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Relationship between the surgical epicondylar axis and the articular surface of the distal femur: an anatomic study

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Abstract Many authors presented the epicondylar axis as the fixed axis of rotation of the femoral condyles during flexion of the knee. Positioning of the femoral component of a total knee arthroplasty (TKA) based on the epicondyles has been proposed. This work is a critical analysis of this concept. Metallic bodies were inserted at the level of collateral ligament insertions on 16 dried femurs, allowing us to locate the surgical epicondylar axis. The dried femurs were studied using standard radiographs and CT-scan. CT cuts were made perpendicular to the epicondylar axis. The medial mechanical femoral angle and the epicondylar angle were measured on the radiographs. The posterior and distal epiphyseal rotations relative to the epicondylar axis (Posterior Condylar Angle, PCA, and Distal Condylar Angle, DCA, respectively) were measured on the CT-scans. PCA and DCA values were compared. The centre of the posterior femoral condyles was located on sagittal reconstructions using the tangent method and was confirmed with circular templates, and then compared to the location of the epicondyles. Circle-fitting of the entire femoral condylar contours centred on the epicondyles was also tried. The mechanical femoral axis was nearly perpendicular to the epicondylar axis but with important variations. The average PCA and DCA were 1.9° ± 1.8° and 3.1° ± 2.1°, respectively. No relationship could be established between the mechanical femoral angle and the PCA. The individual differences between the PCA and the DCA averaged 2.2°. A significant distance was found between the centre of the condylar contours and the epicondyles: 6.5 mm in average on the lateral side (range 2.3–11.3 mm) and 8.4 mm on the medial side (range 4.0–11.6 mm). Circle-fitting of the entire medial or lateral femoral condylar contours centred on the epicondyles was not possible. The centre of the posterior femoral condyles is significantly different from the epicondylar axis, thus refuting the conclusions of previous authors. Furthermore, considering the differences between the distal and posterior condylar angles shown here, as well as the difficulty of repeatably locating the epicondyles during surgery, using the epicondylar axis as the only landmark to position the femoral component during a first intention TKA is not recommended. The surgical epicondylar axis does not appear to be an adequate basis for the understanding of the shape of the distal femur.

Keywords Total knee arthroplasty · Surgical epicondylar axis · Femoral anatomy

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Introduction

The distal part of the femur has been studied extensively regarding its role on knee kinematics [3, 6, 10, 13, 17, 32, 37]. Based on these studies, hypotheses on how to position total knee arthroplasty (TKA) implants have been proposed. One of them is that the epicondylar axis is perpendicular to the mechanical axis of the femur [12, 32, 37], implying that the distal femoral cut should be made parallel to the epicondylar axis to adequately realign the limb and optimize TKA survival. Another frequently cited concept is that the epicondylar axis "approximates the optimal flexion axis of the knee" [10], meaning that flexion of the knee can be perceived as occurring around a fixed axis that nearly coincides with the epicondylar axis. This concept implies that the sagittal curvature of the femoral condyles is centred on the epicondylar axis [3, 10, 13, 17]. Since the epicondylar axis passes through the femoral insertion of the medial and lateral collateral ligaments, it has been proposed as a good reference to perform bone cuts and ligament-balancing to obtain similar flexion and extension gaps, hereby improving TKA long-term survivorship [24, 34, 35]. This would also justify the use of femoral implants with a circular sagittal profile as opposed to elliptical.

Two different epicondylar axes are described in the literature, leading to some confusion when comparing the results of various studies: the clinical epicondylar axis (CEA) joins the apex of both epicondyles. The surgical epicondylar axis (SEA) joins the femoral insertion points of the lateral and deep medial collateral ligaments, knowing that on the medial side the insertion of the deep collateral ligament is different from the apex of the epicondyle [5, 37]. In this study we focus on the surgical epicondylar axis because it is the one used during knee prosthetic surgery, because it was described as being more reproducible, and because it is said to correspond to the mechanical alignment of the tibia and to the optimal flexion-extension axis of the knee [3, 5, 16, 26].

This paper is a critical study of the surgical epicondylar axis in which we test the following hypotheses: first, the epicondylar axis is perpendicular to the mechanical axis of the femur; second, the difference between the epicondylar axis and the distal femoral condyles is the same as the difference between the epicondylar axis and the posterior femoral condyles, making it a good landmark during TKA; third, the epicondylar axis coincides with the contour of the femoral condyles.

Materials and methods

Epicondylar axis identification

Based on the findings of preliminary cadaveric dissections that confirmed the relationship between the collateral ligaments and the epicondyles of the distal femur (Fig. 1), the insertions of the lateral and deep medial collateral ligaments were identified on 16 dried human femurs and metallic needles were inserted in their respective centres. In imaging studies, it then became possible to precisely locate the surgical epicondylar axis as described by Berger et al. [5], by joining the point of entry of each needle in the bone.

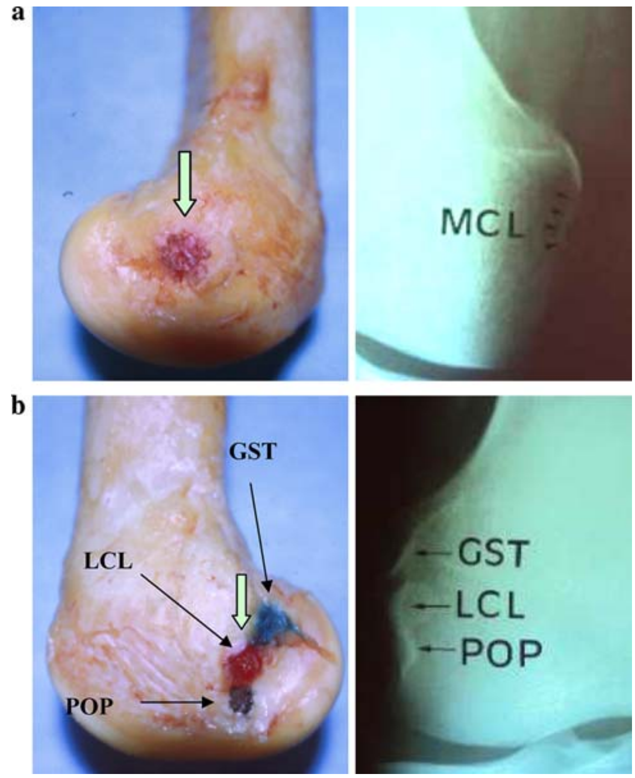

Fig. 1 Anatomical identification and radiologic correspondance of soft-tissue insertions on the medial (**a**) and lateral (**b**) epicondylar regions. **a** Insertion zone (*red area* and *arrowheads*) of the Medial Collateral Ligament (*MCL*) bordered by the crescent-shaped ridge. **b** Insertion zones of the popliteus muscle (*POP*), lateral collateral ligament (*LCL*), and part of the gastrocnemius muscle (*GST*)

Imaging studies

First, an antero-posterior (AP) radiograph of the whole femur was taken for the 16 dried bones. The femurs were positioned on the radiology table resting on the posterior condyles and the posterior part of the greater trochanter.

Then, CT-scans of the distal femur were performed on each specimen using a Hispeed CT/I CT-scan (GE Medical Systems, Inc, Milwaukee, WI, USA). Contiguous 2-mm-thick CT cuts were made parallel to the epicondylar axis by positioning the femurs so that the metallic needles were aligned on the CT's localizing lightbeam.

Angular measurements

Three lines were drawn on each AP radiograph. First, the surgical epicondylar axis (SEA) was drawn by connecting the entry points of the medial and lateral needles in the femur. The centre of the femoral head was located using concentric circular templates best-fitted to the contour of the head. Then, a second line was drawn between the midpoint of the SEA and the centre of the femoral head to

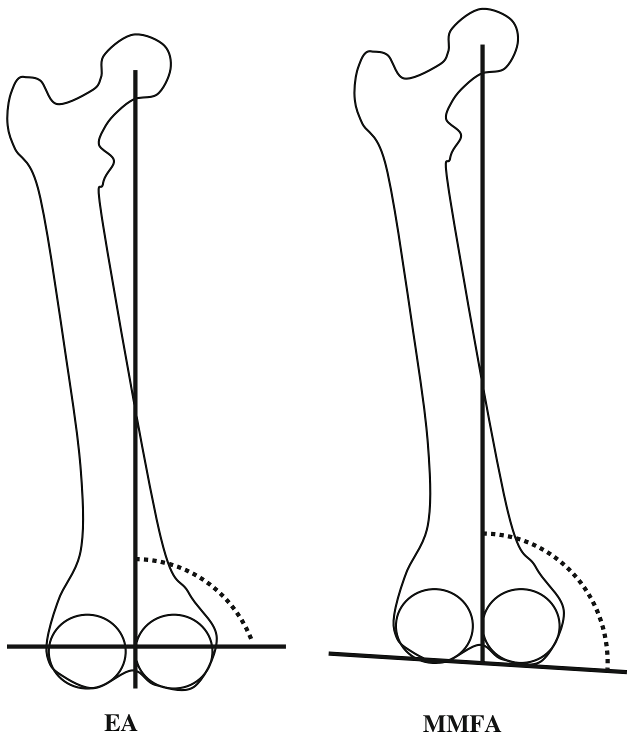

Fig. 2 Angular measurements on the antero-posterior radiographs. *EA* (epicondylar angle), medial angle between the femoral mechanical axis and the surgical epicondylar axis. *MMFA* (medial mechanical femoral angle), medial angle between the femoral mechanical axis and the distal articular surface

create the mechanical axis of the femur. Third, a line tangent to the distal femoral condyles was drawn.

Using these lines, two angular measurements were performed. First, measuring the angle between the medial side of the mechanical axis and the tangent to the distal condyles gave us the Medial Mechanical Femoral Angle (MMFA). The angle between the medial side of the mechanical axis and the SEA was measured and was called Epicondylar Angle (EA) (Fig. 2).

On the CT-scan, the transverse cut passing through the SEA, i.e. the cut where both needles are seen going through the femoral cortex, was used to measure the relative angulation of the SEA and the joint line in the transverse and plane. To do so, the SEA was drawn as well as a line tangent to the posterior femoral condyles. The angle between these two lines was the Posterior Condylar Angle (PCA) [5] (Fig. 3a). The same process was repeated on the coronal reconstruction that included the SEA in order to obtain the Distal Condylar Angle (DCA).

Condylar contour study

Using the transverse cut that included the SEA as a pilot, sagittal reconstructions of the lateral and medial condyles were done at the medio-lateral location where the distance between the epicondylar axis and the articular surface was the largest (usually in the middle of each condyle). The technique of Multi-Planar Reconstruction (MPR) resulted in the images of the reconstructions to be centred on the epicondylar axis. The SEA could be located by drawing diagonal lines through the image: the SEA was located at the crossing point of the two lines. The position of the SEA relative to the contour of both condyles could then be examined: the distance between the SEA and the distal articular surface was labelled d1, the distance between the SEA and the posterior articular surface was labelled d3, while the distance between the SEA and the articular surface between the distal and posterior surfaces was named d2 (Fig. 3b). We verified the hypothesis that the sagittal curvature of the femoral condyles is a circle centred on the

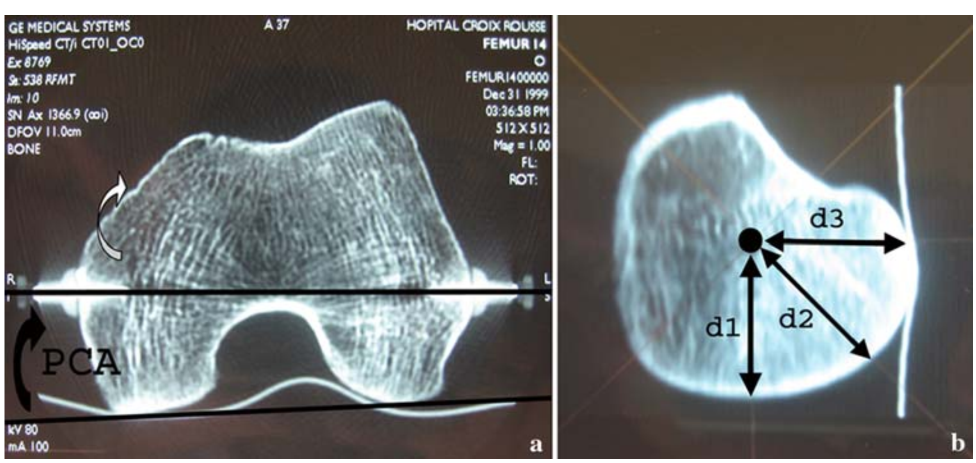

Fig. 3 Measurements performed on CT images and reconstructions. **a** Transverse CT cut at the level of the metallic bodies placed in the lateral epicondyle and the medial epicondylar sulcus. The posterior condylar angle (*PCA*) is the angle between the line connecting the entry point of the metallic bodies (the surgical epicondylar axis) and the line tangent to the articular surface of the posterior femoral condyles. **b** Distances between the epicondylar axis and the distal (d1), intermediate (d2) and posterior (d3) articular surfaces

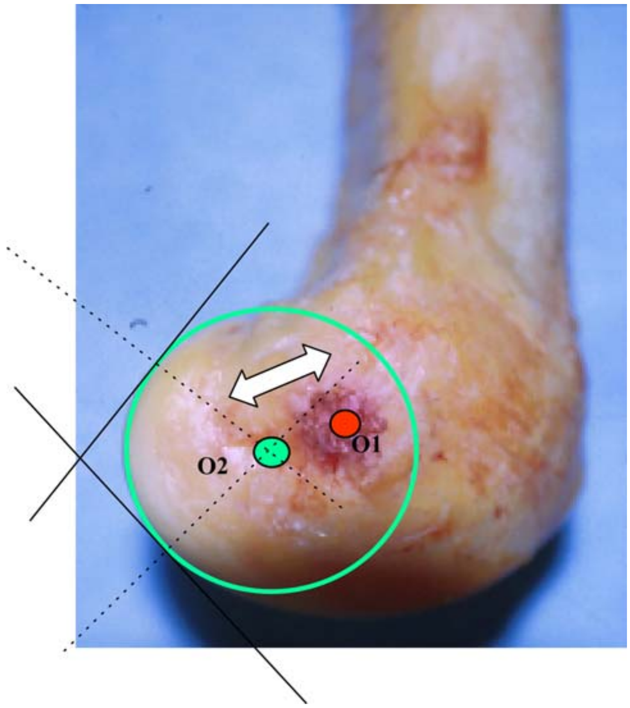

Fig. 4 Distance between the centre of the posterior femoral condyles (O2) and the surgical epicondylar axis (O1)

epicondyles. Using circular templates of various diameters centred on the epicondyles on the sagittal reconstructions, we tried to identify a circle-fitting the whole condylar contours. We also verified the hypothesis of Elias et al. [13] and others [10, 17], stating that the centre of curvature of the posterior femoral condyles coincides with the epicondylar axis. To do so, the medial and lateral sagittal reconstructions were copied on a paper sheet and two lines were drawn tangent to the contour of the posterior condyles. The contact points of the two lines with the condylar contour were chosen so they were separated by a quarter of a circle. Lines crossing the contact points perpendicularly to the tangents were drawn. The crossing of these two latter lines corresponded to the centre of the femoral contours. Circular templates of various diameters were then matched to the femoral contours to validate the position of the centre obtained with the tangent method. The circle was drawn and its radius *r* was measured. Finally the distance between the centre of the femoral contours (O2) and the epicondylar axis (point O1) was measured (O1O2) (Fig. 4).

Data analysis

The difference between the distal condylar angle (DCA) and the posterior condylar angle (PCA) was calculated for each specimen. The average difference for all the specimens was calculated using the real numbers as well as the absolute values to assess the concordance between the DCA and the PCA.

The values of O1O2, d1, d2, and d3 for the medial and lateral condyles were averaged for all the specimens and the standard deviations were calculated.

Statistical differences were assessed using a *P* value of 0.05.

Results

Epicondylar axis identification

The bony landmarks on the dried femurs were well defined. Given their constant relation with the insertion of the deep MCL and the LCL as stated in the literature and as confirmed by our preliminary anatomical study, we were confident that the location of the metallic bodies was within 1 mm of the insertion centre of the corresponding ligament.

Angular measurements

The measured values for the MMFA, EA, DCA, and PCA are presented in Table 1.

The average difference between the DCA and the PCA was 1.2° when using the real numbers (standard deviations of 2.5°) and 2.2° when using the absolute values (standard deviations of 1.5°). Comparison between the PCA and DCA using the Wilcoxon signed rank test revealed a non-significant difference ($P = 0.068$).

Sagittal plane measurements

The distances measured between the surgical epicondylar axis and the articular surfaces are presented in Table 2.

No statistically significant difference between posterior, intermediate, and distal distances were found on the lateral side using the Friedman repeated measures analysis of variance on ranks ($P = 0.223$). On the medial side, the Friedman repeated measures analysis of variance on ranks revealed a significant difference between d1, d2 and d3

Table 1 Angular measurements reported in degrees

	Average value (standard deviation)	Range
MMFA	92.4 (2.5)	88–96
EA	90.3 (2.0)	85–93
DCA	3.1 (2.1)	0–6.5
PCA	1.9 (1.8)	0–5

MMFA medial mechanical femoral angle, *EA* epicondylar angle, *DCA* distal condylar angle, *PCA* posterior condylar angle. See text and Figs. 2 and 3 for details

Table 2 Average distances measured in millimeters between the surgical epicondylar axis and the distal (d1), intermediate (d2) and posterior (d3) articular surfaces

	d1	d2	d3
Medial condyle	25.8 (2.3)	26.1 (2.5)	25.2 (2.1)
Lateral condyle	23.2 (1.9)	23.6 (2.2)	23.2 (2.8)

Standard deviations are between parentheses

($P = 0.023$) but two-by-two comparisons were not significant.

Attempts to identify a circle centred on the epicondyles and fitting the whole femoral contours could not be identified on any of the specimens, either on the medial or the lateral side.

Conversely, a good fit was found between the posterior condylar contours, both medial and lateral, and the circular templates. The centres of the condylar contours determined by using the tangent method were always consistent with those obtained with the circular template method. The average radius of condylar curvature was 17.8 mm on the medial side (standard deviation of 1.4 mm) and 17.8 mm on the lateral side (standard deviation of 1.9 mm). No difference was found between these two values using the Wilcoxon signed rank test ($P = 0.597$). The distance between the condylar contours and the surgical epicondylar axis O1O2 was 8.4 mm on the medial side (standard deviation of 2.1 mm) and 6.5 mm on the lateral side (standard deviation of 2.8 mm), both significantly different from 0 using the paired T test.

Discussion

Methodological issues

Studying the femoral epicondylar axis presents many difficulties, most of them related to the identification of the two points that define the axis. Radiographically, the medial landmark for both SEA and CEA are not always reliably identifiable on CT images [1, 36]. Also, visualization of both the lateral and medial epicondylar landmarks on the same CT cut can be difficult if the CT-scan was not properly oriented, making epicondylar axis measurements impossible. Perhaps more commonly, the crescent-shape and broad insertion area of the medial epicondyle make it visible on multiple CT cuts. The same is true for the medial sulcus. This leads the observer to identify a cut where a part of the medial epicondyle (or sulcus) is visible at the same time than the smaller lateral epicondyle: this phenomenon obviously makes CT identification of the epicondylar axis variable. For these reasons, we chose to place metallic bodies at the location of the epicondylar landmarks; this strategy made the epicondylar axis easily identifiable on the X-rays and the CT images. Most importantly, it made it possible to view both medial and lateral landmarks on the same CT cut; this allowed precise measurements about the epicondylar axis and the performance of sagittal reconstructions perpendicular to the epicondylar axis. Because large errors have been reported for the identification of the epicondyles on cadaveric femurs and during surgery [22, 33], we put great effort in analysing the relationship between the collateral ligaments insertions and the bony landmarks of the epicondylar regions before proceeding to the identification of the specific points of this study. Our preliminary anatomical study confirmed previously reported facts [16] and makes us confident that we identified the SEA points on the dried femurs with a precision of 1 mm as stated before. Because of the metallic bodies, this precision level was reported on the imaging studies. Therefore, we believe our method was optimal to assess the relations between the epicondylar axis and the distal aspect of the femur.

Frontal plane measurements

Our results for the Epicondylar Angle (90.3°, standard deviation of 2.0°) are consistent with those of other authors who report an angle of 90° [12, 32, 37]. Although the DCA could be measured on the radiographs, we chose not to use this method because angle differences have been reported after changing the radiographic incidence [17, 19]. Also, it was logical to use the same precise measurement method for the DCA as for the PCA. Our results for the Distal Condylar Angle (DCA, i.e. the angle between the epicondylar axis and the distal condyles) were 3.1° in average (standard deviation of 2.1°), close to those obtained by Yoshioka et al. [37] (3.8°, standard deviation 2.1°) and Hollister et al. [17] (4.3° and 3.3°, depending on the radiographic view), although these authors used the clinical epicondylar axis. We are not aware of any report of the angulation between the SEA and the distal femoral condyles in the frontal plane, which is odd considering the number of authors referring to the SEA as a surgical landmark for TKAs [3, 5, 21, 22, 26, 27, 30].

Transverse plane measurements

In the transverse plane, we obtained a PCA of 1.9° with a standard deviation of 1.8°. More studies were performed on the clinical epicondylar axis (CEA) than on the SEA [2, 25, 28, 29, 37], but as stated earlier, this axis is prone to variability because of the anatomy of the medial epicondyle and therefore we chose not to study this axis nor to relate our results to its reported values. Previous reports of PCA are in agreement with our values, namely those of Berger et al., who reported a gender-adjusted average PCA of 2.1° [5]. Boisgard et al. [9] studied the PCA on 103 knees using CT-scan images and obtained an average value of 2.65° with values ranging from 0° to 7° (standard deviation of 1.89°). Asano et al. [3] report a PCA of 3.1° with a standard deviation of 1.7°. However, others have measured larger PCA values, like Griffin et al., who reported an average PCA of 3.7° with a standard deviation of 2.2° [15]. Similarly, Akagi et al. [1] measured the PCA on 82 knees using CT cuts and obtained an average value of 4.2° (standard deviation of 2.1°, range from 1° to 12°). As discussed in the next paragraph, many factors can influence the PCA. The most probable one to explain the differences with previously reported PCA values is the method of measurement used because of the significant variations that can be induced after an incorrect identification of the epicondyles, either clinically or radiographically. Demographic factors between the studied populations can also have an influence on the results.

Factors affecting the PCA

Griffin et al. [15], after measuring the PCA during TKA surgery on 107 osteoarthitic knees, noticed that the PCA was significantly larger in valgus knees (defined as knees with an anatomical femoral angle larger than 7°) when compared to neutrally-aligned and varus knees. Because we did not measure the anatomical femoral angle, an exact comparison is not possible, but no correlation can be extracted from our results between the medial mechanical femoral angle and the PCA. This may be due to the small number of femurs studied here compared to the study of Griffin et al. [15]. On the other hand, one may question the validity of the findings of the latter authors when we consider the poor correlation that exists between the anatomical axis of the femur and its mechanical axis, knowing that knee alignment should be measured using the mechanical axis [11, 19]. PCA differences based on gender were proposed by Berger et al., who reported PCA values of 3.5° and 0.3° for male and female individuals, respectively, with a standard deviation of 1.2° for both groups [5]. Although we did not have information on the gender of the specimens studied here, we did not notice the bimodal distribution of the PCA evoked by Berger et al. that would tend to confirm this hypothesis of gender-based differences. Other authors did not find differences of PCA related to gender [15, 16]. The severity of articular degenerative changes has also been implicated in the variability of the PCA [15], as well as age [16], but we did not analyse those aspects. Again, issues related to PCA measurement must be evoked as potentially influencing this angle and, consequently, its variability. However, the fact that we obtained a high variability for the PCA, even with meticulously identified landmarks, tends to prove that the PCA is intrinsically variable.

Sagittal profile of the distal femur

Our results confirmed that the posterior condyles are circular as stated by Elias et al. [13], Eckhoff et al. [12] and others [6, 14, 23]. Their radius of curvature is the same for the medial and lateral sides. This was noted by other authors [1, 6, 14] but with slightly larger values (e.g. 22 mm for Freeman et al. [14], 21 and 22.8 mm on the medial condyle for Elias et al. [13] and Hollister et al. [17], respectively, compared to 18 mm here) which can be explained by the measurement method or by population differences. The centre of curvature of the posterior condyles clearly does not coincide with the epicondylar axis, contrary to previous statements [10, 13, 17]. Because of the precautions we took in the identification process of the epicondylar points as described before, we are confident that the average distance between the SEA and the medial and lateral centres of curvature (8.4 and 6.4 mm, respectively) cannot be explained by measurement errors. Furthermore, careful study of the articles suggesting a coincidence between the epicondylar axis and the centre of curvature of the posterior femoral condyles reveals methodological deficiencies in that conclusion. For instance, Churchill et al. [10] never compare the epicondylar axis and the centre of the posterior femoral condyles directly but only through their closeness to the "optimal flexion axis" determined kinematically, the latter being 2.8 and 3.1 mm far from the posterior femoral contours medially and laterally, respectively. Furthermore, the prominence of the medial epicondyle is used in this study, this structure being more prone to variability as stated before [5]. Similarly, Hollister et al. state that the posterior condyles appear circular when viewed on MRI sections perpendicular to the Flexion–Extension (FE) axis and that this FE axis runs through the collateral ligaments origin [17]. Unfortunately, no details are provided on how this relationship was determined, neither on how it was confirmed by dissection. Finally, Elias et al. are vague in their description of the localisation of the attachment of the collateral ligaments (hence of the epicondylar axis), stating that they "were found to be in the area of the centre of the circle of the medial and lateral posterior femoral circles" [13]. It remains possible that the conclusion of the SEA being coincident with the posterior condylar contour was proposed as a theoretical model in an effort to simplify our perception of knee motion, even if the level of evidence was insufficient. Accordingly, Asano et al. [3] recently failed to prove that the fixed flexion axis of the knee, the SEA and the posterior femoral contour are coincident.

Distances between the SEA and the posterior, intermediate and distal articular surfaces reveal a slightly larger medial condyle relative to the lateral condyle, in agreement with previous authors [12, 13, 17, 18]. However, comparison of the size of the condyles (25.7 and 23.3 mm in average for the medial and lateral condyles, respectively) with the literature is difficult because of differences between the measurement methods and landmarks used by the various studies and the present one. Nonetheless, the medial-to-lateral size ratio of 1.102 is comparable to the ratio of 1.143 found by Churchill et al. [10] and the ratio of 1.139 found by Asano et al. [3]. The apparent homogeneity of the values for d1, d2 and d3 on the medial and lateral condyles may be interpreted as the SEA being the centre of curvature of the femoral condyles. However, significant differences on the medial side were found, reflecting the larger DCA in comparison to the PCA. Furthermore, a detailed analysis of their shape proves the opposite with the posterior condyles fitting a circle perfectly while circle-fitting of the contour of the whole condyles was not possible when using the epicondyles as the centre. Our results are rather consistent with the concept of the lateral condyle having a single curvature for its posterior and distal aspects and the medial condyle having different radii on the posterior and distal parts as stated previously [6, 14]. This is in accordance with the medial condyle being bigger than the lateral when measured as a whole because condylar size clearly depends on which part of it is being considered.

Implications for TKA

Using the SEA to position the femoral component of a TKA is based on the concept that the SEA is perpendicular to the femoral mechanical axis in the frontal plane, as stated earlier [12, 32, 37]. As the normal distal femoral articular surface is angulated of an average of 3° of valgus in relation to the mechanical femoral angle, a distal femoral cut made perpendicular to the mechanical femoral angle and consequently parallel to the SEA will most of the time resect more bone on the medial condyle than the lateral condyle. In that situation, ligament-balancing principles dictate resecting more bone on the posterior medial condyle than on the posterior lateral condyle in order to obtain a similar balance in flexion and in extension. As knee balance is largely related to the collateral ligaments and considering a distal cut performed parallel to their insertion sites (the epicondylar axis), referring to the epicondylar axis for the posterior femoral cut seems logical. Indeed, as reported PCA values are around 3° of external rotation, a posterior cut made parallel to the epicondylar axis will resect more bone on the medial side than on the lateral side, leading to a balanced knee in extension and in flexion. This implies that the DCA and PCA are equivalent. Surprisingly, although this strategy was embraced by many surgeons [3, 5, 26, 27, 30], we are not aware of any study specifically comparing the PCA to the DCA. Our results reveal an average difference of 1.2° between these two values for all the specimens, although not statistically significant (Post hoc power analysis reveals that more than 50 specimens would have been necessary to statistically demonstrate that difference). Individual differences of an average of 2.2° were found when looking at the absolute values, with differences up to 5° in some of our specimens. The larger DCA as compared to the PCA could be explained by the concept that the posterior and distal lateral femoral condyles share the same centre of curvature, as opposed to the medial condyle for which the radius of distal condyle is larger than the posterior condyle's radius [6, 14]. Based on that theory, the distal medial condyle would be further from the medial epicondyle than the posterior condyle while the distances remain the same on the lateral side, therefore the DCA would be larger than the PCA. Given the precision with which the SEA was located and the measurements performed, this tends to discredit the concept that the SEA is the best landmark for optimally positioning the femoral component in TKA because malpositioning remains possible: indeed, based on our findings, performing the posterior and distal femoral bone cuts based on the SEA would result in more bone being resected on the distal aspect of the medial femoral condyle than on its posterior aspects, leading to potential ligament imbalance if not addressed.

Our results suggest that the concept of the femoral contours centred on the epicondylar axis is an oversimplification of the anatomy and kinematics of the distal femur that does not take into account the complex combination of motions that occur at the knee during flexion. Indeed, in a knee without ligament laxity, such a relationship between the collateral ligaments and the curvature of the femoral condyles would make the knee similar to a hinge joint, tending to restrict motions other than pure flexion–extension for the length of the ligaments to remain constant. This is in opposition to studies demonstrating significant motion in the transverse plane during knee flexion [4, 8, 20, 31]. A discrepancy between the SEA and the contour of the femoral condyles, as shown here and elsewhere [12], allows these complementary motions to occur by varying combinations of spinning, gliding and translation on each femoral condyle as demonstrated by Blaha et al. [7]. Some studies suggesting an interpretation of knee flexion based on the SEA also state that this model is not valid for flexion angles over 90° and in hyperextension [3, 10], reinforcing our impression that it is an oversimplification. The kinematic analysis of the knee based on the various parts of the femoral condyles proposed by Freeman et al. [14] appears more realistic as it applies to the whole range of knee motion. Therefore, the shape of the distal femur being more complex than two circular sagittal cross-sections centred on the SEA, positioning the femoral component relative to the SEA can only represent a compromise between the normal shape and function of the femur and what can be achieved with current TKA techniques and implants. The surgeon has to be aware that reliance on the SEA only can lead to ligament-balancing problems because of identification errors of the SEA as well as individual discrepancies between the DCA and PCA. Combining the SEA with other positioning techniques is recommended to optimize primary TKA results.

Conclusion

Our critical study of the surgical epicondylar axis of the distal femur reveals that this axis is not equidistant from the posterior and distal surfaces of the femoral condyles. We also showed that the contour of the femoral condyles should not be interpreted as being centred on the surgical epicondylar axis. The surgical epicondylar axis therefore does not appear to be an adequate basis for the understanding of the shape of the distal femur. These findings may have implications on total knee arthroplasty positioning.

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