Original article

The posterior condylar offset ratio and femoral anatomy in anterior versus posterior referencing total knee arthroplasty

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ABSTRACT

Background: The preservation of joint anatomy is one of the key issues in total knee arthroplasty. The effect of the prosthesis’ referencing system, relative to femoral anatomy, remains unknown. It was sought to determine if femoral anatomy, following total knee arthroplasty is better maintained using either anterior referencing or posterior referencing prosthesis. The posterior condylar offset ratio (PCOR) was employed for preoperative and postoperative radiographic comparison of femoral condyles. It was hypothesized that posterior referencing prosthesis would better restore condylar morphology.

Methods: Sixty-six patients undergoing a total knee arthroplasty with anterior referenced Zimmer® NexGen® LPS prosthesis and ninety-one with posterior referenced Tornier® HLS Noetos® were divided into two groups according to the prosthetic model used and retrospectively compared. PCOR was calculated as the quotient of the distance between the posterior condylar border and the tangent to the posterior cortex of the femoral diaphysis, and the distance between the posterior condylar border and the tangent to the anterior cortex of the femoral diaphysis. PCOR was determined preoperatively and postoperatively and compared within each group and between both groups.

Results: An increase in the PCOR (P<0.0001) following surgery was observed in both anterior referencing and posterior referencing models. No difference was noted when the postoperative PCOR was compared between both groups (P=0.61).

Conclusion: Both anterior and posterior referencing prosthesis lead to a similar increase of the PCOR following total knee arthroplasty.

Level of evidence: Level IV.

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1. Introduction

Total knee arthroplasty (TKA) is one of the most frequently performed orthopaedic surgeries worldwide with significant year-by-year increase [1–4]. Its therapeutic power has been well established for a number of conditions of which osteoarthritis of the knee is the most common [5], especially among the elderly [6]. Other than pain relief, the main objectives of TKA are restoring functional capacity and increasing quality of life [7].

The preservation of joint anatomy is of special importance in successful and lasting TKA. By mimicking bone morphology such as the joint line and maintaining native knee biomechanics, a properly inserted prosthesis is responsible for delaying component wear [8], avoiding infection [9] and facilitating reconstruction in any eventual revision surgery [10]. Prosthetic fitting depends not only on surgical technique but also on the size and positioning of the implant, whose dimensions of the femoral component must equal the thickness of bone removed from the condyles during bone preparation [11].

Condylar resection thickness can be measured directly in the condyles using a posterior referencing system, or indirectly by determining the anteroposterior length after an initial anterior cut, by means of an anterior referencing system [12]. Although posterior referencing will in theory resect condylar bone matter more accurately, the morphological changes imparted by either system have not been studied.

The assessment of these changes can be made radiographically using the posterior condylar offset ratio (PCOR) [13], a revision of the original posterior condylar offset (PCO) proposed by Bellemans et al. for studying range of movement [14]. Being dimensionless, the PCOR corrects the bias introduced by normal joint size distribution naturally occurring in patients and the non-standardized
magnification of each radiograph [15]; in addition, it offers a fast and reproducible way, independent of referencing system, for gauging alterations in condylar offset resulting from implant fit [16].

Thus, it was sought to determine whether condylar anatomy is better maintained using either anterior referencing or posterior referencing prostheses, employing the PCOR for pre- and postoperative radiographic evaluation. It was hypothesized that posterior referencing prostheses would better maintain the dimensions of the femoral condyles, given their direct approach to posterior structures.

2. Materials and methods

2.1. Series

This retrospective study, approved by the local Ethics Committee, included all registers of primary TKA performed for the treatment of idiopathic osteoarthritis of the knee. Exclusion criteria were: revision arthroplasty, unicompart mental arthroplasty, arthroplasty with patellar replacement or arthroplasty for the treatment of secondary osteoarthritis (rheumatoid arthritis, psoriatic arthritis, traumatic, etc.). In addition, exclusion was extended to all cases reporting radiographs with poor condylar alignment that prevented adequate PCOR measurement.

Sampling interval was set as a continuous interval between January 2008 and March 2012, with 711 cases of knee arthroplasty registered at our institution, of which 157 met inclusion criteria. Of these, 66 had been performed with the insertion anterior referenced Zimmer® NexGen® LPS (Zimmer Holdings Inc., Warsaw, IN, USA) prosthesis and 91 with posterior referenced Tornier® HLS Noetos® (Tornier Inc., Amsterdam, Netherlands) prosthesis (Fig. 1).

2.2. Surgical procedure

Surgery was performed according to protocol, using the anteromedial transquadriceps approach. Both prostheses were posterior cruciate ligament sacrificing and fixed bearing models, and were inserted using adhesive cement.

Referencing was assessed as per manufacturers’ instructions. In anterior referencing prostheses, an intramedullary guide was first placed in flexion, followed by a distal femoral guide; the distal femoral cut was made. A sizing guide was then placed on the flat surface of the distal femur and implant size determined with the aid of a femoral boom placed the anterior cortex. A finishing guide was then inserted on the distal femur and adjusted in the coronal plane; a resection guide was also used to gauge medially and laterally for notching. Finally, an anterior cut was made, followed by posterior and chamfer cuts. Femoral component was rotated externally at a fixed 3°, parallel to the average posterior condylar axis.

In the posterior referencing prostheses, an intramedullary screw with a posterior cutting guide and a femoral stylus were first inserted in flexion; the stylus determined component size by resting at the anterior cortex and the size read was then transferred to the cutting guide and a posterior cut was made. Ligament balancing was then assessed in flexion and extension and a distal cutting guide placed, followed by a distal femoral cut. Anterior and chamfer cuts were then made sequentially. Femoral component was inserted parallel to the epicondylar axis.

Fig. 1. Selection process and distribution between groups.
2.3. Radiographic assessment

PCOR was defined as the quotient of the distance between the posterior condylar border and the tangent to the posterior cortex of the femoral diaphysis, and the distance between the posterior condylar border and the tangent to the anterior cortex of the femoral diaphysis. In postoperative radiographs, PCOR was calculated in equal fashion, using the posterior border of the condylar portion of the implant as reference. Tangent lines were drawn at the distal quarter of the femur representing the continuation of both anterior and posterior cortices, and distances were measured at the widest part of the posterior condyle, drawing perpendicular lines to the anatomical axis of the femur (Fig. 2).

Furthermore, all tracings were made in true lateral radiographs of the knee, as defined by superimposition of femoral condyles and demonstration of patello-femoral joint and joint space between the femoral condyles and the tibia; radiographs were retrieved from the electronic picture archiving and communication system (PACS) used at our institution.

Measurements were made by a single observer using Sectra Image Viewer® (Sectra AB, Linköping, Sweden) software. Intraobserver error was determined using the intraclass correlation coefficient in a two-way mixed model in 20 preoperative and 20 postoperative randomly selected radiographs.

2.4. Statistical analysis

Statistical analysis was performed using IBM® SPSS® Statistics, Version 22 (SPSS Inc., IBM, Chicago, IL, USA). Data were analysed as a single group and as two individual subgroups classified according to prosthesis used: anterior referenced Zimmer® NexGen® LPS (group A) and posterior referenced Tornier® HLS Noetos® (group B). Normality of the sample was tested and data were treated as means.

Student’s t-test was applied for independent samples for comparing preoperative and postoperative PCOR between groups, and for dependent samples for comparing the PCOR before and after surgery within each group. The samples’ variance was tested using Levene’s test. Confidence interval was established at 95% and statistical significance at P < 0.05.

Variables introduced were gender, age, knee (left/right), referencing system (anterior/posterior), and preoperative and postoperative PCO and PCOR.

3. Results

The summary of results is displayed on Table 1. PCO on both groups averaged 27.6 mm preoperatively and 30.4 mm postoperatively, with a difference of means of 2.78 ± 3.30 mm.

No differences were observed in the preoperative PCOR between both anterior referencing (group A) and posterior referencing (group B) models. t(155) = 0.11, P = 0.99; CI95% = [−0.13; 0.14], without rejecting null hypothesis (P = 0.97).

<table>
<thead>
<tr>
<th>Group A (n=66)</th>
<th>Group B (n=91)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (M/F)</td>
<td>9/57</td>
<td>9/82</td>
</tr>
<tr>
<td>Age&lt;sup&gt;a&lt;/sup&gt;</td>
<td>47–87 (67.8)</td>
<td>51–84 (66.5)</td>
</tr>
<tr>
<td>Knee (left/right)</td>
<td>28/38</td>
<td>38/53</td>
</tr>
<tr>
<td>Preoperative PCOR&lt;sup&gt;a&lt;/sup&gt;</td>
<td>27.4 (3.23)</td>
<td>27.7 (3.13)</td>
</tr>
<tr>
<td>Postoperative PCOR&lt;sup&gt;a&lt;/sup&gt;</td>
<td>30.1 (3.81)</td>
<td>30.6 (2.96)</td>
</tr>
<tr>
<td>Preoperative PCOR&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.45 (0.04)</td>
<td>0.45 (0.05)</td>
</tr>
<tr>
<td>Postoperative PCOR&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.48 (0.04)</td>
<td>0.48 (0.04)</td>
</tr>
</tbody>
</table>

PCO: posterior condylar offset; PCOR: posterior condylar offset ratio.
<sup>a</sup> Expressed in years, as interval and mean (between parenthesis).
<sup>b</sup> Measured in millimetres.
<sup>c</sup> Expressed in means and standard deviations (between parenthesis).
In group A, difference between preoperative and postoperative PCOR means was 0.03 ± 0.04, with 14 cases where PCOR decreased, 1 where it remained the same and 51 in which the PCOR increased. The difference was significant, \( t(65) = 6.274, P < 0.0001; \ CI95\% = [0.02; 0.04]. \)

In group B, difference between preoperative and postoperative PCOR means was 0.03 ± 0.04, with 14 cases where PCOR decreased, 11 where it remained the same and 66 in which PCOR increased. The difference was significant, \( t(90) = 6.133, P < 0.0001; \ CI95\% = [0.02; 0.03]. \)

The difference in postoperative PCOR between groups A and B was 0.73% and not significant, \( t(155) = 0.514, P = 0.61; \ CI95\% = [-0.01; 0.02], \) not rejecting null hypothesis \( (P = 0.58) \) (Fig. 3).

Intraclass correlation coefficient for preoperative and postoperative radiographs was 0.97 in the two instances.

4. Discussion

Both PCO and PCOR have been important tools for the functional study of the knee, particularly in the fields of articular kinematics, range of motion and joint stability, despite some conflicting evidence in the literature either supporting\cite{17-19} or refuting\cite{20,21} their usefulness. Nevertheless, given their ease of execution and reproducibility, they offer enticing opportunities in the evaluation of joint anatomy, and at least Hamilton et al. have used the PCOR for studying implant positioning\cite{22}.

Although this study focused on the PCOR and its relationship with femoral anatomy, preoperative and postoperative values of the PCO were included for comparison purposes. It is interesting to note the considerable variability between the results obtained by Bauer et al. (28.3 mm and 29.4 mm, for pre- and postoperative PCO respectively)\cite{23}, Kim (24.8 mm and 28.1 mm)\cite{20}, Bellemans et al. (25.8 mm and 23.6 mm)\cite{14} and those of the current study (27.6 mm and 30.4 mm). Together, they support the implementation of a dimensionless parameter, such as the PCOR, when comparing radiographic measurements.

One limitation to be taken into account is the uncertainty pertaining to the measurement of the PCOR in plain radiographs, which might underestimate condylar asymmetry. Voleti et al. determined by MRI techniques that the medial condyle is, on average, 12% bigger than the lateral condyle and that, individually, the PCO of each condyle is bigger than the composite PCO obtained by radiographic means\cite{24}. Furthermore, PCOR assessment in postoperative radiographs is also limited by the external rotation applied to the femoral component, which might distort anteroposterior length measured on radiographs. Nevertheless, the plain radiograph remains the golden standard for pre- and postoperative assessment of TKA given its practicality, with the MRI claiming a largely accessory role\cite{25}.

The preoperative PCOR value was similar in both study groups, suggesting sample homogeneity. It was also comparable to that of Johal et al.\cite{13} and Youm et al.\cite{20,21}, which reinforces the external validity of the study.

Regarding the comparison of prosthetic models, no study has been reported so far comparing anatomical changes of the femur with either anterior or posterior referencing prosthetics. Although one recent study mentioned no significant differences in surgical and clinical outcomes between anterior and posterior referencing minimally invasive TKA\cite{27}, anterior referencing systems will theoretically better fit the implant against the anterior surface of the femur, decreasing the risk of femoral notching or damage to the anterior cortex\cite{12}. On the other hand, posterior referencing systems are less likely to overresect condylar bone matter, which may lead to subsequent flexion instability\cite{13}.

Although it was predicted that posterior referencing prostheses would better mimic condylar anatomy and thus respect preoperative measures, a similar increase of the PCOR was noted in both models. This observation suggests that while both anterior and posterior referencing prostheses incur with comparable measurable changes in femoral anatomy, there is an unaccounted factor that is responsible for systemically increasing the PCOR. The likely explanation may lie in the inability of the plain radiograph to account for the thickness of the femoral cartilage, which is removed during surgery and morphologically replaced by the implant.

Employing MRI techniques, Li et al. devised a study that aimed to calculate the thickness of tibiofemoral cartilage, measuring it in three distinct places across the joint’s coronal plane and in three different levels of flexion, and found the average thickness of femoral cartilage to be 2.2 mm\cite{28}. Recalculating the preoperative PCOR obtained in the current study to include the theoretical thickness of femoral cartilage, an average of 0.49 ± 0.04 is obtained, which is comparable with the postoperative PCOR previously mentioned. Indeed, the studies conducted by Johal et al.\cite{13} and Kim\cite{20} and Malviya et al.\cite{18} have shown an increase in the PCOR following surgery that is very similar to that of the present study \( (0.03 ± 0.04) \).

Although this adjustment can explain the changes occurring in the PCOR, one element left to consider is the discontinuous character of prosthetic sizes, which hinders perfect implant fit.

Since current surgical practice demands that a prosthesis of smaller dimensions be chosen should the patient be found between sizes\cite{25}, it is expectable that during placement of the femoral component, posterior translation of the prosthesis will increase the PCOR while anterior translation will lead to its decrease\cite{13}. Even if the aim of this study was not to evaluate strict prosthetic fit, it is admissible that the decrease in the PCOR observed in 28 of the 157 cases (14 in the anterior referenced and 14 in the posterior referenced model) was due to anterior translation following the insertion of a smaller prosthesis.

Finally, it should be emphasised the size of the study’s sample, which paired with the similarity of findings between this and other publications strengthens the external validity of the study.

An unavoidable limitation to note is the retrospective character of the study, which prevented from ascertaining X-rays’ quality and forced the exclusion of a considerable amount of cases.

It should also be mentioned the inherent difficulty in comparing TKAs employing two different implant designs where engineer- ing variations exist, with unknown repercussion on radiographic morphology. Of note, surgeries were performed by different teams, where professional experience will necessarily vary.
The posterior condylar offset ratio (PCOR) and its relation with femoral anatomy remain areas of great interest for orthopaedic surgeons worldwide studying the joint’s function and performance. In our study, both anterior and posterior referencing prostheses lead to a similar increase of the PCOR.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References