Patellar height relevance in opening-wedge high tibial osteotomy

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KEYWORDS
High tibial osteotomy; Opening wedge; Patellar height

Summary
Introduction: The decrease of patellar height following opening-wedge proximal tibial osteotomy can affect function, and subsequent total knee arthroplasty may be more difficult and give poorer results.

Hypothesis: Pre-operative patellar height is an objective predictor of functional result in opening-wedge osteotomy.

Patients and methods: The effect of opening-wedge high tibial osteotomy (HTO) and internal fixation on patellar height and its functional outcome were assessed. Forty supra-tuberosity medial opening wedge osteotomies were performed in 36 patients presenting with medial femorotibial osteoarthritis and varus deformity. Mean age was 55 years. Mean varus was 9° and mean opening 11°. Minimum follow-up was 22 months, with a mean of 4.2 years. Clinical results were assessed on the International Knee Society (IKS) scale. X-ray measurements (HKA angle, tibial slope, and patellar height as per Caton-Deschamps [CD], Insall-Salvati [IS] and Blackburne-Peel [BP]) were taken pre-operatively, postoperatively and on follow-up.

Results: Patellar height decreased by 10 to 15% ($p < 0.0001$), depending on the selected ratio. Mean CD index was 0.85 preoperatively (S.D. = 0.12), 0.76 postoperatively (S.D. = 0.14) and 0.75 at follow-up (S.D. = 0.14). Mean IS index was 0.95 preoperatively (S.D. = 0.11), 0.86 postoperatively (S.D. = 0.12) and 0.87 at follow-up (S.D. = 0.12). Mean BP index was 0.68 preoperatively (S.D. = 0.10) and 0.58 postoperatively and at follow-up (S.D. = 0.12). Tibial slope was altered by a mean of 1.5° (range: −4 to +9°). There was no correlation between opening angle and patellar lowering. Patellar height decrease did not affect functional results whether height remained normal or became low (total IKS score, 179 and 170, respectively); the poorest functional results, however, were associated with patella infera (total score, 147).

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**Introduction**

Medial opening-wedge high tibial osteotomy (HTO) is a common operation, with initially good results that deteriorate over time [1–3].

Surgery tends to reduce the height of the patella; yet, few studies have included preoperative patellar height as an item in indicating surgical technique. However, a very low patellar height may impact the osteotomy result and cause difficulties for subsequent total knee arthroplasty (TKA) [4–8], once again affecting function. Comparative results between primary and postostotmy TKA are controversial [4,5,9,10], but authors reporting the poorest TKA results following tibial osteotomy frequently implicate patella infera [4–7,11].

With the same osteotomy technique, reported values of patella height loss are varied and hard to compare [12,13]. Different ratios are used, and measurement conditions (knee position and quadriceps contraction status) are not always specified.

The present study sought to quantify change in patellar height with opening wedge supra-tuberosity HTO and to assess functional impact in a series of 40 knees.

The hypothesis was that preoperative patellar height is an objective predictor of functional outcome in opening wedge osteotomy.

**Patients and methods**

A continuous series of 40 knees in 36 patients (23 male, 13 female; mean age: 55 years [44–67 years]) were operated on between 1994 and 2005 for medial femorotibial osteoarthritis with a varus knee deformity. Twenty-seven knees were free of previous surgery, and 13 had undergone medial meniscectomy.

The International Knee Society (IKS) scale [14] was used for preoperative and follow-up (FU) clinical assessment. Meynet’s femoropatellar score [15], published in 1999, could not be used because present series started in 1994. Mean preoperative IKS knee score was 46 (range: 40 to 65) and functional score 54 (range: 45 to 70).

Preoperative X-ray assessment systematically included anteroposterior (AP), schuss, lateral (under 30° flexion without quadriceps contraction), skyline and long-leg bipodal weight-bearing views. Immediate postoperative X-rays comprised AP, lateral and skyline views.

On Ahlbäck and Rydberg’s classification [16], 16 knees (40%) were grade 1 (medial femorotibial narrowing ≤ 50%), 20 (50%) grade 2 (narrowing > 50%) and four (10%) grade 3 (complete narrowing without significant tibial bony wear).

Mean preoperative HKA angle was 171° (range: 165 to 177°). Fifteen knees showed grade 1 or 2 patellofemoral osteoarthritis on the modified Iwano scale [17] without patellar subluxation. Twenty-five knees were free of patellofemoral osteoarthritis on X-ray.

All patients were operated on using the same technique of medial opening-wedge supra-tuberosity HTO with plate fixation: 11 Puddu™ (Arthrex France), 14 Kerboull Cobra type and 15 Numelock™ (Stryker France) plates, with interposition of either bone substitute (n = 17) or iliac crest bone graft (n = 15). Mean opening was 11° (range: 9 to 15°): 9° in eight cases, 10° in seven, 11° in eight, 12° in four, 13° in five and 15° in eight).

Immediate postoperative rehabilitation with brace was prescribed in 39 cases, covering joint amplitude with unlimited range of motion and muscle strengthening. The brace was removed on day 15 and complete weight-bearing was resumed at the end of week 6. Postoperative course included two cases of phlebitis, three of spontaneously resolving hematoma and one deep infection treated by evacuation lavage and antibiotherapy. One osteotomy led to non-union, treated by the same technique again, with iliac crest bone graft. Mean consolidation time was 4 months (range: 3–8 months). No reintervention for plate ablation was required. There were no cases of reflex sympathetic dystrophy.

All patients could be followed up, for a mean of 4.2 years (range: 1.8–12 years). The preoperative X-ray protocol was repeated in all cases, with bipodal weight-bearing long-leg view in 27 cases.

All X-ray measurements were made by three observers, with mean values included for analysis. Patellar height, tibial slope and HKA angle (between the femoral and tibial axes) were measured preoperatively, postoperatively and at end of FU. Patellar height was assessed from the lateral view according to the Caton-Deschamps (CD) (Fig. 1) [18], Insall-Salvati (IS) (Fig. 2) [19] and Blackburne-Peel (BP) (Fig. 3) [20] ratios. On CD, normal height corresponds to an index of between 0.8 and 1.2 and a low height to an index of between 0.6 and 0.8; patella infera was defined by an index lower than 0.6. On IS, low height corresponds to an index lower than 0.8, while on BP normal height corresponds to an index of between 0.54 and 1.

Tibial slope was measured as the angle between the posterior tibial cortex and the tibial plateau in the lateral view.

Preoperative and FU X-ray values were compared by Wilcoxon test and significance was tested by Student t. Correlation between patellar height and degree of opening was assessed by the Spearman test, and correlation between tibial slope and patellar height loss by $\chi^2$. 

**Discussion:** Medial opening-wedge HTO is an established treatment for unicompartmental varus knee osteoarthritis. We do not, however, recommend it in case of preoperative patellar height of less than 0.6 on the CD ratio.

**Level of evidence:** Retrospective, level IV.
Results

Patellar height

Table 1 shows mean values and ranges for each index, pre- and postoperatively and at end of FU.

On the CD method, the patella was lowered in 36 cases (90%), remained constant in one and was heightened in three (Table 2). Thirty were of normal height preoperatively (CD > 0.8), and 10 were low (0.6 < CD < 0.8), including three at the lower threshold (Fig. 4). Postoperatively, five counted as patella infera, including four that had been at the lower threshold for low height (CD approximately 0.6) and one at the lower normal threshold (CD = 0.8) preoperatively. At end of FU, only 14 patellae were of normal height, versus 30 preoperatively.

Figs. 5 and 6 show all pre- and postoperative patellar heights according to the IS and BP ratios.

Depending on the index, 90 or 92.5% had lowered by between 10 and 15.1% (p < 0.0001 for either index). Lowering was stable between immediate postoperative and end-of-FU values (Table 1).

Other results

Postoperative HKA was 183.5° (178–186°).

Tibial slope increased by a mean of 1.5° (−4 to +9°; S.D. = 2.8).

Grade 1 or 2 patellofemoral osteoarthritis on the modified lwano classification was observed in 26 cases at FU.

Table 1 Preoperative, postoperative and follow-up (FU) index values and variation.

<table>
<thead>
<tr>
<th></th>
<th>Preoperative</th>
<th>Postoperative</th>
<th>FU</th>
<th>Pre-/postoperative variation (%)</th>
<th>Preoperative/FU variation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD</td>
<td>Mean</td>
<td>0.85</td>
<td>0.76</td>
<td>0.75</td>
<td>11.2</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>0.60–1.12</td>
<td>0.48–1</td>
<td>0.48–1.12</td>
<td>−10 ; 30</td>
</tr>
<tr>
<td>IS</td>
<td>Mean</td>
<td>0.95</td>
<td>0.86</td>
<td>0.87</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>0.65–1.16</td>
<td>0.60–1.12</td>
<td>0.62–1.14</td>
<td>0 ; 27</td>
</tr>
<tr>
<td>BP</td>
<td>Mean</td>
<td>0.68</td>
<td>0.58</td>
<td>0.58</td>
<td>15.2</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>0.52–0.88</td>
<td>0.35–0.92</td>
<td>0.35–0.92</td>
<td>−22 ; 33</td>
</tr>
</tbody>
</table>

CD: Caton-Deschamps; IS: Insall-Salvati; BP: Blackburne-Peel.
Mean total IKS score at FU was 86 and mean IKS functional score 89 (S.D. = 5.2 and 5.6, respectively). For patellae that became low or remained normal, the total score was 170 and 179 respectively (S.D. = 4.8 and 5.1, respectively) (Fig. 7). In these two groups, change in patellar height did not impact function. In case of patella infera (CD < 0.6), in contrast, the total score was only 147 (S.D. = 6.8) and anterior knee pain was consistently associated. There was, however, no correlation between patellar height at FU and onset or aggravation of patellofemoral osteoarthritis, or between the latter and anterior knee pain.

Nor was there any correlation between degree of osteotomy opening and patellar height loss, on whichever index ($p=0.6$; Table 3).

Finally, there was no correlation between patellar height loss on CD and IS and increase in tibial slope ($p=0.16$ and 0.27, respectively; Table 4).

<table>
<thead>
<tr>
<th>Degree of opening (°)</th>
<th>Number of cases</th>
<th>Variation on CD(%)</th>
<th>Variation on IS(%)</th>
<th>Variation on BP(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>8</td>
<td>9.4</td>
<td>7.8</td>
<td>15.4</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
<td>10.4</td>
<td>7.4</td>
<td>14</td>
</tr>
<tr>
<td>11</td>
<td>8</td>
<td>15.6</td>
<td>13.7</td>
<td>16.1</td>
</tr>
<tr>
<td>12</td>
<td>4</td>
<td>8</td>
<td>11.5</td>
<td>18.2</td>
</tr>
<tr>
<td>13</td>
<td>5</td>
<td>10.8</td>
<td>12.4</td>
<td>18.4</td>
</tr>
<tr>
<td>15</td>
<td>8</td>
<td>11.8</td>
<td>8.2</td>
<td>11.2</td>
</tr>
</tbody>
</table>

CD: Caton-Deschamps; IS: Insall-Salvati; BP: Blackburne-Peel.
Patellar height relevance in opening-wedge high tibial osteotomy

Discussion

Patellar height loss may be due to three factors:

- joint-line elevation with respect to the anterior tibial tubercle, a feature of opening-wedge osteotomy in the supra-tuberosity metaphysis [21–26]: osteotomy increases the distance between the tubercle and the tibial joint surface [27]. The ensuing patellar height loss can be calculated theoretically using the same formula as for osteotomy opening (H) according to tibial width (M) and desired correction angle (B), H = 2Msin (B/2) (Fig. 8).

  Given that the tibial tubercle lies laterally just off-center to the tibial metaphysis, the tibial opening at its maximum is half of what it is at the posteromedial edge. The osteotomy opening tends to be much less as the tibial metaphysis is narrower anteriorly than posteriorly and so has to be less wide anteriorly than at the posteromedial edge;

- altered tibial slope, a parasitic phenomenon, has to be avoided as far as possible. Kaper et al. [28], using the IS and BP ratios, reported increased tibial slope to be associated with patella infera. In the present series, a mean of 1.5° increase in tibial slope tended to be associated with decreased patellar height, although the correlation failed to achieve significance;

- patellar ligament relaxation or shortening, for whatever reason: quadriceps collapse (immediate postoperative, or due to prolonged immobilization) or late dystrophic phenomena [24,28–30]. This may explain the absence of correlation in the present series between patellar height and degree of osteotomy opening, and the occurrence of patellar height loss in classic lateral closing wedge HTO [25,31]. Rigid internal fixation is required with early rehabilitation to reduce the incidence of patella infera. In contrast, the one case of postoperative immobilization in the present series was associated with the greatest fall in patellar height index.

Other studies like the present reported almost systematic patellar lowering [12,13,21–24,32]. Not all were clear about the degree of knee flexion applied in calculating patellar height, which one recent study found to vary considerably depending on whether the quadriceps were contracted or not [33]. The present study imposed the same condition (no quadriceps contraction) on preoperative, postoperative and FU radiography.

Another point is that the ratios use the tibia as reference, whereas it would be more logical to locate the patella with respect to the femur. Bernageau and Goutallier [34] recommend measuring the distance between the inferior edge of the patellar cartilage and the top of the trochlea, with the knee in extension. This would, in terms of the present study, have required imposing comparable quadriceps contraction at pre- and postoperative measurement, which we were unable to ensure reliably. It is noteworthy that Miura et al. [35] reported no change in patellar height following tibial osteotomy, using the femur as reference.

It emerges from a number of studies that the assessment of patellar height depends upon which of the ratios is used and that their reliability is open to discussion [12,13,32]. Rogers et al. [36] reported significant interobserver differences in index measurement. To minimize this factor of uncertainty, in the present study, the mean of three observers’ measurements was used for analysis.

The IS index is independent of both tibial slope and femorotibial joint line, and hence of the degree of osteotomy opening. Variation is thus entirely a matter of patellar ligament shortening. However, the IS index shows poor reproducibility and repeatability, due to the difficulty of locating the patellar tendon and anterior tibial tubercle, especially on postoperative X-ray. In the present series, the IS index gave postoperative and enduring patellar height loss in 90% of cases, with no cases of ascension. This suggests that patellar ligament contraction is more or less inevitable following this operation, but to varying degrees. Certain authors [24,37,38] report that external fixation of the osteotomy reduces patellar ligament shortening and hence patellar height loss.

The BP index is dependent upon tibial slope and takes the three factors of patellar height loss into account; it was consistently altered by surgery (Table 2).

The CD index appeared to be the most interesting in analyzing the present results. It shows better reproducibility [39], and also distinguishes between low patella and patella infera. In the present series, all patellae that were preoperatively in the lower region for low patellae (CD near

Table 4 Tibial slope value.

<table>
<thead>
<tr>
<th></th>
<th>Mean (°)</th>
<th>Range (°)</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative</td>
<td>4.8</td>
<td>0–10</td>
<td>2.4</td>
</tr>
<tr>
<td>Postoperative</td>
<td>6.3</td>
<td>0–14</td>
<td>3</td>
</tr>
<tr>
<td>FU</td>
<td>6.2</td>
<td>0–14</td>
<td>3</td>
</tr>
<tr>
<td>Variation</td>
<td>1.5</td>
<td>–4 ; +9</td>
<td>2.8</td>
</tr>
</tbody>
</table>

FU: follow-up.
0.6) proved infera at FU and clinically associated with bad clinical outcome and anterior knee pain.

**Conclusion**

In the present series, medial opening-wedge HTO with plate fixation entailed significant patellar height loss on whichever index. Selective analysis of the results on each index and a review of the literature suggest that this was due not only to the osteotomy opening but also to tissue response to surgery and/or increased tibial slope. For patients with a preoperative CD index approximating 0.6, the tibial osteotomy should not use the opening-wedge technique.

**Conflict of interest**

None.

**References**


