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# Calculating position of joint line of knee using various radiological parameters based on Indian population

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**Abstract**
Restoration of the joint line of the knee is an important technical goal of a total knee arthroplasty. Failure to restore the joint line of the knee to anatomical position can lead to mid-flexion instability, a reduction in range of motion, impingement of the patellar tendon against the tibial tray, and gap imbalance. The presence and integrity of bone and soft tissue landmarks makes restoration of the joint line Successful. Restoration of the joint line both difficult and unreliable especially in revision TKA, where the necessary landmarks are often missing or obscured. Numerous methods, ranging from relative references, to absolute distances have been described for joint line restoration, yet a lack of consensus remains. The aim this study was to determine a reproducible, quantitative relationship between position of joint line and identifiable anatomical landmarks in Indian population after studying randomly selected Indian population. Results of our study indicate that Femoral diameters are statistically different for Sexes while Tibial diameters are not, IMD is 1.75 times LFJL,CTD is 2.7 times PTFJL, PCO is more important in predicting range of motion in TKA. PCJL:FD and IED:LEJL are also significant.

**Keywords:** Anatomical landmarks, Joint line, PCO, Revision TKA, TKA

## Introduction
In the technical goals of a total knee arthroplasty (TKA), restoration of the joint line of the knee is important. Failure to restore the joint line of the knee to anatomical position can lead to mid-flexion instability, a reduction in range of motion, impingement of the patellar tendon against the tibial tray, and gap imbalance. Unfortunately, successful restoration of the joint line relies heavily on the presence and integrity of bone and soft tissue landmarks. Unlike in primary TKA, in revision TKA, the necessary landmarks are often missing or obscured, making restoration of the joint line both difficult and unreliable. Numerous methods, ranging from relative references, including "2 finger breadths from the tibial tubercle," to absolute distances, including "10 mm from the fibular styloid," have been described for joint line restoration [1], yet a lack of consensus remains. Alternatively, the joint line of the knee can be estimated on a preoperative radiograph by measuring the distance from the joint line of the knee to either the medial epicondyle, fibular head, or tibial tubercle [2].
Anatomical studies have evaluated the distances from the femoral epicondyles, fibular head, and tibial tubercle to the joint line of the knee, in addition to the ratios of these absolute distances to femoral or tibial widths, compensating for sex and size differences. Although these previous studies yielded valuable anatomical relationships, the absolute distances can be variable. Also, during revision TKA, the identification of the necessary anatomical landmarks can be exceedingly difficult. The aim of this study was to find if there is reproducible, quantitative relationship between the position of the joint line of the knee and identifiable anatomical landmarks about the knee.

## Materials & Methods
100 randomly selected conventional radiographs of normal adult human knees, aged 20-50 years, came to our Hospital for vague knee pain symptoms were examined after obtaining proper consent. Exclusion Criteria was ligamentous pathology, degenerative changes in articular cartilage as radiologically seen by plain radiographs or MRI, osteochondral defects. In our study, Conventional X-rays were taken in True AP and Lateral views.

AP view were taken such a way that femoral and tibial condyles are symmetrical and head of fibula slightly overlapping the lateral tibial condyle. Lateral views were taken with femoral condylar overlap [3]. Institute's Ethical committee approval has been obtained. Anatomical landmarks identified are:

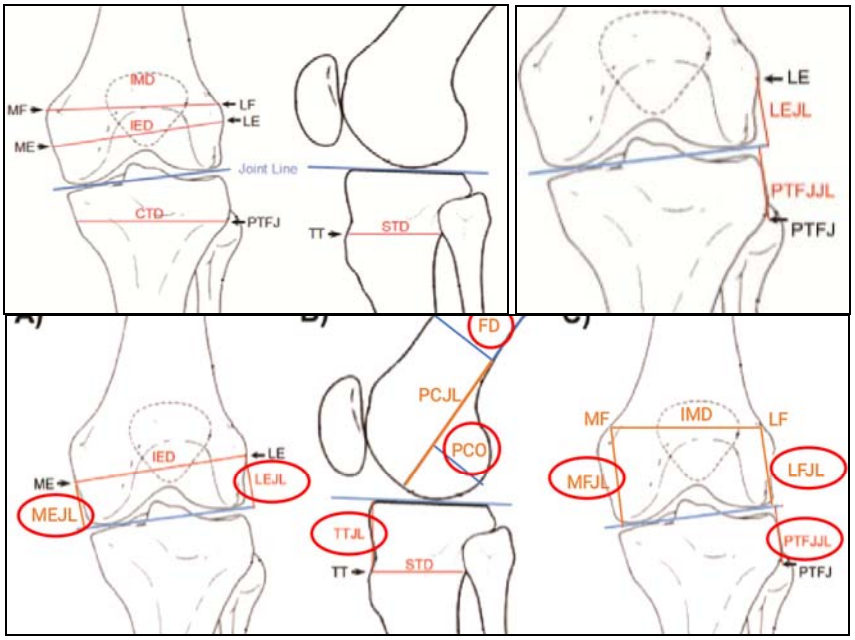


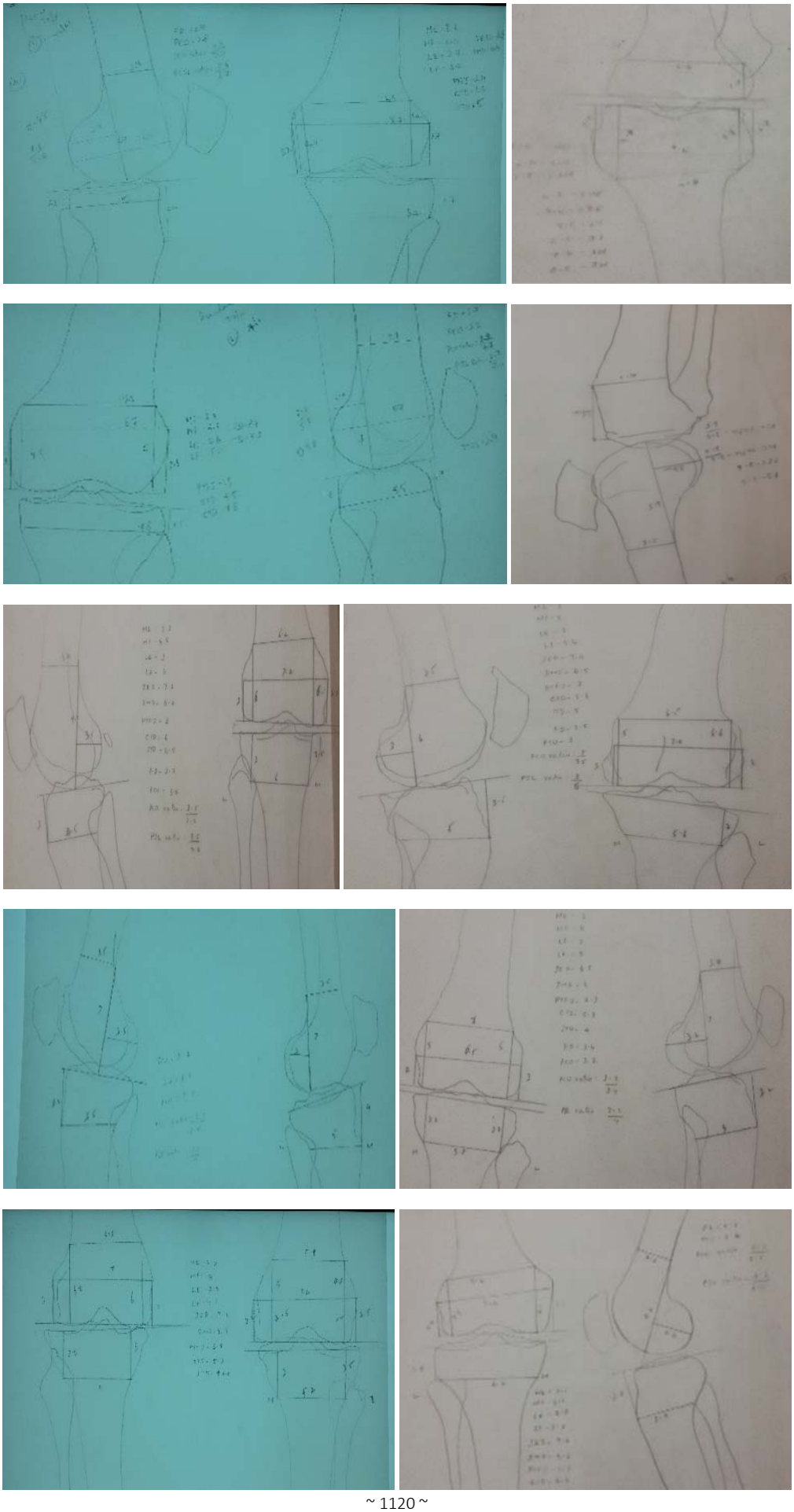

**Fig 1:** shows measurements of diameters and anatomical landmark

1. Medial epicondyle (ME): the medial-most point on the femur from which the medial collateral ligament originated; coronal section (ME to the joint line of the knee: MEJL) [1].
2. Lateral epicondyle (LE): the most prominent bony point of the femur from which the lateral collateral ligament originated; coronal section (LE to the joint line of the knee: LEJL) [1].
3. Medial flare (MF): the point at which the medial femoral metaphyseal flare met the medial condylar cortex and also where the epiphyseal scar met the medial cortex; coronal section (MF to the joint line of the knee: MFJL) [1].
4. Lateral flare (LF): the point at which the lateral femoral metaphyseal flare met the lateral condylar cortex and also where the epiphyseal scar met the lateral cortex; coronal section (LF to the joint line of the knee: LFJL) [1].
5. Proximal tibio-fibular joint (PTFJ): the center of the horizontal portion of the proximal tibio-fibular joint; coronal section (PTFJ to the joint line of the knee: PTFJJL) [1]
6. Tibial tubercle (TT): the proximal most corner of the junction between the tuberosity and the anterior cortex of the tibia; sagittal section. If this corner was not identifiable, the most proximal point of the patellar tendon insertion was chosen (TT to the joint line of the knee: TTJL). The absolute perpendicular distance between the joint line and each anatomical landmark was measured and reported [1, 2].

The following diameters were measured (figure.1)

1. Interepicondylar diameter of the femur (IED): the distance between the ME and the LE in the coronal plane, also known as the surgical transepicondylar axis; coronal section [1].
2. Intermetaphyseal diameter of the femur (IMD): the distance between the MF and the LF in the coronal plane [1].
3. Coronal Tibial diameter (CTD): the diameter of the tibia at the level of the PTFJ in the coronal plane, perpendicular to the tibial shaft [1].
4. Sagittal tibial diameter (STD): the diameter of the tibia at the level of the TT in the sagittal plane, perpendicular to the tibial shaft [3].
5. Femoral diameter (FD) [1].
6. Posterior condylar offset (PCO): was measured relative to a line drawn parallel to the posterior cortex of the distal femur and the joint line was measured from the posterior condylar flare to the articular surface. A ratio was then calculated for these measurements relative to the width of the femur at the level of the flare. It is a modification of Belleman's technique [1, 4].

The collected data were analysed with IBM. SPSS statistics software 23.0 Version. To describe about the data descriptive statistics frequency analysis, percentage analysis were used for categorical variables and the mean & S.D were used for continuous variables. The reliability was assessed with Intra class correlation(ICC).To find the significant difference between the bivariate samples in Independent groups the Unpaired sample t-test was used. To assess the relationship between the variables Pearson's Correlation was used. In all the above statistical tools the probability value.05 is considered as significant level.



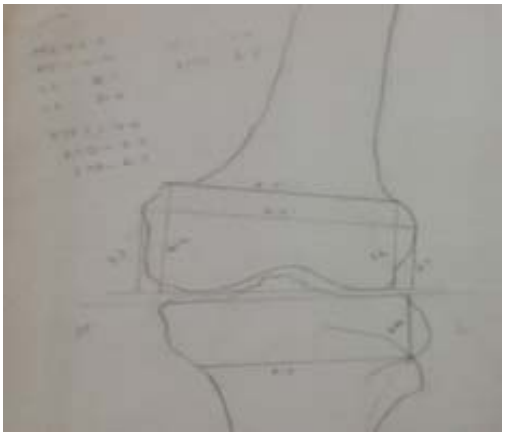


**Fig 2:** Few illustrations of measurements

**Table 1:** Group Statistics

| Variable | Male | Female | Range | | Mean | SD | Mean difference | P value |
|---|---|---|---|---|---|---|---|---|
| ME | 3.06 | 2.87 | 2.0 | 3.9 | 2.948 | 0.3948 | 0.1900 | 0.019 |
| MF | 4.46 | 4.56 | 3.5 | 6.5 | 4.529 | 0.6201 | -0.1020 | 0.428 |
| LE | 2.55 | 2.58 | 2.0 | 3.6 | 2.574 | 0.3425 | -0.0260 | 0.7150 |
| LF | 3.94 | 4.15 | 3.1 | 6.0 | 4.077 | 0.6581 | -0.2133 | 0.1160 |
| TT | 3.73 | 3.3 | 2.0 | 5.0 | 3.472 | 0.6260 | 0.4314 | 0.0010 |
| PTFJ | 2.35 | 2.28 | 1.4 | 3.5 | 2.312 | 0.5317 | 0.0613 | 0.5450 |
| IED | 7.95 | 7.42 | 6.5 | 9.2 | 7.625 | 0.6796 | 0.5242 | 0.0000 |
| IMD | 6.28 | 5.99 | 4.5 | 8.0 | 6.105 | 0.5950 | 0.2933 | 0.0160 |
| STD | 4.48 | 4.44 | 3.5 | 5.5 | 4.459 | 0.5600 | 0.0407 | 0.7260 |
| CTD | 6.32 | 6.19 | 5.2 | 7.8 | 6.248 | 0.6319 | 0.1306 | 0.3180 |
| PCO | 2.99 | 2.91 | 1.5 | 4.0 | 2.943 | 0.5668 | 0.0792 | 0.4510 |
| PCJL | 7.03 | 6.82 | 5.0 | 9.0 | 6.906 | 0.5918 | 0.2153 | 0.0770 |
| PCO RATIO | 1.01 | 0.96 | 0.50 | 1.40 | 0.9798 | 0.20602 | 0.05041 | 0.2370 |
| PCJL RATIO | 2.52 | 2.34 | 1.50 | 3.40 | 2.4133 | 0.37459 | 0.18398 | 0.0160 |
| FD | 2.8 | 2.96 | 2.3 | 4.0 | 2.902 | 0.3929 | -0.1645 | 0.0410 |
| ATJL | 3.74 | 3.67 | 2.7 | 5.1 | 3.700 | 0.4367 | 0.0679 | 0.4530 |

**Table 2:** Derived Ratios

| Variable | Minimum | Maximum | Mean | Std. deviation | P. value |
|---|---|---|---|---|---|
| PCJL:FD | 1.50 | 3.40 | 2.4133 | .37450 | 0.016 |
| PCO:FD | .52 | 1.41 | 1.0314 | .21471 | 0.128 |
| IED:MEJL | 2.17 | 3.27 | 2.6167 | .29598 | 0.128 |
| IED:LEJL | 2.17 | 3.83 | 3.0060 | .42061 | 0.019 |
| CTD:PTFJL | 1.49 | 5.20 | 2.8575 | .77906 | 0.431 |
| LE:PTFJL | .63 | 3.40 | 1.1735 | .32796 | 0.258 |

**Table 3:** Comparison Analysis

| Ratio | GRH study | Gavin *et al.* | Rajagopal *et al.* | Mountnay *et al.* | Servien *et al.* | Nicholas *et al.* |
|---|---|---|---|---|---|---|
| IED:MEJL | 2.616 | 2.8+/-0.3 | 3.0+/-0.3 | 3.1+/-0.2 | | |
| IED:LEJL | 3.006 | 3.2+/-0.2 | 3.3+/-0.2 | 3.4+/-0.2 | 3.5+/-0.3 | |
| CTD:PTFJL | 2.857 | 3.3+/-0.5 | | | | |
| LEJL:PTFJL | 1.17 | 1.0+/-0.1 | | | | |
| PCO:FD | 1.03 | | | | | 0.76 |
| PCJL:FD | 2.44 | | | | | 1.9 |
| MEJL | 2.94 | 2.76 | | 2.64 | 2.83 | |
| MFJL | 4.52 | 4.15 | | | | |
| LEJL | 2.57 | 2.36 | | 2.58 | 2.36 | |
| LFJL | 4.07 | 3.51 | | | | |
| TTJL | 3.47 | 2.09 | | | 2.23 | |
| PTFJL | 2.31 | 2.22 | | | | |

**Correlation and regression analysis**

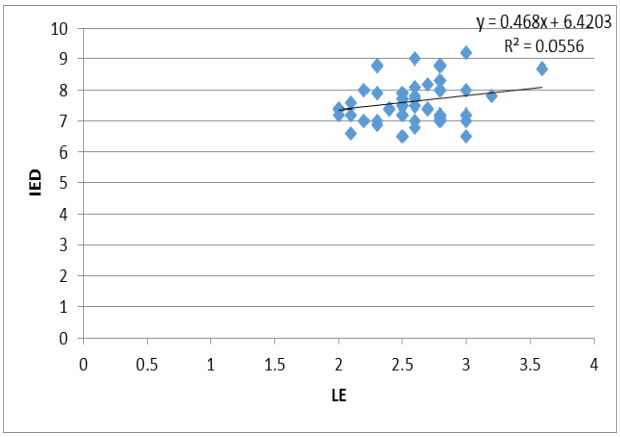



**Fig 3**

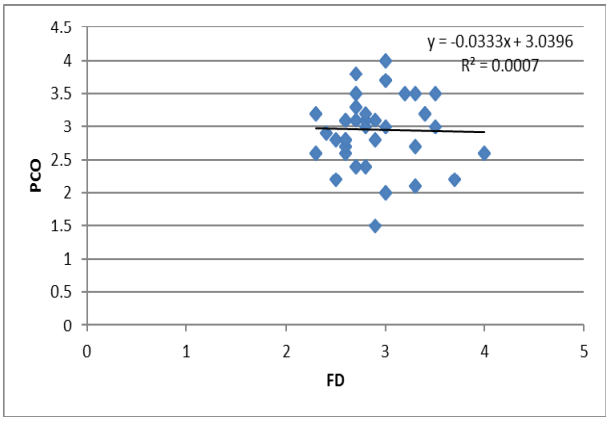



**Fig 4**

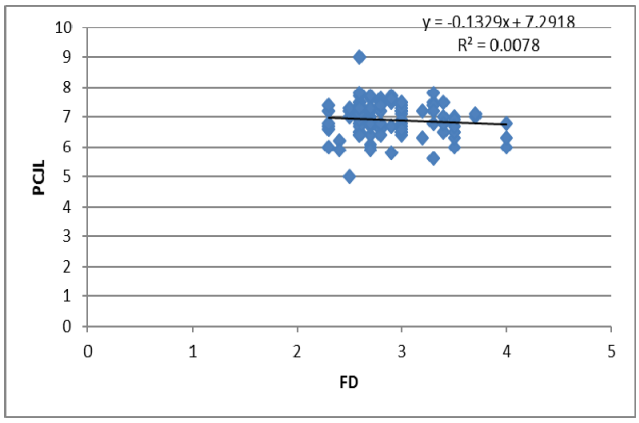



**Fig 5**

## Results

The absolute distances of various anatomical landmarks to the joint line of knee are presented in the tables 1 and 2. Femoral & Tibial diameters are also tabulated. ME, IT, IED, IMD, FD are statistically different for Sexes indicated by $p<0.05$. Thus, femoral diameters are statistically different for Sexes while Tibial diameters are not. LE found to be at equidistant to joint line as PTFJ**.** LEJL found to be 1/3rd IED. PCJL:FD and IED:LEJL are also significant with $p<0.05$. The data corroboration reveals that, ME is about 3cm from joint line. LEJL is 1/3rd of IED and is at equidistant to joint line as PTFJ. FD is found to be similar to PCO. IMD is 1.75 times LFJL (Gavin *et al*., IMD = 2 LFJL). CTD is 2.7 times PTFJL (Gavin *et al*., CTD = 3 PTFJL) [1].

Correlation & Regression for above variables were done and based on it there is a positive correlation between FD and LE, FD and IED, LE and IED which is indicated by scatter charts and pearson correlation(figure 3,4,5).

## Discussion

This study has shown the reproducible and reliable accuracy in finding the joint line with respect to the anatomical landmarks about the knee and has also postulates that the joint line is at a constant ratio from both the femoral and the tibial anatomical landmarks. The absolute distances found in our study is comparable with other studies as shown in comparision analysis table (table-3).Our study extensively studied with 14 Absolute distances, 8 Ratios which is not find in any other similar study.

Johal *et al*. in his study showed that PCO ratio was found to be 0.44 in western population [4]. Wang *et al*. demonstrated a significantly greater PCO in Chinese population than western population with a value of 0.47 in females and 0.46 in males [5]. The PCO:FD ratio in our study is 1 indicating that PCO is higher in Indian Population. In Nicholas *et al*. study with western population, the PCO:FD ratio is 0.75 [6]. Further in our study it is shown that the sexual difference is statistically significant. In our study all measurements are based on conventional radiographs so the issues of unreliability associated with Nicholas *et al*. study, which was done on digital radiographs, related to magnification problems are not an issue in our study. Gavin *et al*. [1] reported that CTD is three times PTFJL, IMD is two times LFJL, LEJL is one-third the IED, PTFJ is superior landmark than fibular head or styloid, LEJL is accurate measurement for joint reconstruction and IMD,IED,CTD,STD are statistically different between both sexes. In our study CTD is 2.7 times PTFJL, IMD is 1.75 times LFJL, ME, IT, IED, IMD, FD are statistically different for sexes. Further as per Gavin *et al*. IED:LEJL was statistically not significant but in our study it was found to be statistically significant. In our study restoration of PCO was important than LEJL measurement.

Importance of PCO Restoration after TKR is that it is essential to provide stability in flexion and optimise the range of motion [4, 5]. This Variation according to ethinicity is also shown by Wang *et al*. Study with Chinese Population [5]. Distal femoral bone loss in revision TKR may result in the surgeon undersizing the femoral component and using a thicker polyethylene to balance the knee [7]. The use of IM stems to provide implant stability influences the AP position of the condylar portion of the femoral component. The use of straight stems has been demonstrated to result in a diminished PCO relative to offset stems. PCO is an independent predictor of range of movement after TKR, with increasing PCO having a direct correlation with increasing range of movement [8]. Malviya *et al*., demonstrated that after primary TKR, joint line was not a predictor of range of movement, but they found PCO to have a greater and more significant [8].

Importance of Joint Line Restoration is that a good knee score is directly related to the position of the joint line [9]. The joint line is often malpositioned, frequent elevated using the available surgical techniques, especially the ones based on balancing the flexion and extension gaps,as well as some surgeons rely on conventional methods. These commonly used methods lack accuracy in positioning the joint line within the narrow acceptable limits of ±8 mm (Figgie *et al*. 1986; Partington *et al*. 1999; Laskin 2002), or even ±4 mm (Hofmann *et al*. 2006) of the optimal position [10, 11].

Previous anatomical and radiographic studies have attempted to establish a reproducible relationship between the fibular head and the tibial plateau, but the exact point of reference on the fibular head from which to make observations is lacking. In addition, the fibular styloid is variable in morphology and the fibular styloid can be excised intraoperatively, during the proximal tibial cut, and is not always available as a reference during revision TKA [11-13]. The fibular head is highly variable and unreliable as an anatomical landmark. Compared with the fibular head, the PTFJ used in this study is a superior anatomical landmark, The PTFJ is a clearly defined anatomical landmark that can be seen on a plain radiograph, the PTFJ can be found at the intersection of the lateral prominence of the fibular head and the fibular styloid. Now, after the disappearance of the anatomical landmarks used for the restoration of the joint line, the clinical effect of its malposition could be deleterious, So, we describe a method that is accurate and reproducible.

## Conclusion

In TKA, successful restoration of the joint line can be verified by ensuring the joint line lies equidistant from the LE and the PTFJ. If the epicondyles are visible, determine the IED of the femur. The femoral articular line is approximately one-third this distance from the LE. When posterior condyles are not available, especially during revision TKA, FD value can be used as offset distance. The restoration of the joint line level during a revision total knee arthroplasty has a major positive effect on the clinical outcome, reduced risks of re-intervention and precocious complications.

The method we described may help as an accurate, reproducible, reliable and easily applicable for planning a successful Primary & Revision total knee arthroplasty.

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