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The Linear Coronal Knee Offset (LCKO)—Preliminary Study of New Method of Measuring Knee Varus/Valgus Malalignment

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Abstract

Introduction Considerable attention is focused on preoperative templating of radiological images in patients undergoing total knee arthroplasty to obtain optimal alignment and outcome. Several radiological measurements have been described.

Purpose In this study, we illustrate a new linear measurement: The linear coronal knee offset (LCKO) that can be used to analyze the coronal configuration on long leg alignment radiographs commonly undertaken during preoperative templating.

Methods A retrospective search was performed of our Picture Archiving and Communication System and Radiology Information System to identify 100 lower limbs anteroposterior, weight bearing, long leg alignment view radiographs of patients referred to knee clinics over 1 year with knee pain.

Demographic details, clinical indication, standard radiological measurement of the anatomical tibiofemoral angle, and the LCKO were measured and data were analyzed using Student's *t*-test. In addition, intraclass correlation coefficient was used to analyze for intraclass reliability.

Results The average age of patients was 36.3 years (range: 12–80 years) with a male predominance. The LCKO was statistically significant between the three cohorts of patients. The mean LCKO in normal cohorts was 0.24 cm, varus was −0.6 cm, and valgus was 1.72cm. There was good inter and interobserver reliability (Kappa of 0.8 and 0.8, respectively).

Conclusion The novel LCKO measurement provides a simpler method in assessing coronal lower limb malalignment and can easily identify a normal, varus, or valgus knee deformity.

Keywords
- alignment
- tibiofemoral angle
- preoperative templating
- total knee arthroplasty
- reliability

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Introduction

Total knee arthroplasty (TKA) has evolved as one of the most effective surgical procedures in the management of painful, symptomatic osteoarthritis (OA) of knee following failed conservative treatment. The primary aim of TKA is to improve knee function and range of movement, decrease pain, and restore the mechanical axis.[1–3]

Many factors influence the successful outcomes of TKA including patient's selection, pre- and postoperative rehabilitation programs, surgical experience, and prosthesis design.[4–9] In more recent practice, a great deal of focus has been on preoperative templating to aid surgical planning and bone and soft tissue releases to achieve optimal limb-length alignment.[7,10–12] Digital preoperative templating has been found to be particularly helpful in allowing surgeons to plan their surgical approach, bone osteotomies, anticipate and deal with challenging intraoperative encounters, predict implant sizes and overall, reduce the risk of premature implant failure.[7,10–12]

Routine anteroposterior (AP) long leg alignment and lateral and skyline radiographs, with a standard magnification have historically been used for preoperative TKA templating. In most recent studies, a large emphasis has been placed on the importance of attaining a neutral coronal alignment (CA) of the knee. Various measurements have been established and described in the literature.[13–15] Despite this, determining the ideal CA poses a great challenge for reconstructive knee surgeons.[16–20]

We describe a new linear measurement that can be utilized to analyze the CA on long leg alignment radiographs, which has never been described in the literature. We feel this approach is more simple, quick and can be easily calculated, making it a valuable tool for preoperative templating for TKA, for orthopaedic and early career surgeons. Additionally, this measurement can complement other established measurements used by knee surgeons, increasing their confidence in accurately completing osteotomies.

Patients and Methods

Study Design

Local ethical committee approval was obtained for this project. A retrospective evaluation of Radiology Information System and Picture Archiving and Communication System was performed to identify 50 consecutive cases referred to knee clinics over a 1-year period with knee pain. The imaging acquired included weight bearing, long leg alignment AP views of the lower limb including all three joints of the ipsilateral hip, knee, and ankle articulations. All images were calibrated to represent real-life measurements; hence, a marker was not required. Patients with a history involving surgery of the knee, hip or ankle, and lower limb, infection, or tumors were excluded.

Image Analysis

All radiographs were analyzed by senior author (RB), musculoskeletal radiologist with over 10 years of experience, and one radiology registrar. In addition, one reader repeated measurements after a cooling period to evaluate for intra-observer reliability.

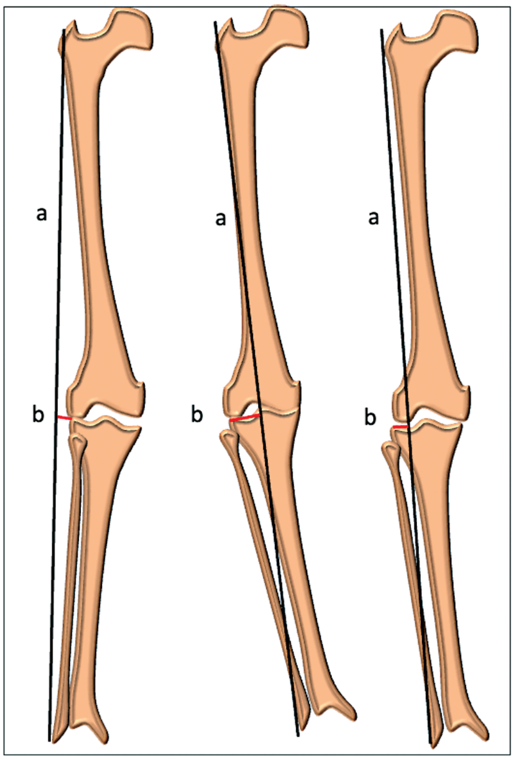

Fig. 1 Schematic showing measurement of linear coronal knee offset (LCKO). Line a is lateral line tangential to greater trochanter and lateral malleolus. Line b (LCKO) which is perpendicular line is drawn from the lateral edge of lateral tibial plateau to the line a.

Calculation of the Linear Coronal Knee Offset

The linear coronal knee offset (LCKO) is measured on weight bearing lower limb AP radiographic imaging. For utmost precision, the patella must be aligned in the AP projection in the center of the femoral condyles with both ankle in neutral position. In addition, it is crucial to verify that the images are not rotated, and that patients do not have any flexion deformities as such conditions could potentially impact the accuracy of the measurements. The LCKO is measured by first, drawing a lateral line tangential to greater trochanter and lateral malleolus. A second perpendicular line is drawn from the lateral edge of lateral tibial plateau to the first line. The distance of the perpendicular line corresponds to the LCKO. (►**Figs. 1** and **2**).

Methodology

Data Collection

Data collected included patient demographics, indication, standard radiological measurement of the anatomical tibiofemoral angle (TFA), and a LCKO measurement calculated for each patient. TFA of 5 to 7 degrees of valgus was considered as normal, less than 5 degrees was varus, and over 7 degrees was valgus orientation of the knee. Data was recorded on a Microsoft Excel data spreadsheet and SPSS 24.0 software

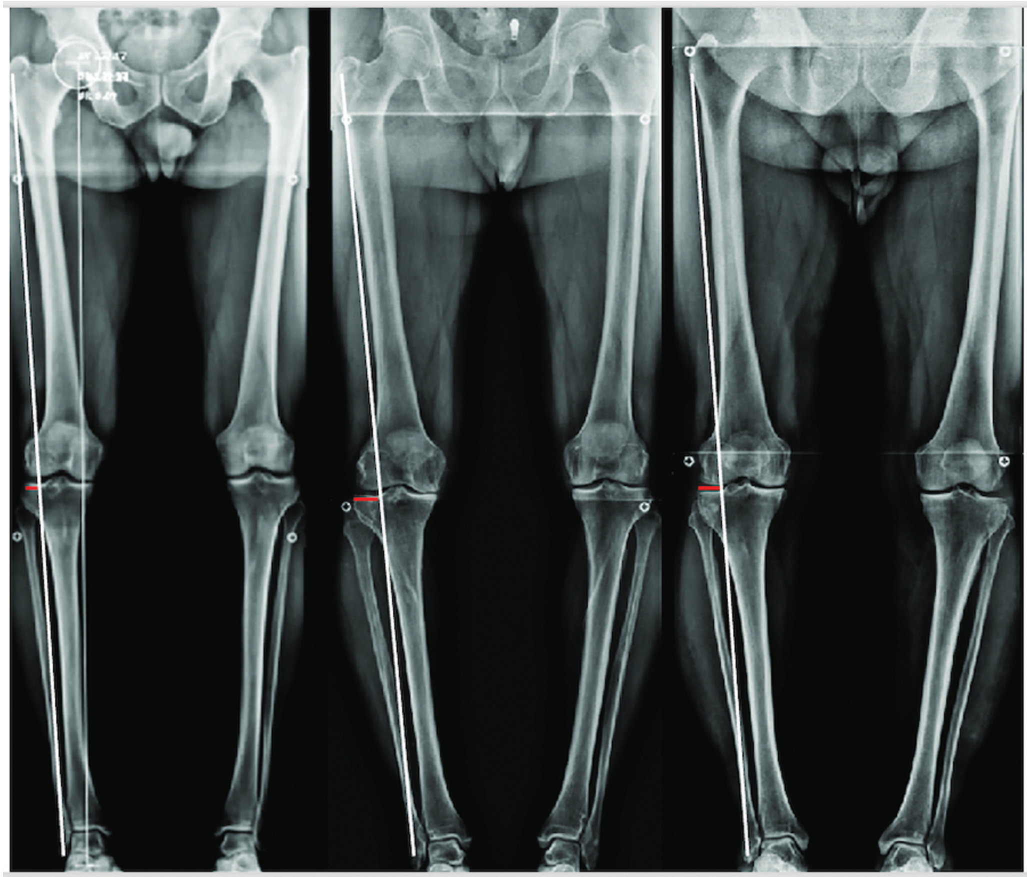

Fig. 2 Long leg films showing measurement of linear coronal knee offset (red line) in three cases.

(SPSS Inc. Chicago, Illinois, United States). Analysis of variance was used for statistical analysis. Kappa correlation was used to assess intra- and interobserver reliability. The intraclass correlation coefficient (ICC) is usually between 0 and 1 (below 0.5 indicate poor, 0.5 to 0.75 being moderate, 0.75 to 0.9 good, and over 0.9 suggests excellent reliability).

Results

Among 50 consecutive cases (100 lower limbs), there was a male predominance (30 males and 20 female). Based on the TFA, there were three cohorts. There were more males in the normal and valgus cohort with equal proportion in the varus cohort. The mean age of entire cohort patients was 36.3 years (range: 12–80 years). Descriptive statistics of three cohorts are described in ►**Table 1**. The LCKO was statistically significant between the three cohorts. The mean LCKO in normal cohorts was 0.24cm (99% confidence interval [CI]: −0.068–0.58), varus was −0.6 (99% CI: 1.84–0.65,) and valgus was 1.72cm (99% CI: 1.38–2.1; ►**Table 1**) There was good intra- and interobserver reliability (Kappa of 0.8 and 0.8, respectively).

Discussion

Frontal lower limb malalignment (FLLM) is strongly interrelated with progression of knee OA, and the measurement of FLLM is helpful in apprehending the progression as well as guiding the management of knee OA.[1–4] The importance of achieving a neutral alignment of the knee has been well acknowledged in the literature through multiple clinical and biomechanical studies, and has been proven to balance soft tissue forces, improve knee function, reduce implant failure and revision rates.[5–7] Establishing the precise CA for TKA, however, remains to be one of the greatest challenges for reconstructive knee surgeons.[7–10] To yield a near successful alignment, accurate preoperative planning is essential, and with the modern advanced use of digital software imaging systems, the measurement of FLLM has become swifter and more straightforward in producing satisfactory patient outcomes.[11–13]

Standing whole lower limb plain radiographs form the benchmark technique is evaluating FLLM in the weight bearing axis as well as other contributing angles that may lead to a deformity.[4] Different measurements and techniques have been described in the literature which include, the valgus correction angle (VCA), Mikulicz line, and mechanical mTFA.

The mTFA has historically been the gold-standard technique in calculating FLLM.[14] This is done by drawing a straight line from the center of the knee to the center of the femoral head (mechanical axis of the femur), and from the center of the knee to the ankle (mechanical axis of the tibia). Subsequently, the medial angle formed by the

Table 1 Descriptive statistics of the linear coronal knee offset (LCKO) among the three study cohorts of patients

Parameters	Valgus knee	Normal	Varus knee
Number of patients	58	20	22
Average age (years)	35.37	30.16	43.42
Maximum age (years)	80	80	80
Minimum age (years)	12	16	12
Male	36	13	11
Female	22	7	11
Mean	1.72	0.24	−0.6
Standard deviation (cm)	1.10	0.45	2.06
Standard error of mean (SEM)	0.13	0.10	0.44
90% confidence interval (CI)	1.52–1.95	0.07–0.42	−1.35–0.16
95% confidence interval (CI)	1.47–2	0.04–0.45	−1.51–0.32
99% confidence interval (CI)	1.38–2.1	−0.068–0.580	−1.84–0.65
Minimum	0	−0.5	−6
Median	1.6	0	−0.3
Maximum	4.40	1.30	3.00

mechanical axis of the femur and tibia is known as the hip–knee–ankle angle (HKA), and measures 0/180 degrees in normal knees.[15–17]

Although commonly utilized, many factors influence the HKA, yielding inaccurate and variable results. These include patient height, pelvic width, femoral head deformities, or inadequate radiographs.[16,18–21] In these situations, the VCA can instead be used. This is measured by determining the angle between two lines—the angle between a straight line connecting the center of the femoral head to the center of the distal femur and a second line along the anatomical long axis of the tibia. The resultant angle is approximately 6 ± 1 degrees of valgus with the mTFA. A normal VCA is interpreted as a value between 173 and 175 degrees, where a greater value indicates a varus deformity and a lesser value indicated a valgus deformity. However, comparable to the mTFA, many studies have proved the unreliable results of the VCA, which can significantly be affected by axial limb rotation and flexion deformities, with high variability and low interobserver reliability in multiple studies.[22–24] Moreover, both the latter are angular measurements, hence, can be difficult to analyze and interpret, especially for those surgeons early within their careers.

The novel LCKO measurement we feel provides a simpler method in assessing FLLM, with high interobserver reliability. Moreover, it can easily identify a normal, varus, or valgus knee deformity with a subsequent increase in deformity classification dependent on the values. We also found this measurement easier and quicker to calculate than conventional methods and can be used as an adjunct to other measurements to categorize knee deformities as well as aid with surgical planning, especially for early career surgeons.

We hope this uncomplicated technique can be used in future clinical studies and aid clinicians with preoperative planning for conventional TKA, high tibial osteotomies, as well as analyzing postoperative robotic knee procedures that preoperative utilize long leg alignment films for referencing.

Limitations

There are a few limitations that we can associate with this study. First, this being a retrospective study with a relatively small sample size that can reduce the robustness of the findings. Despite this, the LCKO was found to possess high ICC with a score of 0.8 and thus increases our confidence in the findings.

Conclusion

This study described an innovative method to measure coronal lower limb malalignment. The LCKO is easier to calculate with good intra- and inter-observer reliability. This can complement traditional methods to evaluate angular knee deformities.

Larger, multicenter studies will be beneficial to underpin our findings and support decision-making process in patients undergoing TKA achieve mechanical limb alignment.

Funding
None.

Conflict of Interest
None declared.

References

1 Cerejo R, Dunlop DD, Cahue S, Channin D, Song J, Sharma L. The influence of alignment on risk of knee osteoarthritis progression according to baseline stage of disease. Arthritis Rheum 2002;46 (10):2632–2636
2 Sharma L, Song J, Felson DT, Cahue S, Shamiyeh E, Dunlop DD. The role of knee alignment in disease progression and functional decline in knee osteoarthritis. JAMA 2001;286(02):188–195
3 Cooke TD, Li J, Scudamore RA. Radiographic assessment of bony contributions to knee deformity. Orthop Clin North Am 1994;25 (03):387–393
4 Moreland JR, Bassett LW, Hanker GJ. Radiographic analysis of the axial alignment of the lower extremity. J Bone Joint Surg Am 1987;69(05):745–749
5 Hsu RW, Himeno S, Coventry MB, Chao EY. Normal axial alignment of the lower extremity and load-bearing distribution at the knee. Clin Orthop Relat Res 1990; ((255):215–227
6 Tetsworth K, Paley D. Malalignment and degenerative arthropathy. Orthop Clin North Am 1994;25(03):367–377
7 Ritter MA, Faris PM, Keating EM, Meding JB. Postoperative alignment of total knee replacement. Its effect on survival. Clin Orthop Relat Res 1994; ((299):153–156
8 Fang DM, Ritter MA, Davis KE. Coronal alignment in total knee arthroplasty: just how important is it? J Arthroplasty 2009;24(6, Suppl):39–43
9 Longstaff LM, Sloan K, Stamp N, Scaddan M, Beaver R. Good alignment after total knee arthroplasty leads to faster rehabilitation and better function. J Arthroplasty 2009;24(04):570–578
10 Lotke PA, Ecker ML. Influence of positioning of prosthesis in total knee replacement. J Bone Joint Surg Am 1977;59(01):77–79
11 Cooke TD, Scudamore RA, Bryant JT, Sorbie C, Siu D, Fisher B. A quantitative approach to radiography of the lower limb. Principles and applications. J Bone Joint Surg Br 1991;73(05):715–720
12 Prakash U, Wigderowitz CA, McGurty DW, Rowley DI. Computerised measurement of tibiofemoral alignment. J Bone Joint Surg Br 2001;83(06):819–824
13 Sled E, Costigan P, Cooke TDV, Sheehy L, Hundt H, Qiu M. Measuring malalignment in knee OA. Osteoarthritis Cartilage 2005;13:S120
14 Insall JN, Binazzi R, Soudry M, Mestriner LA. Total knee arthroplasty. Clin Orthop Relat Res 1985; (192):13–22
15 Tang WM, Zhu YH, Chiu KY. Axial alignment of the lower extremity in Chinese adults. J Bone Joint Surg Am 2000;82(11): 1603–1608
16 Moreland JR, Bassett LW, Hanker GJ. Radiographic analysis of the axial alignment of the lower extremity. J Bone Joint Surg Am 1987;69(05):745–749
17 Hernigou P, Medevielle D, Debeyre J, Goutallier D. Proximal tibial osteotomy for osteoarthritis with varus deformity. A ten to thirteen-year follow-up study. J Bone Joint Surg Am 1987;69 (03):332–354
18 Sikorski JM. Alignment in total knee replacement. J Bone Joint Surg Br 2008;90(09):1121–1127
19 Bellemans J, Colyn W, Vandenneucker H, Victor J. The Chitranjan Ranawat award: is neutral mechanical alignment normal for all patients? The concept of constitutional varus. Clin Orthop Relat Res 2012;470(01):45–53
20 Lin Y-H, Chang F-S, Chen K-H, Huang K-C, Su K-C. Mismatch between femur and tibia coronal alignment in the knee joint: classification of five lower limb types according to femoral and tibial mechanical alignment. BMC Musculoskelet Disord 2018;19 (01):411
21 Hirschmann MT, Hess S, Behrend H, Amsler F, Leclercq V, Moser LB. Phenotyping of hip-knee-ankle angle in young non-osteoarthritic knees provides better understanding of native alignment variability. Knee Surg Sports Traumatol Arthrosc 2019;27(05): 1378–1384
22 Willcox NM, Clarke JV, Smith BR, Deakin AH, Deep K. A comparison of radiological and computer navigation measurements of lower limb coronal alignment before and after total knee replacement. J Bone Joint Surg Br 2012;94(09):1234–1240
23 Swanson KE, Stocks GW, Warren PD, Hazel MR, Janssen HF. Does axial limb rotation affect the alignment measurements in deformed limbs? Clin Orthop Relat Res 2000; ((371): 246–252
24 Koshino T, Takeyama M, Jiang LS, Yoshida T, Saito T. Underestimation of varus angulation in knees with flexion deformity. Knee 2002;9(04):275–279

