Original Article

Can Patellar Facet Height Be Used to Estimate the Level of the Knee Joint Line?

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Objective: To determine the Pearson correlation coefficient (r) and ratio of the adductor tubercle to joint line distance (ADJ) and the patellar facet height (PFH) by sex.

Materials and Methods: From 100 knee radiographs, the authors measured the ADJ and PFH and determined the ADJ-PFH distances and ADJ-PFH ratios for males and females. In addition, the authors measured these parameters and recorded the clinical outcomes [knee society scores (KSS) and range of movement (ROM)] in 22 patients (22 knees) that underwent revision total knee arthroplasty (TKA) with metal augmentation distal femur; Gp I (n=17)/without metal augmentation distal femur; Gp II (n=5).

Results: The PFH correlated positively with ADJ in males (r=0.647, p<0.001) and females (r=0.648, p<0.001) but the mean PFH and ADJ distances were significantly higher in males: (i) 31.79±2.75 versus 29.39±2.16 mm (p<0.001), and (ii) 41.35±3.78 versus 40.10±2.96 (p=0.028), respectively. The ADJ: PFH ratio was significant (p=0.042) lower in males 1.31±0.10 versus females 1.36±0.12. The KSS in Gp I patients was significantly higher than Gp II (p≤0.001). However, the ROM in Gp I versus Gp II patients were not significantly different. The mean ADJ: PFH ratio was significantly (p=0.003) in Gp I: 1.31 versus 1.07.

Conclusion: The ADJ correlated well with the PFH. The ratio of ADJ-PFH was 1.31 and 1.36 for male and female, respectively. The ADJ-PFH ratios and KSS were significantly lower in TKA patients without metallic augmentation. Revision TKAs should include metallic augmentation of the distal femur.

Keywords: Patellar height, Joint line level, Medial epicondyle, Lateral epicondyle, Transepicondylar axis width, Adductor tubercle

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Restoration of the knee joint line (KJL) following revision total knee arthroplasty (TKA) is important for clinical outcomes[1-10]. Elevation of KJL following revision TKA can decrease the range of motion (ROM)[4,7,8], increased the incidence of maltracking of the patellofemoral joint and pain[3,4], and mid-flexion instability[4,5]. The KJL is estimated from the medial and lateral epicondyle, fibular head, adductor tubercle, femoral width (FW), and the transepicondylar width (TEW)[11,12]. The medial epicondyle to joint line distance (MEJ) and TEW shows a very good correlation but medial epicondyle is difficult to identify intraoperatively[13-15]. The adductor tubercle is easier to identify intraoperatively, and the ratio between ADJ and FW is an accurate method for determining the KJL[8]. However, in patients with severe bone loss, which extends as far as the medial and lateral epicondyles, measuring-accurately the TEW or FW is challenging and primary TKAs have generally been associated with KJL elevation[1,2]. Therefore, the fibular head is used for determining KJL in patients with severe bone loss, even though the fibular head to joint line distance (FHJ) shows a poor correlation with the femoral joint line[10] and this may affect the clinical outcome.

The objectives of the present study were to determine the relationship between and ratio of adductor tubercle to joint line and the patellar facet height (ADJ-PFH) in males and females.

Materials and Methods

This was a retrospective knee radiographic study in patients with osteoarthritis (OA), who attended the

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Orthopaedic department of Thammasat University hospital (TUH). It was approved by the Human Research Ethical Committee (Reg.no: MTU-EC-OT-1-089/57). The inclusion criteria were patients with primary Ahlback 1 and 2 (i.e., no bone loss) medial OA of the knees[1] and aged older than 40 years who may have undergone a TKA. The exclusion criteria were post-traumatic, rheumatoid, gouty arthritis, and infectious arthritis. Annteroposterior (AP) and lateral knee radiographs were evaluated using the PACC system (McKesson Corporate Headquarters, San Francisco, CA, USA).

An additional cohort of patients that undergone a TKA was also sought from the case notes (2000-14) and was divided into two groups (Gps), Gp I was those with metallic augmentation and Gp II was those without metallic augmentation.

Outcome measures

The PFH was measured in lateral plain radiograph (Figure 1) and was the distance between the highest and lowest point of the vertical ridge of the patella facet. The MEJ, LEJ, FW, ADJ, and FHJ were also measured using Luyckx's technique (Figure 2a, b)[8]. The MEJ was defined as the perpendicular distance between the medial epicondyle and the virtual cutting block, the LEJ was the perpendicular distance between the lateral epicondyle and the femoral joint line, FW was the most external point of the medial and lateral epicondyles, ADJ was the perpendicular distance between the adductor tubercle and virtual cutting block, and FHJ was the distance from the highest point of the fibular head to the joint line tangent of the tibial plateau (Figure 2b)[10]. Two orthopaedic surgeons (Reutiwarangkoon C and Tanakanyarat N) measured the PFH, MEJ, LEJ, FW, ADJ, and FHJ twice within 2 weeks between the first and second measurement.

The demographic data of patients with and without augmentation of distal femoral component following revision TKA were including age, sex site, body mass index (BMI), knee society score (KSS), and range of movement (ROM). The ratio of ADJ-PFH, post-operative KSS, and post-operative ROM were also recorded and compared between the two groups.

Statistical analysis

The authors used Pearson's correlation coefficient to determine the correlation between the PFH and ADJ, FW, MEJ, LEJ, and FHJ for all patients. The unpaired Student's t-test was used to compare the difference in measured distances, between males and females, of KSS, ROM, BMI, and the ratio of ADJ-PFH. The inter- and intra-observer reliability were tested with the intraclass correlation coefficient (ICC). An ICC of 0.81 to 1.00 was defined as very good, 0.61 to 0.80 as good, 0.41 to 0.60 as fair to moderate, and less than 0.40 as poor. Proportional data were compared using chi-squared or Fisher's exact test, as appropriated. All analyses were performed using SPSS version 13 (IBM, USA).

Figure 1. The patellar facet height was the distance between the highest point of the facet and the lowest point of the facet obtained from lateral films.

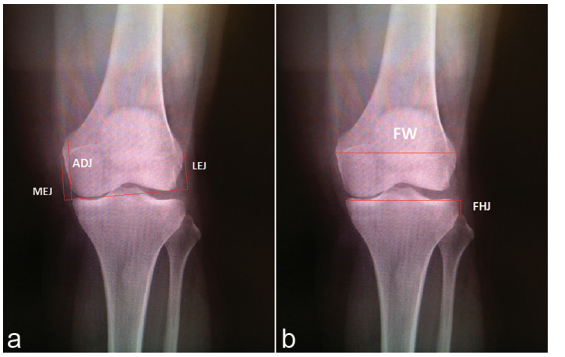

Figure 2. Measurements technique of the adductor tubercle to the joint line distance (ADJ), medial epicondyle to the joint line distance (MEJ), and lateral epicondyle to the joint line distance (LEJ) (a). Measurements technique of femoral width (FW) and fibula head to joint line distance (FHJ) (b).

Table 1. The Pearson's correlation for the patellar facet height and others joint line distances in male and female

Variable	Pearson's correlation			
	Male (n=50)		Female (n=50)	
	Coefficient	p-value	Coefficient	p-value
PFH and ADJ	0.647	<0.001	0.648	<0.001
PFH and FW	0.471	0.001	0.619	<0.001
PFH and MEJ	0.746	<0.001	0.813	<0.001
PFH and LEJ	0.553	<0.001	0.423	<0.001
PFH and FHJ	0.287	0.04	0.166	0.236

PFH=patellar facet height; ADJ=adductor tubercle to joint line distance; MEJ=medial epicondyle to joint line distance; LEJ=lateral epicondyle to joint line distance; FW=femoral width; FHJ=fibular head to joint line distance

Table 2. The results of patellar facet height, ADJ, FW, MEJ, LEJ, and FHJ in male and female

Variable	Male (n=50) Mean±SD (range)	Female (n=50) Mean±SD (range)	p-value
PFH (mm)	31.79±2.75 (26.16 to 37.28)	29.39±2.16 (24.94 to 33.89)	<0.001
MEJ (mm)	32.23±2.34 (27.11 to 41.05)	30.68±1.68 (26.33 to 34.63)	<0.001
LEJ (mm)	26.99±1.99 (23.38 to 31.91)	25.98±2.51 (19.14 to 31.85)	0.02
FHJ (mm)	13.92±2.56 (6.52 to 17.68)	11.61±3.20 (3.23 to 19.93)	0.001
FW (mm)	85.94±6.10 (70.77 to 98.18)	79.35±5.43 (70.05 to 93.58)	<0.001
ADJ (mm)	41.35±3.78 (32.98 to 51.75)	40.10±2.96 (34.05 to 48.70)	0.028
Ratio of ADJ/PFH	1.31±0.10 (1.16 to 1.50)	1.36±0.12 (1.16 to 1.61)	0.042

SD=standard deviation; PFH= patellar facet height; ADJ=adductor tubercle to joint line distance; MEJ=medial epicondyle to joint line distance; LEJ=lateral epicondyle to joint line distance; FW=femoral width; FHJ=fibular head to joint line distance

Results

One hundred knee radiographs from 100 patients (females 50) were examined. The patients mean age was 65.9 (range 49 to 83) years. The ratio of right to left knees was 2:3. The Pearson's correlation showed good correlation between PFH with ADJ, FW, MEJ, LEJ, and FHJ for males and females, except between the PFH and FHJ in females (Table 1). The mean PFH and all other measured distances parameters were significantly greater in males compared to females. (Table 2). The inter- and intra-observer reliability scores were very good (ICC 0.89 to 0.98) for all of the parameters except LEJ, which was good (ICC 0.62). The mean ADJ-PFH ratio in females was significantly (p=0.04) higher than in males at 1.36±0.12 (1.16 to 1.61) versus 1.30±0.10 (1.16 to 1.50) (Table 2).

In the 22 identified TKA patients, the demographic characteristics were not significantly different between Gp I and II even though Gp II only had five females (Table 3). Gp I patients had good clinical outcomes. The KSS improved significantly from 35.29±2.64 (27 to 37) pre-operatively to 98.12±3.49° (92 to 100) post-operatively, and ROM improved from 100.29±18.99° (45 to 125) to 116±10.68° (90 to 130). However, Gp II patients had significantly (p=0.001) lower KSS scores versus Gp I patients (Table 4). Gp II patients also had worse post-operative ROM versus Gp I patients, but the difference was not statistically significant (p=0.32) (Table 4).

The mean ADJ:PPFH ratio was significantly higher (p=0.042) in females (1.36) compared to males (1.31) (Table 4). In Gp II, the ADJ-PFH ratio was significantly less (p=0.003) compared to all Gp I patients and became more significant (p<0.001) when comparing only Gp I females.

The operative time, knee alignment, femoral, and tibial component alignments were not significantly different between the two groups (Table 4).

Discussion

There are many bony landmarks in use for the estimation of the KJL during revision TKA[1-9]

Table 3. Demographic data of patients who underwent revision TKA

Variables	Patients who underwent TKA, Mean±SD (range)		p-value
	With applied metal augment at distal femur (n=17)	Without applied metal augment at distal femur (n=5)	
Age	71.59±6.99 (57 to 80)	69.00±6.96 (63 to 80)	0.48
Sex (male/female), n	3/14	0/5	0.31
Site (right/left), n	11/6	4/1	0.52
KSS (points)	35.29±2.64 (27 to 37)	37.00±7.31 (27 to 44)	0.42
ROM (°)	100.29±18.99 (45 to 125)	99.00±10.25 (90 to 115)	0.89
BMI (kg/m^2)	27.71±3.07 (22.22 to 33.29)	26.06±3.88 (22.22 to 30.81)	0.33

TKA=total knee arthroplasty; SD=standard deviation; KSS=knee society score; ROM= range of motion; BMI=body mass index

Table 4. Secondary outcomes of patients who underwent revision TKA

Variables	Patients who underwent TKA, Mean±SD (range)		p-value
	With applied metal augment at distal femur (n=17)	Without applied metal augment at distal femur (n=5)	
Ratio of ADJ-PFH in overall	1.31±0.12 (1.14 to 1.59)	1.07±0.06 (1.02 to 1.16)	0.003
Ratio of ADJ-PFH in female	1.32± 0.12 (1.15 to 1.59)	1.07±0.06 (1.02 to 1.16)	<0.001
Ratio of ADJ-PFH in male	1.28± 0.19 (1.14 to 1.42)	0	N/A
Post KSS (points)	98.12±3.49 (92 to 100)	89.00±2.74 (87 to 92)	<0.001
Post ROM (°)	116.18±10.68 (90 to 130)	111.00±6.52 (100 to 115)	0.32
Operative time (minutes)	126.88±10.47 (110 to 145)	124.00±12.94 (110 to 140)	0.61
Knee alignment (°)	5.18±0.73 (valgus 4 to valgus 6)	5.6±0.55 (valgus 5 to valgus 6)	0.25
Femoral component alignment (°)	5.35±0.70 (valgus 4 to valgus 6)	5.8±0.55 (valgus 5 to valgus 6)	0.19
Tibial component alignment (°)	Varus 0.3±0.44 (varus 1 to 0)	Varus 0.4±0.55 (varus 1 to 0)	0.49

TKA=total knee arthroplasty; SD=standard deviation; ADJ=adductor tubercle to joint line distance; PFH=patellar facet height; KSS=knee society score; ROM=range of motion; N/A=not available

and earlier used techniques have measured bone loss at the distal femur that did not extended to the epicondyle[1-9]. The present study is the first study to show the correlation between the PFH and the ADJ and suggests that the ADJ-PFH ratio could be used to estimate the KJL during revision TKA especially in patients with severe bone loss.

The present study also showed good correlations between the PFH and the FW, MEJ, LEJ, and FHJ in males and females, except the FHJ in females. Therefore, based on the present data, the authors would not recommend using the FHJ for estimating the KJL during revision TKA. Martin et al also found that the MEJ correlated poorly with the FHJ and that the FHJ was not accurate for estimating KJL[12]. The present study also found that the mean PFH and the mean distances for the other joint line measurements were significant greater in males compared to females, consistent with the findings of Luyckx et al[8]. The present study has shown that the ratio of ADL-PFH in females was higher than the ratio of ADL-PFH in males.

The present study also determined the clinical outcomes of patients with and without metallic augmentation of the distal femur. While the present study had few patients, the data suggested a possible better outcome for revision TKA patients who also had metallic augmentation of the distal femur. The mean ADJ-PFH ratios in GpI were 1.28 and 1.32 for males and females, respectively. The mean ratio in Gp II, which only consisted of females, was significantly lower in patents who underwent a TKA with applied metal augmentation at the distal femur and they had poorer clinical outcomes. The mean ADJ-PFH ratios of Gp II was only 1.07. Therefore, the authors believe the femoral component should, whenever possible,

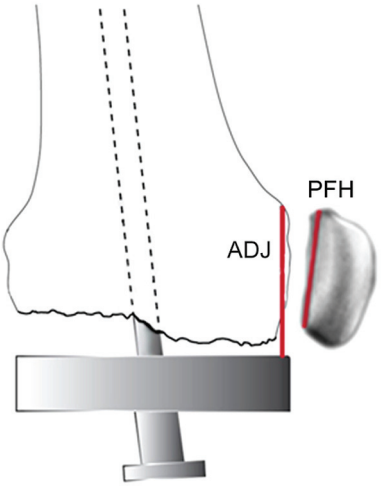

Figure 3. Technique for calculating the ADJ from the PFH intraoperatively. The ADJ was the perpendicular distance between adductor tubercle and virtual cutting block. The ADJ was 1.3 X PFH and 1.4 X PFH for male and female, respectively.

ADJ=adductor tubercle to joint line; PFH=patellar facet height

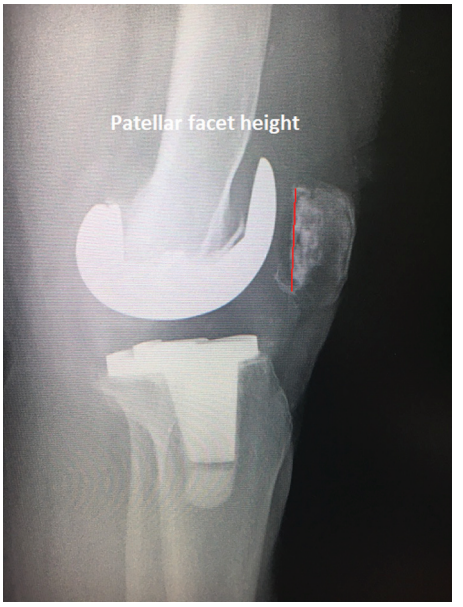

Figure 4. The PFH also should be measured in patient underwent TKA with resurfacing patella.

PFH=patellar facet height

be applied with metal augmentation for restoring the distal femoral joint line, as shown in Figure 3 when using the ADJ-PFH ratio.

There are some limitations to the present study. Firstly, the study included patients with Alhback I and II medial knee OA, and excluded individuals with normal knees. However, such patients do not have bone erosion by definition and should, therefore, be similar to normal individuals. Secondly, the present study measured knee joint parameters from plain X-ray films, and these may be less accurate compared to MRI images. However, Romero et al[13] used plain films and Griffin et al[7] used MRI and both found similar TEW:MEJ and TEW:LEJ correlations[7,13]. Moreover, orthopedic surgeons use primarily plain films in their practice, especially in resource-limited settings. Thirdly, the results of the present study are from Thailand and cannot be generalized with confidence to other populations. More data are needed from diverse populations to see if there are significant differences between populations. Fourthly, the PFH may be easier to measure in a non-resurfacing patella but the PFH can still be measured in patients with resurfacing patellae who do not have severe bone loss (Figure 4).

Conclusion

The PFH showed a good correlation with ADJ in males and females and the mean ratio of ADJ-PFH was 1.30 and 1.36 for males and females, respectively. The patients with metal augmented femoral components had a mean ADJ-PFH ratio close to 1.3 and they all had good KSSs and ROM. Therefore, the ADJ-PFH ratio should be the new bony landmark to estimate the KJL during revision TKA, especially in patients with severe bone loss that extends to the femoral epicondyle.

What is already known on this topic?

The KJL can estimated from the medial and lateral femoral epicondyles, fibular head, adductor tubercle, FW, and the TEW. The two most popular techniques for estimating the KJL are the (i) regression equation of the MEJ and TEW where MEJ = 0.3951 × TEW + 0.66 and (ii) ratio between ADJ and FW where the mean value is 0.52[8,13]. In patients with severe bone loss that extends to the medial and/or lateral condyles, the ADJ, MEJ, TEW, and FW cannot be calculated thus, the FHJ has to be used for estimating the KJL even though the FHJ shows poor correlation with the femoral joint line.

What this study adds?

The PFH showed good correlations with the ADJ, MEJ, LEJ, TEW, and FHJ, except the FHJ in females. The mean ADJ-PFH ratios were 1.31 and

1.36 for males and females, respectively. These values should be useful for orthopedic surgeons practicing in Thailand.

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Conflicts of interest

The authors declare no conflict of interest.

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