Can Interepicondylar Distance Predict Joint Line Position in Primary and Revision Knee Arthroplasty?

T. S. Rajagopal, FRCS, and D. Nathwani, FRCS

Abstract

Restoration of the position of the prosthetic joint line (JL) to the same level as the original JL is a challenging problem in primary and revision knee arthroplasty, and there is no reliable method for achieving this objective.

We hypothesized that there is a constant ratio between the interepicondylar distance (IED) and the perpendicular distance from this interepicondylar line to the JL and analyzed 100 computed tomography scans of the knee to study this relationship. The IED and the perpendicular distance from this interepicondylar line to the JL was measured using both the clinical epicondylar axis (CEA) and the surgical epicondylar axis (SEA).

Results showed that the ratio between the IED and the perpendicular distance from the interepicondylar line to the JL was 3.0 using the CEA and 3.3 using the SEA.

The ratio was found to be constant, irrespective of the patient's sex or height.

We suggest using the CEA because of the ease in localizing epicondyle peaks and conclude that the position of the JL from the interepicondylar line is one-third the IED using the CEA. This will prove to be a valuable aid in restoring the JL position during knee arthroplasty.

Restoration of the position of the prosthetic joint line (JL) to the same level as the original JL is one of the important principles in primary and revision total knee arthroplasty. This has been described as a crucial factor in improving the range of movement and maintaining the normal kinematics of the knee.[1] During revision, accurate restoration of the JL is technically difficult because of changes in the geometry of the distal femur from the primary surgery, bone loss resulting from osteolysis, or removal of the components and recutting of the bone. There is no standard method by which one can estimate JL position.

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Am J Orthop. 2011;40(3):175-178.

Some anatomical landmarks—the tibial tuberosity, the inferior pole of the patella, the medial femoral epicondyle, and the fibular head—have been used to predict the position of the original JL. Among these, the inferior pole of the patella was found to be unreliable because of variation in patella position. Investigators have also found that the JL lies 23 to 35 mm distal to the medial femoral epicondyle and 10 to 32 mm proximal to the tibial tuberosity.[1-3] In addition, the distance from the fibular head to the natural JL varies considerably, from 4 to 22 mm.[1,3,4] Using a fixed distance from a bony landmark in all patients is not a very accurate way of predicting JL position, as this distance is likely to change with the size and morphology of the patient's knee. It has been suggested that the joint level can be determined using a ratio of the interepicondylar distance (IED) and the distance to the JL.[4,5] This would help in overcoming the differences that arise from knee size. However, Berger and colleagues[6] described 2 types of epicondylar axes: surgical and clinical. A ratio of 3.0 to 3.4 has been described in relation to the surgical epicondylar axis (SEA).[5] The literature does not include any measurements regarding the clinical epicondylar axis (CEA). Some surgeons prefer using the CEA, because of the ease in locating epicondyle peaks, rather than the SEA, which uses the sulcus of the medial epicondyle (Figure 1).

In the study reported here, we hypothesized that there is a constant ratio between the IED and the perpendicular distance from this interepicondylar line to the JL, analyzed the consistency of this relationship, and tried to establish a ratio that may be useful in predicting JL position based on analysis of computed tomography (CT) scans. We studied this relationship

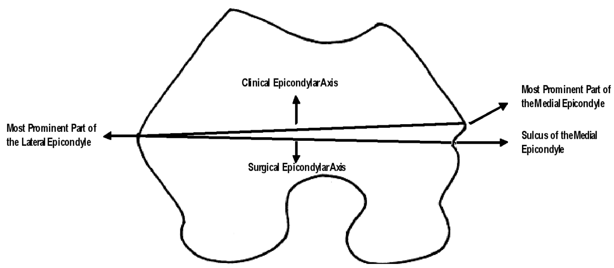

Figure 1. Landmarks around distal femur, and 2 types of epicondylar axes.

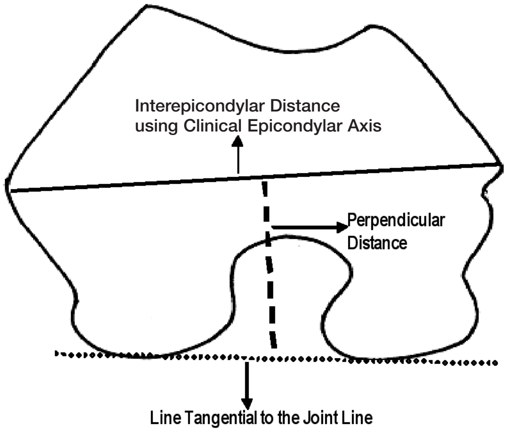

Figure 2. Measurement of interepicondylar distance and perpendicular distance using clinical epicondylar axis.

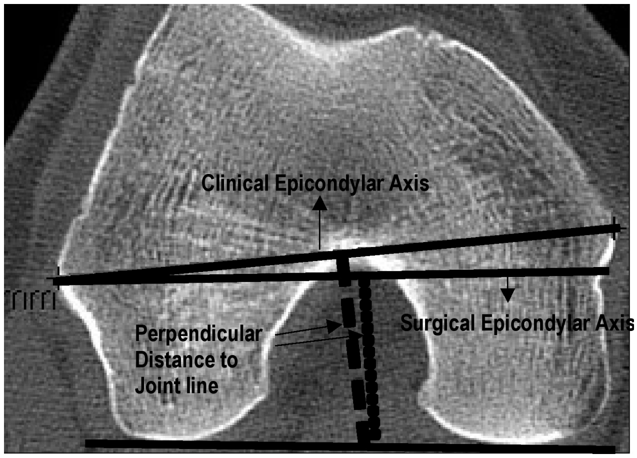

Figure 3. Lines and measurements on computed tomography scan.

using both the SEA and the CEA to see if there is an advantage in using one over the other.

Materials and Methods

We studied the 3-dimensional helical CT scans of consecutive patients presenting to Charing Cross Hospital, London, England between January 2005 and June 2006 who underwent knee CT. The most common indication for a knee CT scan was a proximal tibia fracture (67%), usually a fracture of the tibial plateau. We excluded patients who had fractures of the distal femur or who had previously undergone distal femur surgery. We also excluded those patients who had preexisting clinical or radiologic evidence of arthritis in their knees.

A standard CT scan protocol was followed to eliminate variation that could affect the measurements. Patients were placed supine with the knee in full extension in the CT scanner and the extremity adjusted to allow scans to be perpendicular to the mechanical axis of the limb. Axial CT slices 3 mm in thickness were obtained over the distal femur from the level of the proximal pole of the patella.

CT scans were carefully scrutinized by 2 observers to identify the one on which the femoral epicondyles were most prominent. The lateral epicondylar prominence, the sulcus of the medial epicondyle, and the most prominent part of the medial epicondyle were identified. The CEA and the SEA were then drawn as described by Berger and colleagues.[6] The CEA was the line connecting the lateral epicondylar prominence and the most prominent part of the medial epicondyle. The SEA was drawn by connecting the lateral epicondylar prominence and the sulcus of the medial epicondyle (Figure 1). The JL was drawn by a line tangential to the femoral posterior condylar surfaces. The IED was measured using both the CEA and the SEA for each knee. The midpoints of both axes were marked, and the perpendicular distance from this midpoint to the JL was then measured and recorded (Figures 2, 3). All measurements were done with PACSWEB® digital measurement tools.

All variables measured were entered into a computer data sheet. The data were analyzed with Statistical Package for Health Sciences, Version 15 (SPSS, Chicago, Illinois) to see if there was a proportional relationship between the

Table I. Summary of Study Results (N = 100)

	Clinical Epicondylar Axis			Surgical Epicondylar Axis		
Distance, mm	IED Using CEA, mm	CEA to JL[a], mm	CEA–JL Ratio (x:1)[b]	IED Using SEA, mm	SEA to JL[c], mm	SEA–JL Ratio (x:1)[d]
Minimum	70.6	22.5	2.6	69.0	19.7	2.8
Maximum	96.8	32.4	3.5	96.0	29.0	3.9
Range	26.2	9.9	0.9	27.0	9.3	1.1
Mean	82.6	27.7	3.0	80.9	24.6	3.3
Median	83.1	27.6	3.0	81.8	24.2	3.3
SD	6.1	2.1	0.21	5.8	2.1	0.25

Abbreviations: IED, interepicondylar distance; CEA, clinical epicondylar axis; JL, joint line; SEA, surgical epicondylar axis.

[a]Perpendicular distance from clinical epicondylar axis to joint line.
[b]Ratio of interepicondylar distance to joint line using clinical epicondylar axis.
[c]Perpendicular distance from surgical epicondylar axis to joint line.
[d]Ratio of interepicondylar distance to joint line using surgical epicondylar axis.

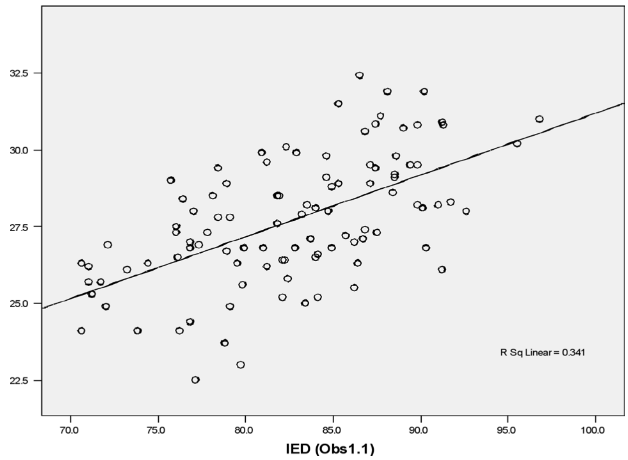

Figure 4. Regression line with scatter plot of observed points showing good linear fit. IED, interepicondylar distance.

IED and the vertical distance to the JL. Simple linear regression analysis was used to examine the consistency of this relationship, and the regression line was drawn.

Results

A total of 116 patients underwent knee CT during the study period; 16 patients were excluded. One hundred patients—67 men and 33 women were included in the study. Mean age was 44.6 years (range, 17-82 years). The sample consisted of mixed multiethnic patients representative of an urban population. CT scans were obtained of the left knee in 55 patients and of the right knee in 45 patients. Both observers were able to determine the prominences of the medial and lateral epicondyles in all cases. The sulcus of the medial epicondyle could not be identified in 14 knees (14%), and the SEA could not be constructed. Table I summarizes the data from the study.

Mean IED using the most prominent part of the medial and lateral epicondyles, the CEA, was 82.6 mm (range, 70.6-96.8 mm). Mean perpendicular distance from this line to the JL was 27.7 mm (range, 22.5-32.4 mm). The ratio of these distances ranged from 2.6 to 3.5, and the median and mean (SD) ratios were 3 (0.21).

Mean IED using the lateral epicondylar prominence and the sulcus of the medial epicondyle, the SEA, was 80.9 mm (range, 69-96 mm). Mean perpendicular distance from this line to the JL was 24.6 mm (range, 19.7-29 mm). The ratio of these distances ranged from 2.8 to 3.9, and the median and mean (SD) ratios were 3.3 (0.25). However, we observed the difficulty in identifying the sulcus of the medial epicondyle in a substantial number of patients and felt that use of SEA may be unreliable for this purpose.

Student *t* test showed no significant difference (P = .29) in mean clinical epicondylar ratio between men (3.0; SD, 0.2) and women (2.9; SD, 0.2). Similarly, there was no statistically significant difference (P = .1) between the 4 stratified height groups (Table II).

Linear regression analysis was performed with the IED using CEA as the independent variable and the distance to the JL as the dependent variable. After confirming that the assumptions underlying the regression model were satisfied, linear regression analysis showed a good linear relationship between the 2 variables. The regression equation was:

Distance to JL = (0.2 × IED) + 11 mm

Correlation coefficient R was 0.58, and R^2 was 0.34, which means that 34% of the variability in the dependent variable was explained by the independent variable. The regression equation was significant ($F_{1,98}$ = 50.616, $P<.001$). The slope of the equation or the regression coefficient was 0.201 (95% confidence interval, 0.145-0.257), also statistically significant (t = 7.114, $P<.001$). The regression line with the observed points plotted was drawn, and it showed a good linear fit (Figure 4).

Then we attempted to simplify the method of calculating the position of the JL from the IED. Mean ratio of the IED and the distance to JL using the CEA was 3.0. Simply dividing the IED by 3 would give an estimate of JL position. We applied this to all observed values of IED using CEA and calculated the predicted distance to the JL. The difference between the observed distance to the JL and the predicted distance to the JL using the ratio of 3 was found to be within 1 mm in 70% of the cases and within 4 mm in 99% of the cases. Therefore, we suggest dividing the IED by 3 to predict JL position rather than using the slightly more complex regression equation.

Table II. Values of Ratio Using Clinical Epicondylar Axis in Relation to Patient Sex and Height (N = 100)

	No. of Patients	Mean	Median	SD	Minimum	Maximum	Range
Sex							
Male	67	3.0	3.0	0.20	2.6	3.5	0.9
Female	33	2.9	2.9	0.19	2.7	3.4	0.8
Height, m							
1.51–1.60	8	2.9	2.9	0.20	2.7	3.3	0.6
1.61–1.70	25	3.0	2.9	0.25	2.6	3.4	0.8
1.71–1.80	42	3.0	3.0	0.18	2.6	3.3	0.7
1.81–1.91	25	3.0	3.0	0.18	2.7	3.5	0.8

Discussion

JL position is a key factor in the stability and optimal functioning of the knee in both primary and revision arthroplasty. A malpositioned JL can result in ligament imbalance, instability and alteration in the normal kinematics of the knee. JL malposition has also been shown to lead to increased incidence of anterior knee pain and decreased flexion. Other problems include patella baja and impingement of the posterior soft tissues by the femoral component.[7-9] It also has been shown that functional outcome is adversely affected by excessive alteration of the JL.[10,11]

Most investigators have found that, of the features used to predict JL position, the inferior pole of the patella and the Insall-Salvati ratio are unreliable.[1,3,4,6] This could be because of the variability in patella position, scarring, or contracture of the patellar tendon. The predicted position of the JL from the fibular head has varied from 4 mm to 22 mm in various studies.[1,3,4] Similarly, there is large variation, from 23 mm to 35 mm, in the suggested distance of the position of the JL from the medial epicondyle.[1-3] The distance from the tibial tuberosity to the JL was found to be least consistent, with the reported range being 10 mm to 32 mm.[4] In any case, using a standard value from a fixed bony point is unlikely to give an accurate estimation of the JL in all patients. Therefore, we have attempted to establish a ratio that may be applicable irrespective of the size and morphology of an individual knee.

We have used the IED, as the femoral epicondyles are usually found preserved at time of revision. They are easily identified using the standard surgical approaches. We prefer using the CEA rather than the SEA because of the ease of localizing the epicondyle peaks during surgery. The reported difficulty in locating the sulcus of the medial epicondyle has varied from 25% to 60%.[12-14] In the present study, it was difficult to localize the sulcus of the medial epicondyle in 14% of the cases. Using the CEA, we have shown that the IED is 3 times the perpendicular distance from this line to the JL. It is also easier to remember and apply the ratio of 3. As the epicondyles are usually found preserved during revision surgery, one can measure the IED and divide it by 3, which will give an accurate estimate of the position of the JL from the middle of the CEA.

Computer-assisted navigation has helped in improving the optimal positioning of the prosthesis in knee arthroplasty. However, the latest generation of navigation software does not provide a reliable method for establishing JL position. This could compromise the results of both primary and revision procedures. The IED is easily calculated when computer navigation is used in primary and revision surgery, and modern software for computer-assisted knee arthroplasty could be modified accordingly.

Martin and Whiteside[9] found that a 5-mm change in JL position resulted in a significant change in stability. In their cadaveric study, a 5-mm elevation in JL position resulted in increased laxity during midflexion, whereas significant tightening occurred when JL was displaced downward by 5 mm. Partington and colleagues[10] showed that JL elevation of more than 8 mm resulted in worse clinical and functional outcomes. Similar results were reported by Figgie and colleagues.[8] Recently, Porteous and colleagues[11] reported that alteration of the JL by 5 mm affected the outcome after revision knee arthroplasty. Our method of restoration of JL position ensures that it is within 2 mm in 92% of cases and within 4 mm in 99%.

Conclusion

We conclude that the position of the JL from the interepicondylar line is one-third of the IED using the CEA. This will prove to be a valuable aid in estimating the position of the natural JL and restoring the prosthetic JL to the same level, especially when there is significant bone loss at the tibiofemoral articulation.

Authors' Disclosure Statement

The authors report no actual or potential conflict of interest in relation to this article.

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