, the Insall-Salvati ratio, patellar tilt, gender, obesity and age.

These discrepancies in various studies with respect to outcome with and without patellar resurfacing may be attributed to different designs of the anterior flange of the femoral components used, which can have varying effects on patellofemoral biomechanics. The conclusions from any particular study are only true for the specific prosthesis evaluated.

According to several studies, anterior knee pain from an unresurfaced patella is secondary to the altered patellofemoral biomechanics. We speculated that the design of the femoral component was a major factor in post-operative patellofemoral symptoms after TKR without patellar resurfacing. We therefore investigated the conformity of various femoral components to prosthetic patellar implants and to a native cadaver patella at different angles of flexion.

**Materials and Methods**

Five designs of total knee prosthesis and one random fresh-frozen normal patella from a female cadaver were evaluated. Only prostheses and the patella from the right knee were used. The prostheses had an anteroposterior dimension of approximately 60 mm and included the Low Contact Stress mobile-bearing (DePuy, Warsaw, Indiana), the Miller-Galante II (Zimmer, Warsaw, Indiana), the NexGen (Zimmer), the Porous-Coated Anatomic (Howmedica, Rutherford, New Jersey) and the Total Condylar non-modular prostheses (Howmedica). The cadaver knee had no grossly visible abnormality of the articular surface. The patellar and femoral components of the prosthesis and the normal patella were scanned using the Advanced Topometic Sensor (ATOS; GOM mbH, Braunschweig, Germany).

Three-dimensional (3D) models of the prostheses and patella were reconstructed and assessed by computer. To allow comparison of each design, the 3D model of the femoral component was first articulated with its corresponding patellar component and then with the native patella.

According to previous studies, the patellofemoral contact area is located in the lower part of the articular surface of the patella at a low angle of flexion (0° to 30°), but migrates from the distal third to the proximal region during flexion of the knee. The contact area is orientated as a broad transverse medial-to-lateral band.

For our study, a transcondylar line of the femoral component was used as its axis of rotation. The anterior flange
of the femoral component and the articular surface of the patella were divided into three equal contact lines from the proximal to distal pole. First, the proximal part of the femoral component was articulated with the distal part of the patella at a low angle of flexion (0° to 30°), then the middle part of the femoral component was articulated with the middle part of the patella at an angle of flexion (30° to 60°) and finally, the distal part of the femoral component was articulated with the proximal part of the patella at a high angle of flexion (60° to 90°) (Fig. 1). This is a simplified model and the influence of soft-tissue balancing and rotational positioning of the femoral component were not considered. Therefore, it represented an ideal situation.

The apex of the patellar surface was approximated to the lowest portion of the femoral concave surface at a distance of 5 mm (Fig. 2). The curvature of the patellofemoral contact surfaces was divided into eight equal zones from medial to lateral at intervals of 1.5 mm. Tangential lines of the radial curvature were drawn in each zone on both surfaces (Fig. 2). The conformity of the patellofemoral joint in terms of the angle of intersection of tangential lines was measured using the software package Pro/ENGINEER Wildfire 2.0 PTC (Parametric Technology Corporation, Needham, Massachusetts). The angle of intersection in each section was measured at least five times in each position of flexion and the mean angle was calculated. The lower the angle of intersection, the better the conformity, which was assessed at low, mid, and high angles of flexion from 0° to 90°.

**Statistical analysis.** This was carried out using SPSS software version 12.0 (SPSS Inc., Chicago, Illinois). The conformity of the patellofemoral joints in the five different designs was assessed when articulated with their corresponding patellar component and the native patella at various angles of flexion. The difference in conformity in the various prostheses was evaluated by a t-test, with the value of significance set at p ≤ 0.05.

**Results**
Conformity was assessed for all the prostheses with their corresponding prosthetic patellar component. The Total Condylar prosthesis had a high mean angle of intersection, of 11.36° (0.55° to 39.19°) at mid and high angles of flexion. This indicates low conformity of the patellofemoral articulation with its corresponding component. The mean angles of intersection of 2.25° (0.02° to 10.52°) were low for the other four types of prosthesis in the examined range of flexion, indicating good conformity of the patellofemoral joint.

The conformity of all femoral components with the native patella was also evaluated. The femoral component of the Total Condylar prosthesis was the least satisfactory. The mean angle of intersection remained high at both low and high angles of flexion, with a mean of 8.58° (0.14° to 29.9°). At a high flexion angle, the mean angle of intersection was low in the middle sections of the patellofemoral joint. There was no actual contact between the two surfaces since the patellar rode on the medial and lateral edge of the femoral component. The deep patellar groove gave a small area of contact with the patella at high flexion.

The mean angle of intersection was also high for the Miller-Galante II prosthesis when tested with the native patella (mean 11.20°; 5.80° to 16.72°). The conformity of the patellofemoral joint was unsatisfactory throughout the arc of flexion. The mean angle of intersection was lower (mean 6.51°; 0.07° to 9.89°) for the Porous-Coated Anatomic prosthesis. The Porous-Coated Anatomic femoral component did not match the native patellar articular surface perfectly but it had better conformity than the Miller-Galante II or Total Condylar femoral components.

The Low Contact Stress femoral component demonstrated optimal conformity with the native patella since it had the lowest mean angle of intersection of 2.39° (0.04° to 4.56°). There was no significant difference (p > 0.208) between the conformity with the native patella and with its corresponding patellar component at any angle of flexion (Table I). The proximal portion of the Nexgen femoral component had low conformity with the native patella. At a low angle of flexion, its mean angle of intersection was high at 11.40° (5.75° to 14.26°). However, at mid and high angles of flexion, the conformity was much better, with mean angles of intersection of 3.57° (1.40° to 4.56°) and 4.54° (0.91° to 9.39°), respectively. The Nexgen prosthesis behaved similarly to the Low Contact Stress prosthesis at mid and high angles of flexion. It also had good conformity with the native patella at these angles and there was no significant difference between the conformity (p > 0.294) with the native patella and with its corresponding prosthetic patellar component (Table I).

**Discussion**
The results of our study showed that there was a difference between the conformity of the anterior flange of different femoral components when articulated with the native
surgical technique rather than to whether the patella had knee pain was related to the design of the component or component. They suggested that post-operative anterior subsequent revision in the knees without a patellar post-operative anterior pain, there was increasing need for the knees with and without patellar resurfacing as regards that although there was no significant difference between blind study of 118 Miller-Galante II TKRs. They concluded stairs in the knees which had not undergone resurfacing.

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Table I. The p-value for each femoral component, comparing the results achieved with the corresponding patellar component and native patella at three different angles of flexion

<table>
<thead>
<tr>
<th>Design</th>
<th>Flexion angle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Low Contact Stress</td>
<td>0.208°</td>
</tr>
<tr>
<td>Miller-Galante II</td>
<td>0.001</td>
</tr>
<tr>
<td>NexGen</td>
<td>0.001</td>
</tr>
<tr>
<td>Porous-Coated Anatomic</td>
<td>0.002</td>
</tr>
<tr>
<td>Total Condylar</td>
<td>0.001</td>
</tr>
</tbody>
</table>

* no significant difference in the conformity of the prosthesis if articulated with the native patella and with its corresponding patellar component.

This is likely to affect the kinematic function of the patellofemoral joint which may influence the results of TKR if the patella is not resurfaced.

Every femoral component is designed to articulate with its corresponding patellar component. The anatomical design of the anterior flange of the femoral component is not always compatible with the native patella, which may explain why some patients develop patellofemoral symptoms after TKR with a non-resurfaced patella. The Total Condylar knee prosthesis with an available patellar component was first introduced in the mid-1970s. In a study by Picetti et al, 100 knees were replaced with this prosthesis without resurfacing the patella. They found that 29% of patients had persistent anterior knee pain, and 39% had difficulty climbing or descending stairs. Similarly, Soudry et al described 27 knees treated using the Total Condylar TKR without resurfacing the patella. One-third of the patients had difficulty climbing stairs. The unresurfaced patellae were associated with a high incidence of post-operative patellofemoral pain. In our study, the Total Condylar femoral component had the worst conformity (mean 6.51°; 0.07° to 9.89°) with the native patella at a low angle of flexion (i.e. at a low angle of flexion), the conformity was much better (mean 3.57°; 1.40° to 4.56°) at mid or high angles of flexion. A prosthesis with a femoral component having good conformity with a native patella at a high angle of flexion could be expected to produce satisfactory results after TKR without patellar resurfacing.

In a large randomised, controlled trial of 220 Miller-Galante II TKRs, Wood et al found a significantly higher incidence of anterior knee pain and difficulty in descending stairs in the knees which had not undergone resurfacing of the patella. Barrack et al described a prospective, double-blind study of 118 Miller-Galante II TKRs. They concluded that although there was no significant difference between the knees with and without patellar resurfacing as regards post-operative anterior pain, there was increasing need for subsequent revision in the knees without a patellar component. They suggested that post-operative anterior knee pain was related to the design of the component or surgical technique rather than to whether the patella had been resurfaced. Although the conformity of the Miller-Galante II femoral component to its corresponding patellar component was satisfactory, it showed poor conformity (mean 11.20°; 5.80° to 16.72°) with the native patella in our study. This prosthesis did not have a geometry compatible with the native patella. This was true throughout the flexion arc. The Miller-Galante II may work well if the patellar component is used. However, when the patella is not resurfaced, the small contact area with a native patella increases the patellofemoral pressure.

Feller et al reported a randomised, controlled trial of patellar resurfacing versus no resurfacing in 40 patients with the Porous-Coated Anatomic prosthesis. Those without resurfacing had significantly better ability to climb stairs. They concluded that there was no significant benefit to be found from resurfacing of the patella. The Porous-Coated Anatomic femoral component is asymmetrical with divergent medial and lateral condyles, both of which have a different radius of curvature. The anterior flange of this component is similar to that of the normal femoral condyle. The lateral condyle protrudes further anteriorly and extends more proximally than the medial condyle. With an anatomical femoral surface contour, the Porous-Coated Anatomic femoral component had satisfactory conformity (mean 6.51°; 0.07° to 9.89°) with the native patella in our study. The results were better than those of the Total Condylar and Miller-Galante II prostheses.

Keblish et al studied bilateral TKR in 30 patients using the Low Contact Stress prosthesis without patellar resurfacing on one side and with resurfacing on the other. They found no difference in the prevalence of anterior knee pain or in the ability to ascend and descend stairs. The authors attributed the excellent clinical and radiological results to the near anatomical shape of the anterior flange of the femoral component. In another study of the Low Contact Stress prosthesis examining 436 TKRs, Muller and Wirz suggested that one of the conditions for success in TKR without patellar resurfacing was to have a prosthesis with an anatomical femoral groove. The Low Contact Stress prosthesis has an anatomical femoral groove and the femoral component had perfect conformity (mean 2.39°; 0.04° to 4.56°) with the native patella throughout the range of movement. There was no significant difference in the measured conformity with the native patella compared with its own patellar component.

Climbing stairs is an activity which requires loading of the patellofemoral joint at high degrees of flexion of the knee. Although the Nexgen prosthesis had poor conformity with the native patella near full extension (i.e. at a low angle of flexion), the conformity was much better (mean 3.57°; 1.40° to 4.56°) than the native patella at high angles of flexion. A prosthesis with a femoral component having good conformity with a native patella at a high angle of flexion could be expected to produce satisfactory results after TKR without patellar resurfacing.
Our study had several weaknesses. The method of measuring the conformity of the patellofemoral joint was based on the assumption that rotational positioning of the femoral component and soft-tissue balancing do not influence conformity. This may only be true in an ideal situation. Another limitation was that the data were acquired with a normal, not an arthritic, cadaver patella. In clinical circumstances the anatomy of the actual patella in patients with an osteoarthritic knee may be different from that measured in our study.

The cause of patellofemoral pain after TKR in which the patella is not resurfaced is probably multifactorial. If proper positioning of the component and soft-tissue balancing are achieved, the most important factor for low patellofemoral stress appears to be the geometry of the femoral component. Our study examined the relative conformity of the patellofemoral joint of different prosthetic designs in an ideal situation using a computer model. If the surgeon prefers not to resurface the patella, a more anatomical design of femoral component is recommended to allow for better congruity of the patellofemoral joint.

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References


