International Journal of Orthopaedics Sciences

E-ISSN: 2395-1958
P-ISSN: 2706-6630
IJOS 2022; 8(3): 12-16

www.orthopaper.com
Received: 11-04-2022
Accepted: 20-05-2022

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Observational study of radiographic analysis of axial alignments of the lower extremity in northwest Indian adult population

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DOI: https://doi.org/10.22271/ortho.2022.v8.i3a.3165

Abstract
Background: The current study is conducted to find the radiographic axial alignments of the lower extremity in north-west Indian adult population.
Methods: A observational study was conducted from May 2018 to May 2020. A total of 137 patients aged between 18-30years coming to hand clinic were randomly selected and full-length weight bearing anterior posterior and lateral view x-rays of left leg was performed and angles were measured using bone ninja application for following axial angles. Femoral neck shaft angle (frontal/sagittal plane), medial proximal femoral angle, anatomical/mechanical lateral distal femoral angle, medial proximal tibial angle, lateral distal tibial angle, posterior proximal/distal femoral angle, anterior distal femoral angle, joint line congruence angle (knee joint), mechanical/anatomical tibio femoral angle.
Results: In our study medial inclination of the tibial plateau in Indian adult population is 5.4+/- 2.4 degree was greater than the commonly reported 3 degree. The tibio femoral valgus angle was 5.4degree with a range of 4-8 degree.
Conclusion: Adult Indian population have more varus alignment of knee and significant higher medial inclination of tibial plateau than the counterpart western population. A 5 degree of external rotation of femoral component instead of commonly used 3degree is necessary while performing total knee arthroplasty in Indian population.

Keywords: Lower extremity, Indian population, medial proximal tibial angle, lateral distal femoral angle, arthroplasty

Introduction
The alignment of human lower limb has been an area of ongoing study for decades. The axial angles play a very important role in planning of major surgeries like lower limb deformity correction, total knee replacement, high tibial osteotomy. Not just surgeries even degenerative changes like osteoarthritis of knee its prevalence, its involvement of knee compartments in the due course of the disease, higher prevalence of medial compartment osteoarthritis in some ethnic groups may have relation with varying lower limb axial alignments [1]. However, a clear definition of "normal axial and rotational alignment" in non-arthritic adults has not been established yet. Any femur, patella and tibia axial and rotational malalignment might have a direct effect on the load transmitted through the joint leading to increase cartilage wear and degeneration [2]. Knee surgeons learned from total knee arthroplasty (TKA) procedures that a malposition of implants due to axial and/or rotational malalignment can result in higher revision rates and lower patient-reported outcome scores [3]. Likewise, it is conceivable that the axial and rotational alignment of lower limb may be crucial for the biomechanics of native hip knee and ankle. The deleterious effect of axial malalignment (i.e., valgus and varus deformities) of hip, knee and ankle joints is well recognized in the developing of osteoarthritis (OA) [2]. The values quoted in various standard books are of western population and various international studies show variation in normal axial angles of bones of lower extremity in different ethnic groups. Newer designs of total knee arthroplasty to specific ethnic people are present due to different lower limb axial alignments [4, 5]. To understand deformities of the lower extremity it is important to first understand and establish the parameters and limits of

normal alignments of the lower extremity. Here we are going to study various axial angles of lower extremity radiologically in Indian population.

Materials and methods

The observational study was conducted from May 2018 to May 2020 in a tertiary care hospital. A total of 137 randomly selected (chit box method) Indian adult patients aged between 18-30 years of both sexes coming to the orthopedic hand clinic outpatient department were included. A written informed consent was taken from all participants. Any patients with congenital lower limb deformities, acquired bony lower limb deformities and previous lower limb surgeries were excluded. Full length left lower limb x-rays were performed and following angles calculated using bone ninja application. Femoral neck shaft angle (frontal plane) (FNSA), Femoral neck shaft angle (sagittal plane), Medial proximal femoral angle (MPFA), Anatomical lateral distal femoral angle (ALDFA), Mechanical lateral distal femoral angle (MLDFA), Medial proximal tibial angle (MPTA), Lateral distal tibial angle (LDTA), Posterior proximal femoral angle (PPFA), Posterior distal femoral angle (PDFA), Posterior proximal tibial angle(PPTA), Anterior distal tibial angle (ADTA), Joint line convergence angle (knee joint) (JLCA), Mechanical tibio-femoral angle (MTFA), Anatomical tibio-femoral angle (ATFA). [Fig 1-3] Full length standing anterior posterior and lateral view x-rays taken with 300mA x-ray machine keeping legs slightly internally rotated. We did not have the facility for large cassette to take a single full length lower limb x-ray. Then 2 x-ray one from hip to knee and another from knee to ankle joint where taken and x-ray stitching was performed to get the full-length lower limb x-ray. The subject was made to stand bare-footed, with hip, knee in full extension, the ankle plantigrade, patellae facing forward with tibiae vertical and with slight internal rotation. There was equal weight bearing on both limbs. The tube is focused at the knee, the film-focus distance adjusted according to the height of the patient. No grid was used due to non-availability of long grid. Exposure was set to 75-95kv depending on distance and size of patient. 30-50mA per second setting used with individualized adjustments**.** The left lower limb full length x-rays thus obtained where studied using the bone ninja application for calculating the axial angles as mentioned in the aim of the study. Bone ninja is a computer-based application developed by Baltimore medical college and international center for limb lengthening used for calculating various bone measurements and angles using soft copies of x-rays.

Fig 1: Full length radiograph of the left lower limb taken after accurately aligning the films.

Fig 2: Axial angles of frontal plane measured with the help of Bone Ninja application

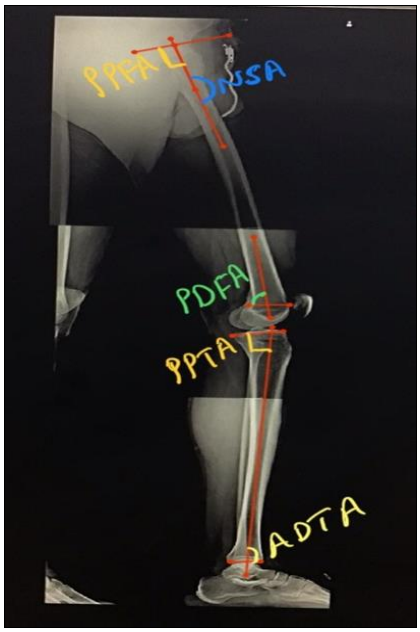

Fig 3: Axial angles of sagittal plane measured with the help of Bone Ninja application

Results

The mean range and standard deviation of various axial alignments of left lower limb in 137 normal Indian adult population with a mean age of 25 years which includes 122 males and 15 females. The proximal femoral geometry including FNSA with a mean of 129.4 degree in frontal plane and 175.6 degree in sagittal plane and average MPFA was 85.6 degree. Further MPFA being 85.4 degree in males and 87.5 degree in females shows significant increased angles in females (p value less than 0.001). (Table 2) The distal femoral geometry with mean MLDFA of 89.6 degree has propensity of decreasing valgus orientation complementing to it the

MPTA OF 83.7degree and that making the medial tibia plateau inclination of 6 degree. Further MPTA being 83.6 degree in males and 84.9 degree in females shows a significant increased angle in females (p-value of <0.001). (Table 3) The joint lines of knee joint are not parallel rather they have a mean convergence angle of 1.2degree. The MTFA with a 1.9degree varus and a TFA with a 5 degree of valgus show significant increasing mechanical varus and decreasing anatomical valgus propensity. Females in particular had a MTFA of 1.1degree varus and ATFA of 6.5degree valgus. The mean anatomical and mechanical LDFA were 85.9 (Range 84-89) and 89.6 (Range 87-94) respectively. The mean LDTA was 89.2 (Range 85-93). The mean PPFA was 89.8 (Range 86-95). The mean PDFA was 85.7 (Range 80-90). The mean PPTA was 81.3 (Range 76-86). The mean ADTA was 83.5 (Range 80-88). The mean MTFA was 1.8 (Range 0-3). The mean ATFA was 5.2 (Range 4-8). The mean JLCA was 1.2 (Range 1-3). Table 1 summarizes all measured angles in this study.

Table 1: Various lower limb measurements in Indian adult population

Angles	Mean	Range	Standard deviation(SD)
FNSA(FRONTAL)	129.4	120-137	3.6
FNSA(SAGGITAL)	175.6	167-180	2.9
MPFA	85.6	79-90	2.4
ALDFA	85.9	84-89	1.1
MLDFA	89.6	87-94	1.30
MPTA	83.7	80-86	1.4
LDTA	89.1	85-93	1.9
PPFA	89.8	86-95	2.00
PDFA	85.7	80-90	2.3
PPTA	81.3	76-86	2.3
ADTA	83.5	80-88	2.2
MTFA	1.8	0-3	0.8
ATFA	5.2	4-8	0.9
JLCA	1.2	1-3	0.8

Table 2: AMPFA of study participants (N=137)

	Mean	SD	Min	Max	p value*
Male	85.4	2.3	79	90	0.001
Female	87.5	1.9	84	90	
Overall	85.6	2.4	79		

Table 3: AMPTA of study participants (N=137)

	Mean	SD	Min	Max	p value*
Male	83.6	1.3	80	86	<0.001
Female	84.9	1.4	82	86	
Overall	83.7	1.4	80	86	

Discussion

Orthopaedic procedures often involve correction of a deformity. Knee operations such as high tibial osteotomy, total knee arthroplasty, total hip arthroplasty often aim at correction of a deformity toward normal alignment. However, such normal anatomy remained an area of controversy because of the substantial ethnical variations. Modifications applied by designers of a total knee arthroplasty systems are based on alignment values documented by Moreland *et al*. on Caucasians and Hsu *et al*. on white subjects [6, 7]. Moreland *et al*. described a 3 degree varus alignment of the knee joint surface with reference to mechanical axis of tibia [6] In this study Indian population had the significantly higher medial inclination. This was contrary to what observed in white, Iranian and Chinese studies [6-9]. (Table 4) Tang *et al*. described a 5degree varus alignment in Chinese population [9]. The amount of this medial inclination should be taken into consideration while determining the amount of femoral cut external rotation in TKA if the tibial cut is placed perpendicular to the mechanical axis. It seems that an average of 5 degrees of external rotation of the femoral component may produce a rectangular flexion gap in Indian patients rather than a classically defined 3degree angle.The study showed a major difference between the MLDFA, ALDFA, MPTA, ADTA, ATFA as published by Moreland *et al*. Moreland *et al*. in their study found that, LDFA is sometimes assumed to be equal to the MPTA [6]. In contrary, we obtained unequal values of LDFA (89 degree) and MPTA (84 degree). Therefore, we propose to measure LDFA and MPTA discretely. In the present study over Indian population, mechanical axis of the femur and the tibia did not yield a straight line. This was similar with the findings of Tang *et al.* in their study with Chinese Population [9]. In contrast to the general consensus described that mechanical axis of femur and tibia are aligned. To justify this difference, two points should be noticed. One is more medial inclination (MPTA) of the knee beside increased joint line congruence angle (JLCA) and the other is apparently higher amount of tibia varus in Indian population that is less scrutinized in similar studies. MPTA and JLCA can be implied as an indicator of medial joint inclination. The angle formed by the mechanical axis of the femur and the femoral anatomical has implication in performing proper distal femoral cut during total knee arthroplasty. The use of an intramedullary guide for the distal femoral cut is currently standard practice in total knee arthroplasty [10]. Most of the instrumentation systems offer a standard 6-degree cutting block to guide the distal femoral cut in order to match the commonly reported 6-degree physiological valgus angulation of the femur Moreland *et al*. [6]. But in this study the physiological femur valgus angle is 5degree. We recommend the designers to note this point while designing implants for Indian population. Our method with simple radiography is cost effective module compared to augmented reality hologram systems and artificial intelligence system in presurgical planning especially in developing countries like India [11, 12]. The intramedullary guide is represented in our study by femoral anatomical axis, which did not intersect the mechanical axis of the femur at the centre of the knee. In order to produce a distal femoral cut that is perpendicular to the mechanical axis of the femur is 6 degrees of valgus angulation with respect to femoral anatomical axis of the femur the entry point of the intramedullary rod should be shifted medially [13]. Epidemiological studies imply geographical variation in prevalence of osteoarthritis. The ratio of knee hip osteoarthritis is reported 9:1 for Chinese as an example of Asian population, comparing with 3:1 for white individuals of United States, and 1:2 for Swedish as well higher rates of medial compartment osteoarthritis in Indian population [14-16]. The racial differences in the axial alignment of the lower extremity especially distal femoral and proximal tibial varus angulation tendency may justify the discrepancy. Along with Chinese study by Tang.et.al, we found larger knee joint- obliquity angle and increased MPTA resulting in more varus alignment of the knee joint in the present study [9]. This altered alignment can be attributed as a cause of increased prevalence knee osteoarthritis (especially medial compartment osteoarthritis knee).

Various axial alignments difference between the Western and Indian ethnic population highlighted in this study has a major bearing on the various orthopedic implants used on daily basis

for fracture fixation and management. Commonly used implants for the management of proximal femoral fractures like dynamic hip screw, proximal femoral nail should be manufactured with proper proximal angulation to match specifically the femoral neck shaft angle and MPFA of Indian population for better operative ease and better biomechanical stability. The dynamic hip screw is commonly available with a plate barrel angle of 135-140 degree [17]. We recommend a 130degree angulation for biomechanics and correlation with neck shaft angle of Indian population. The neck shaft angle and MPFA play a very important role in deciding the horizontal and vertical offset of total hip replacement prosthesis [18]. We recommend that the implant manufacturers take these values into account while designing implants for Indian population for better biomechanics and reducing the chance of implant failures.

Deformity correction surgeries have a major chunk in the field of orthopedics and during correction of a deformity of the lower limb it is a standard practice to take the normal axial angles of the opposite normal limb as standard or in case both limbs are deformed then mean angles given in standard books are taken into consideration and using axial angles published in various standard journals literatures are of Western population and this study shows a major difference between them and the normal axial angles of Indian ethnic group. Various angles MPFA and NSA played a very important role in correction of coxa valga and coxa vara [19]. LDFA and MPTA play important role in correction of genu valgum, genu varum and fixed flexion deformity of knee [20]. Limitation to our study was small sample size and control group. Further we couldn't calculate separate significant values in males and females respectively due to improper proportion of gender distribution.

Conclusion

Present study shows that North West Indian adult population has a more varus alignment of the knee joint which substantiates the high pre-valance of medial compartment knee osteoarthritis in this population, current designs of total knee replacement should take these differences into consideration to provide optimal Outcomes. Further we suggest large multi-centric studies with larger sample size needs to support our study.

Funding

No funding was required in this study.

Conflict of interest

The authors declare that they have no competing interest.

Availability of data and material

Not applicable

Code availability

Not applicable

Ethics approval

Ethical committee approval number: 195/MC/EC/2018

Consent to participate

All patients gave consent to study

Consent for publication

All authors and patients gave consent to publication

Table 4: Comparative table of various axial alignments with different ethnic groups

Various axial angles (degree)	Present study	Moreland (Caucasian) [6]	Tang *et al*. (Chinese) [9]	Hsu *et al*. (White) [7]	Jabalameli M *et al*. (Iranian) [8]
FNSA (FRONTAL)	129.4±3.6				
FNSA (SAGITTAL)	175.6±2.9				
MPFA	85.6±2.4				
ALDFA	85.9±1.1				83.2±3
MLDFA	89.6±1.3				
MPTA	83.7±1.4				
LDTA	89.1±1.9	90.7±3.2	91.4±3.1		91.7±2.8
PPFA	89.8±2				
PDFA	85.7±2.3				
PPTA	81.3±2.3				
ADTA	83.5±2.2				
MTFA	1.8±0.8	1.5	2.2	2.3	
ATFA	5.2±0.9				
JLCA	1.2±0.8				

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