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Determination Of The Offset Of Tibial Plateau In Relation To The Tibial Shaft In Indian Population.

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ABSTRACT

Tibial plateau fractures are complex injuries of the knee. The tibial plateau is one of the most critical load-bearing areas in the human body. Early detection and appropriate treatment of these fractures are essential in minimizing patient's disability in range of movement, stability and reducing the risk of documented complications. To determine the relation of the tibial plateau offset in relation to the tibial shaft in a normal Indian population using 124 slice computed tomography. This Cross-sectional Study was conducted in year December-2019- June 2021 At PSG Institute Of Medical Sciences And Research Coimbatore. In the CT images of the tibia, using Axial cuts, the axis of the medullary cavity is determined. At a distance of seven cm from the tibial plateau, the center of the cross-section of the tibia is marked. And a similar point is taken at a distance of eleven cm from the tibial plateau. The line joining these two points is extended proximally and distally represents the anatomic axis of the tibial shaft. Correlation analysis (the Pearson correlation coefficient) was performed to determine the associations between the dimension of the tibial plateau and the offset of the tibial shaft from the tibial plateau, P value <0.05 was considered as statistically significant. The Mean Lateral Medial Dimension of the Tibial Plateau was found to be 7.3±0.04. this was found to be similar across the age categories(p=0.484) but was significantly lower in females in comparison to the male counterparts (6.78 ± 0.05 and 7.55 ± 0.04 respectively) (p<0.001). The Mean Posterior Anterior Dimension of the Tibial Plateau was found to be 5.11 ±0.03. this was found to be similar across the age categories (p=0.308) but was significantly lower in females in comparison to the male counterparts (4.76 ± 0.04 and 5.27 ± 0.03 respectively) (p<0.001). The Mean Lateral Medial Distance of the Tibial Plateau was found to be 3.89 ± 0.03. this was found to be similar across the age categories(p=0.189) but was significantly lower in females in comparison to the male counterparts (3.46 ± 0.04 and 3.89 ± 0.03 respectively) (p<0.001). The Mean Posterior Anterior Distance of the Tibial Plateau was found to be 3.22 ±0.03. This was found to be significantly lower in extreme groups (p=0.03) across the age categories and also was significantly lower in females in comparison to the male counterparts (2.97 ± 0.05 and 3.33 ± 0.04 respectively) (p<0.001). The Mean Lateral Medial Offset of the Tibial Plateau was found to be 0.10 ± 0.02 towards the Medial direction. This was found to be pointing towards the medial direction in all age categories with offset significantly higher in more than 70 years age group (p = 0.028) but was similar in females and males (p= 0.382) towards the medial direction. The Mean Posterior Anterior Offset of the Tibial Plateau was found to be 0.67 ± 0.03 towards the Anterior direction. This was found to be pointing towards the Anterior direction in all age categories with offset significantly lower in more than 70 years age group (p<0.001) but was similar in females and males (p= 0.114) towards the Anterior direction. The Mean Offset of the tibial shaft from the tibial plateau was found to be 0.75 ± 025. this was found to be significantly lower in the more than 70 years category (p= 0.003) and was significantly lower in females in comparison to the male counterparts (0.65± 0.04 and 0.79 ± 0.03 respectively) (p=0.01). Accordingly, an anterior offset tibial keel or stem seems to be a more suitable choice for Indian patients undergoing primary or revision total knee arthroplasty. In the case of medial-lateral offset, we need both medial and lateral offset stemmed implant as the medial offset is seen in 86 knees and the lateral offset is seen in 39 knees almost ¼ th of the study subjects.

Keywords: Tibial shaft axis, tibial plateau, total knee arthroplasty, computed tomography

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INTRODUCTION

Total knee arthroplasty is one of the mostcommon surgeries being done for arthritis of the knee joint. Though there is no maintenance register of the patient who underwent total knee arthroplasty in India, the practice of developing a register has been introduced recently. It shows the increase in Total knee arthroplasty surgeries nowadays [1]. The long-standing success of the surgery relies on the life of the prosthesis which in turn depends on the accurate placement of the implant [2-4].

There exist an offset between the proximal tibia and the tibial shaft. This offset varies with various ethnic groups [5, 6]. The presently available implants are based on the anatomic studies of the western population. Previous studies have suggested that the relation of the tibial shaft is in the anterolateral offset direction in relation to tibial plateau in Chinese and Korean population and medial offset in Caucasian and western population [7-9]. There are no studies in the Indian population to study the proximal tibial offset.

MATERIALS AND METHODS

Methods

This Cross-sectional Study was conducted in year December-2019- June 2021 at PSG Institute of Medical Sciences and Research Coimbatore. In the CT images of the tibia, using Axial cuts, the axis of the medullary cavity is determined. At a distance of seven cm from the tibial plateau, the center of the cross-section of the tibia is marked. And a similar point is taken at a distance of eleven cm from the tibial plateau. INCLUSION CRITERIA: The patients who have undergone lower limb computed tomography in our hospitalthat is stored in our PACS system. EXCLUSION CRITERIA: Patients who have a fracture and significant bone abnormality are excluded.

Methodology

After the ethical committee approval, the computed tomography images of the tibia of the patients who underwent CT and images stored in the hospitalPACS system matching the inclusion and exclusion criteria were selected. Axis of the tibial shaft: In the CT images of the tibia, using Axial cuts, the axis of the medullary cavityis determined. At a distance of seven cm from the tibial plateau, the center of the cross-section of the tibia is marked. And a similar point is taken at a distance of eleven cm from the tibial plateau. The line joining these two points is extended proximally and distally represents the anatomic axis of the tibial shaft. To find the center of the proximal tibia at the level of the tibial plateau. According to Akagi et al observation in the Asian population, the line connecting the middle of the posterior cruciate ligament to the medial border of patellar tendon attachment is parallel to the anteroposterior axis of the rotational alignment of the tibial tray. The tibial tray should cover maximal coverage of the tibial plateau, for that, a rectangle is placed in the axial cut CT of the tibial plateau which represents thetibial tray with its sides adjusted to the outer cortex of the tibial plateau in anterior, medial and lateral sides and the posterior cortex of the medial tibial plateau is taken as the posterior limit for the rectangle. The anteroposterior axis is parallel to the rotational alignment of the axis. The center of the rectangle is marked which represents the center of the tibial plateau.

Statistical Analysis

Data entry was made in the Microsoft Excel 2007 softwareand Analysis was done with IBM SPSS (International Business Machines Corporation -Statistical Package for the Social Sciences) v.23.1 Windows package. Continuous variables are expressed in Mean ± SD. Categorical variables are expressed in percentages with 95% Confidence interval (CI).Correlation analysis (the Pearson correlation coefficient) was performed to determine the associations between the dimension of the tibial plateau and the offsetof the tibial shaft from the tibial plateau. P value <0.05 was considered as statistically significant.

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RESULTS

Table 1: Characteristics of the study participants (n=172)

Variable	Category	Number	Percentage
Age	< 40 years	8	4.7%
	40-49 years	29	16.9%
	50-59 years	40	23.3%
	60-69 years	59	34.3%
	>= 70 years	36	20.9%
Gender	Male	117	68.0%
	Female	55	32.0%

In this study, we had studied CT images of 172 participants. The characteristics of the study participants are depicted in the Table1. The mean age of the participants was 60.21 with the age ranging from 21 to 87.

Table 2: Data of Lateral Medial Dimension reading across Age and Gender (n=172)

	No.	Mean	StandardError	Minimum	Maximum	p Values †
Male	117	7.55	0.04	6.34	8.71	
Female	55	6.78	0.05	6.02	7.60	<0.001***
< 40 years	8	7.44	0.12	6.85	7.96	
40-49 years	29	7.28	0.09	6.10	8.09	
50-59 years	40	7.18	0.08	6.12	7.87	0.484
60-69 years	59	7.35	0.07	6.02	8.71	
>= 70 years	36	7.33	0.09	6.40	8.45	
Total	172	7.30	0.04	6.02	8.71	-

†- Using independent t test for Gender and ANOVA for Age categories,
* Significant at p <0.05level; **- Significant at p <0.01level; ***- Significant at p <0.001 level

The Mean Lateral Medial Dimension of the Tibial Plateau was found to be 7.3± 0.04. this was found to be similar across the age categories(p=0.484) but was significantly lower in females in comparison to the male counterparts (6.78 ± 0.05 and 7.55 ± 0.04 respectively) (p<0.001).

Table 3: Data of Posterior Anterior Dimension reading across Age and Gender (n=172)

	n	Mean	StandardError	Minimum	Maximum	p Values †
Male	117	5.27	0.03	4.17	6.49	<0.001***
Female	55	4.76	0.04	4.06	5.49	
< 40 years	8	5.14	0.09	4.81	5.56	0.308
40-49 years	29	5.06	0.08	4.19	6.05	
50-59 years	40	5.04	0.07	4.17	5.91	
60-69 years	59	5.09	0.06	4.06	6.49	
>= 70 years	36	5.24	0.07	4.56	6.17	
Total	172	5.11	0.03	4.06	6.49	-

†- Using independent t test for Gender and ANOVA for Age categories,
* Significant at p <0.05level **- Significant at p <0.01level ***- Significant at p <0.001 level.

The Mean Posterior Anterior Dimension of the Tibial Plateau was found to be 5.11 ± 0.03. this was found to be similar across the age categories (p=0.308) but was significantly lower in females in comparison to the male counterparts (4.76 ± 0.04 and 5.27 ± 0.03 respectively) (p<0.001).

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Table 4: Data of Lateral Medial Distance reading across Age and Gender (n=172)

	n	Mean	StandardError	Minimum	Maximum	p Values †
Male	117	3.89	0.03	3.15	5.00	<0.001***
Female	55	3.46	0.04	2.71	4.73	
< 40 years	8	3.75	0.12	3.15	4.23	0.189
40-49 years	29	3.74	0.07	2.89	4.72	
50-59 years	40	3.71	0.06	2.87	4.74	
60-69 years	59	3.71	0.04	2.71	4.48	
>= 70 years	36	3.89	0.07	3.21	5.00	
Total	172	3.75	0.03	2.71	5.00	-

†- Using independent t test for Gender and ANOVA for Age categories,
* Significant at p <0.05level; **- Significant at p <0.01level; ***- Significant at p <0.001 level

The Mean Lateral Medial Distance of the Tibial Plateau was found to be 3.89 ± 0.03. this was found to be similar across the age categories(p=0.189) but was significantly lower in females in comparison to the male counterparts (3.46 ± 0.04 and 3.89 ± 0.03 respectively) (p<0.001).

Table 5: Data of Posterior Anterior Distance reading across Age and Gender (n=172)

	n	Mean	StandardError	Minimum	Maximum	p Values †
Male	117	3.33	0.04	2.15	4.54	<0.001***
Female	55	2.97	0.05	1.90	3.72	
< 40 years	8	3.05	0.21	2.24	3.87	0.03*
40-49 years	29	3.39	0.07	2.15	4.23	
50-59 years	40	3.23	0.08	1.90	4.26	
60-69 years	59	3.25	0.05	2.20	4.54	
>= 70 years	36	3.05	0.07	2.36	4.28	
Total	172	3.22	0.03	1.90	4.54	-

†- Using independent t test for Gender and ANOVA for Age categories,
* Significant at p <0.05level; **- Significant at p <0.01level; ***- Significant at p <0.001 level

The Mean Posterior Anterior Distance of the Tibial Plateau was found to be 3.22 ± 0.03. This was found to be significantly lower in extreme groups (p=0.03) across the age categories and also was significantly lower in females in comparison to the male counterparts (2.97 ± 0.05 and 3.33 ± 0.04 respectively) (p<0.001).

Table 6: Data of Lateral Medial Offset reading across Age and Gender (n=172)

	n	Mean	StandardError	Minimum	Maximum	p Values †
Male	117	0.12	0.03	-0.67	1.12	0.382
Female	55	0.08	0.03	-0.61	0.64	
< 40 years	8	0.03	0.13	-0.60	0.47	0.028*
40-49 years	29	0.10	0.05	-0.19	0.77	
50-59 years	40	0.12	0.04	-0.61	0.83	
60-69 years	59	0.03	0.04	-0.67	0.53	
>= 70 years	36	0.22	0.05	-0.42	1.12	
Total	172	0.10	0.02	-0.67	1.12	-

†- Using independent t test for Gender and ANOVA for Age categories,
* Significant at p <0.05level; **- Significant at p <0.01level; ***- Significant at p <0.001 level

The Mean Lateral Medial Offset of the Tibial Plateau was found to be 0.10 ± 0.02 towards the Medial direction. This was found to be pointing towards the medial direction in all age categories with offset significantly higher in more than 70 years age group (p = 0.028) but was similar in females and males (p= 0.382) towards the medial direction.

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Table 7: Data of Posterior Anterior Dimension reading across Age and Gender (n=172)

	n	Mean	StandardError	Minimum	Maximum	p Values †
Male	117	0.70	0.04	-0.67	1.12	0.114
Female	55	0.60	0.05	-0.61	0.64	
< 40 years	8	0.48	0.20	-0.22	1.41	<0.001***
40-49 years	29	0.86	0.06	-0.17	1.37	
50-59 years	40	0.71	0.06	-0.36	1.56	
60-69 years	59	0.71	0.05	-0.65	1.67	
>= 70 years	36	0.44	0.06	-0.17	1.20	
Total	172	0.67	0.03	-0.65	1.67	-

†- Using independent t test for Gender and ANOVA for Age categories,
* Significant at p <0.05level; **- Significant at p <0.01level; ***- Significant at p <0.001 level

The Mean Posterior Anterior Offset of the Tibial Plateau was found to be 0.67 ± 0.03 towards the Anterior direction. This was found to be pointing towards the Anterior direction in all age categories with offset significantly lower in more than 70 years age group (p <0.001) but was similar in females and males (p= 0.114) towards the Anterior direction.

Table 8: Data of Mean Offset of the tibial shaft from the tibial plateau across Age andGender (n=172)

	n	Mean	StandardError	Minimum	Maximum	p Values †
Male	117	0.79	0.03	0.10	1.78	0.01*
Female	55	0.65	0.04	0.00	1.41	
< 40 years	8	0.65	0.14	0.23	1.38	0.003**
40-49 years	29	0.89	0.06	0.16	1.71	
50-59 years	40	0.76	0.05	0.13	1.44	
60-69 years	59	0.78	0.04	0.21	1.78	
>= 70 years	36	0.59	0.05	0.00	1.33	
Total	172	0.75	0.25	0.00	1.78	-

†- Using independent t test for Gender and ANOVA for Age categories,
* Significant at p <0.05level; **- Significant at p <0.01level; ***- Significant at p <0.001 level.

The Mean Offset of the tibial shaft from the tibial plateau was found tobe 0.75 ± 025. this was found to be significantly lower in the more than 70 years category (p = 0.003) and was significantly lower in females in comparison to the male counterparts (0.65 ± 0.04 and 0.79 ± 0.03 respectively) (p=0.01).

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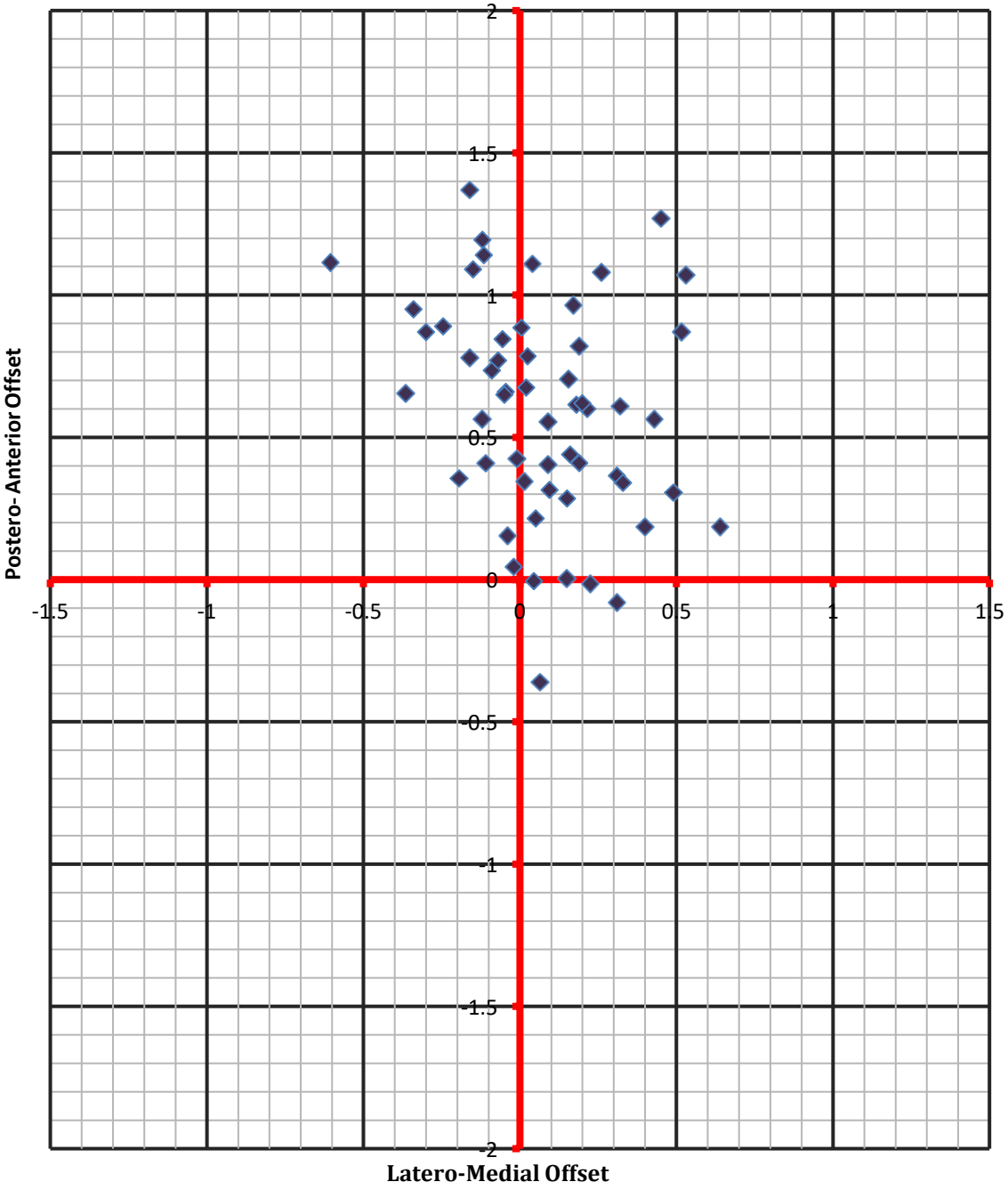
Figure 1: Depicting the Offset of the Tibial Shaft from Center of the Tibial Plateau.(n=172)



The cross point (0) of the mediolateral axis and anteroposterior axis represents thecenter of the Tibial Plateau.

Figure 1 depicting the Offset primarily in the Anterio Medial segment in the studypopulation. The distribution across gender and age is depicted in Figures 1-3.

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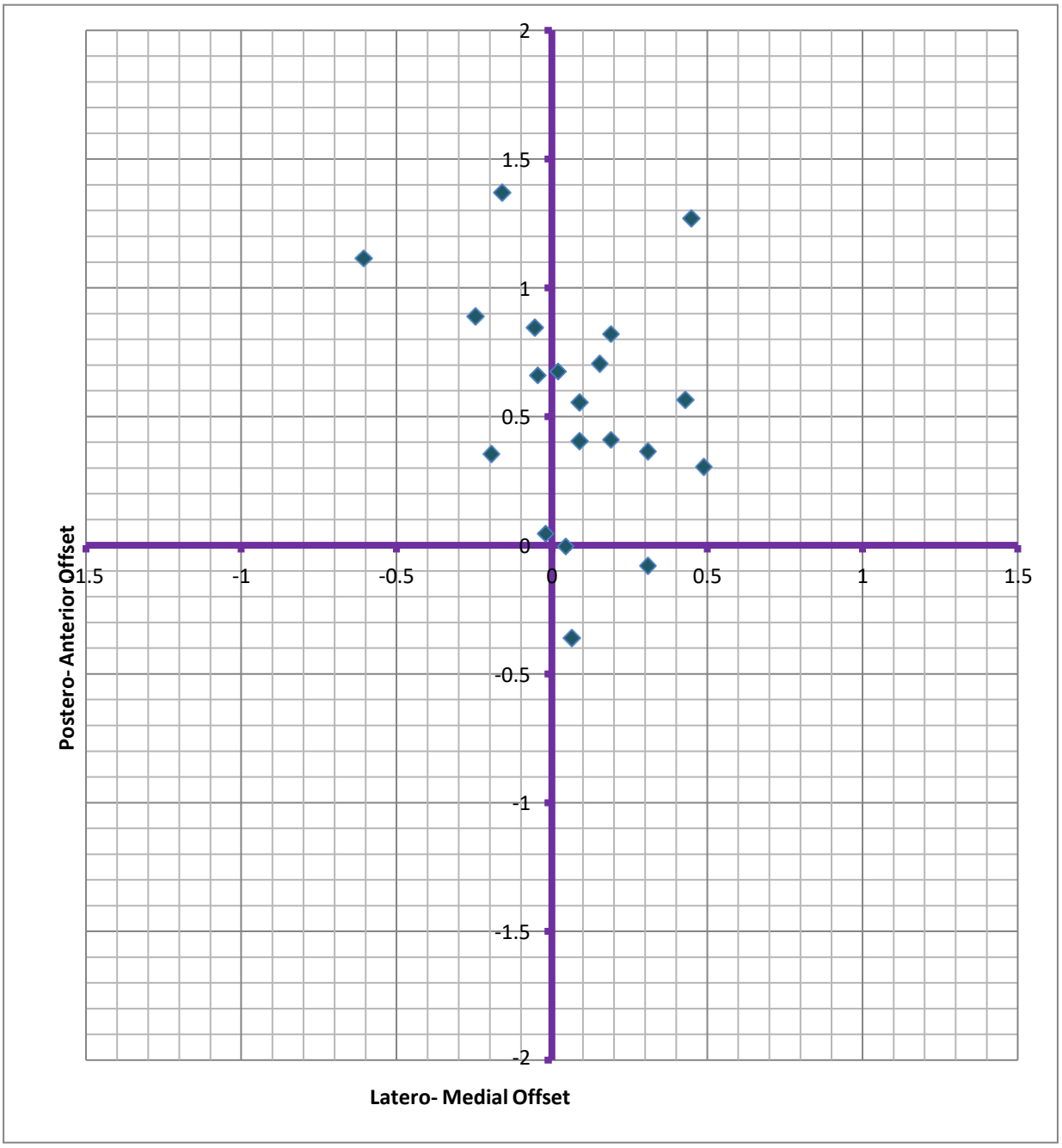
Figure 2: Depicting the Offset of the Tibial Shaft from Center of the TibialPlateau in males of the study population (n=117)



The cross point (0) of the mediolateral axis and anteroposterior axis represents the center of the tibial plateau.

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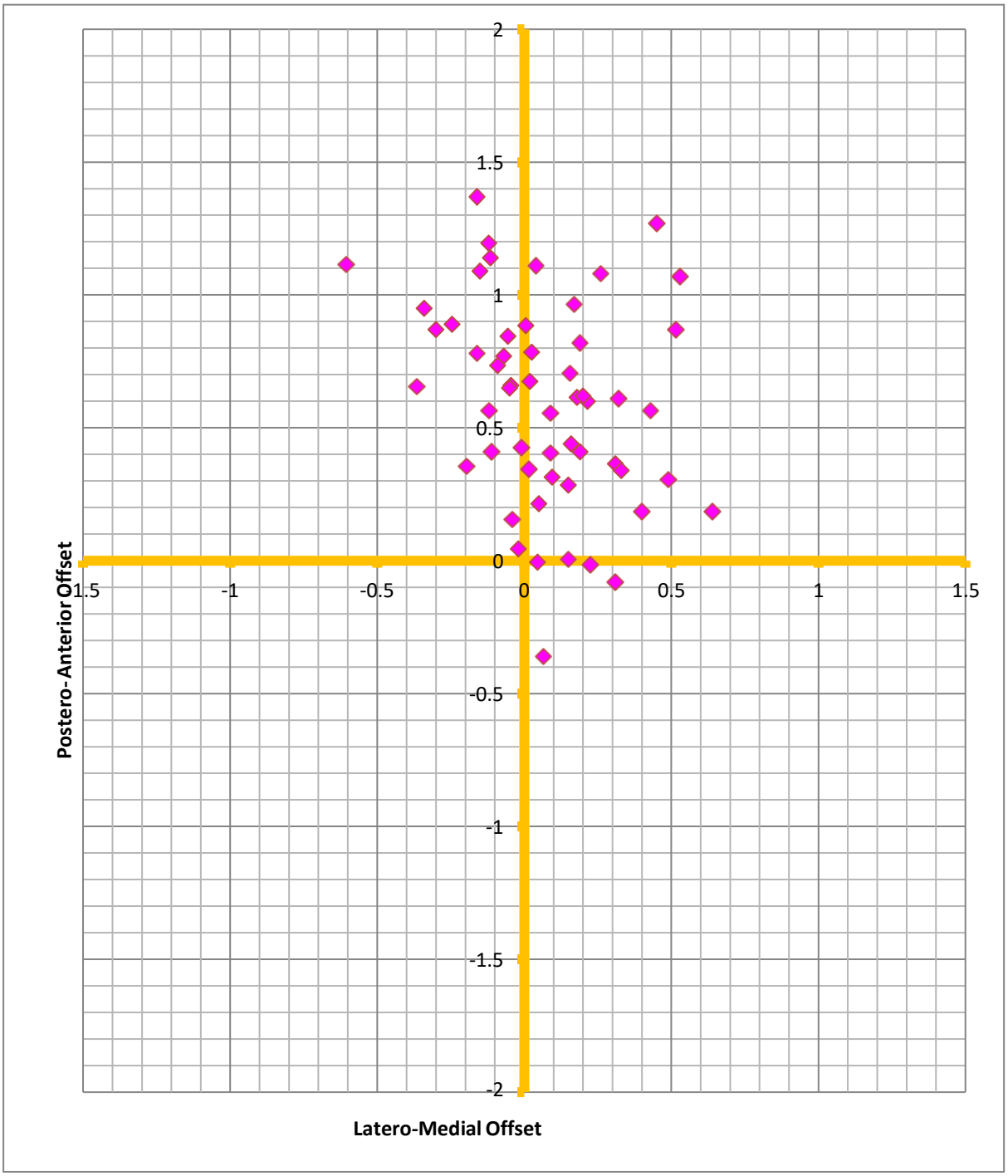
Figure 3: Depicting the Offset of the Tibial Shaft from Center of the TibialPlateau in Females of the study population (n=55)



The cross point (0) of the mediolateral axis and anteroposterior axis represents the center of the tibial plateau.

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DISCUSSION

In total knee arthroplasty, long stems are used so that they can provide support for a tibial component. It is advantageous in certain circumstances like a fracture, revision total knee arthroplasty. The offset stems have been made available so that there can be given maximal tibial coverage with orwithout minimal overhang. The designs of most of these stems are based on anatomic data of Western populations However, anatomic features of Indian populations differ from those of Western populations [10]. These morphologic differences of the tibia may be important to consider when designing a stemmed tibial component and also during implantation of the stem. Our results confirmed that the axis of the tibial shaft is not as same as the center of the tibial plateau in Indian study subjects. The offset of the tibial shaft from the tibial plateau averaged 7.5 mm when theresection level was just distal to the subchondral bone of the tibial plateau [11]. Abraham et al. performed total knee arthroplastyin twenty metaphysis where the offset of the center of the tibial shaft axis from the center of the tibial plateau 4.1 mm at the resection level of the fibular head. So both Abraham and our current observations suggest that a tibial component with an offset stem would be more suitable for Indian patients who need a tibial component with a long stem. We also noted that there was a large variation in the offset of the tibial shaft from the tibial plateau, ranging from 0mm (both the axes, the axis of the tibial shaft is and the center of the tibial plateau overlaps) to 17.8 mm, so it would bedesirable to have a wide range of offset stems available from 0 to 20 mm, in 2-mm or 4-mm increments [12].Previous western studies have revealed that theaxis of the tibial shaft is, on the average, located anteromedial to the center of the tibial plateau in the Western population, for whom a medially offset stem seems more suitable. The Chinese studies the relationship of the tibial shaft axis to the center of the tibial plateau was different as it is typically located anterolateral to the center of the tibial plateau in Chinese study subjects .The Korean studies the relationship of the tibial shaft axis to the center of the tibial plateau was different as it is typically located anterolateral to the center of the tibial plateau in Korean study subjects [13].

In Japanese studies, the relationship of the tibial shaft axis to thecenter of the tibial plateau was different as it is typically located anterolateral to the center of the tibial plateau in Japanese study subjects [14]. Pangaud C et all study, total knee arthroplasty was done with a medially offset stemmed tibial component, in those patients, contact between the keel tip and the medial tibial cortex was seen in sixteen knees, andcement was found to have leaked out of the breeched medial cortex of the tibia in one knee Therefore he presumed that an anterolaterally offset tibial keel or stem would be a better option for Korean (Asian) patients [15]. In our studies, the Mean Lateral Medial Offset of the Tibial Plateau was found to be 0.10 ± 0.02 towards the Medial direction. This was found to be pointing towards the medial direction in all age categories with offset significantly higher in more than 70 years age group ($p = 0.028$) but was similar in females and males ($p= 0.382$) towards the medial direction , The tibial shaft axis was located lateral to the center of the tibial plateau in 39 (1mm or more) out of 172 knee and medial to the center of the tibial plateau in 86 (1mm or more)knee and both the axis were at the sagittal plane in 47 patients [16]. The Mean Posterior Anterior Offset of the Tibial Plateau was found to be 0.67 ± 0.03 towards the Anterior direction. This was found to be pointing towards the Anterior direction in all age categories with offset significantly lower in more than 70 years age group ($p <0.001$) but was similar in females and males ($p= 0.114$) towards the Anterior direction. The tibial shaft axis was located posterior to the center of the tibial plateau in 6 (1mm or more) out of 172 knees. The tibial shaft axis was located anterior to the center of the tibial plateau in 155 (1mm or more) out of 172 knees. The tibial shaft axis was coinciding with the center of the tibial plateau in coronal plane 11(less 1mm) out of 172 knees [17.]The tibial shaft axis was coinciding to the center of the tibial plateau in both sagittal and coronal plane in only 3 (less 1mm) outof 172 knees. This shows that the tibial component with offset is important to be considered for long stem tibial component design [18]. The tibial shaft axis was located both anterior and medial to the center of the tibial plateau in 86 (1mm or more) out of 172 knees. The tibial shaft axis was located anterior and lateral to the center of the tibial plateau in 39 (1mm or more) out of 172 knees. it is almost 25% of the study population [19]. In our study, the offset of the tibial shaft from the tibial plateau inthe male group was significantly larger than that in the female group. The larger offsetin our male group was to be expected because the male study subjects generally had a larger tibial plateau than the female study subjects. However, the correlation was not strong between the tibial shaft offset and the tibial plateau dimension in either the sagittal or the coronal plane [20]. The Mean Offset of the tibial shaft from the tibial plateau was found to be 0.75 ± 025. this was found to be significantly lower in the more than 70 years category ($p = 0.003$) and was significantly lower in females in comparison to the male counterparts (0.65 ± 0.04 and 0.79 ± 0.03 respectively) ($p=0.01$). The Mean Lateral Medial Dimension of the Tibial Plateau was found to be 7.3± 0.04. this was found to be similar across the age

categories(p=0.484) but was significantly lower in females in comparison to the male counterparts (6.78 ± 0.05 and 7.55 ± 0.04 respectively) (p<0.001) [21]. The Mean Posterior Anterior Dimension of the Tibial Plateau was found to be 5.11 ± 0.03. this was found to be similar across the age categories (p=0.308) but was significantly lower in females in comparison to the male counterparts (4.76 ± 0.04 and 5.27 ± 0.03 respectively) (p<0.001). Therefore, the difference in offset between the sexes isgeometric instead of size-related. So during primary or revision total knee arthroplasty with a long stem extension, a male patient requires a larger stem offset than does a female patient [22]. It is not clear if aging itself leads to changes in knee morphology. In our study, the Mean Posterior Anterior Dimension of the Tibial Plateau was found to be 5.11 ± 0.03. this was found to be similar across the age categories (p=0.308) but was significantly lower in females in comparison to the male counterparts (4.76 ± 0.04 and 5.27 ± 0.03 respectively) (p<0.001) [23]. The Mean Lateral Medial Dimension of the Tibial Plateau was found to be 7.3± 0.04. this was found to be similar across the age categories(p=0.484) but was significantly lower in females in comparison to the male counterparts (6.78 ± 0.05 and 7.55 ± 0.04 respectively) (p<0.001). However, aging is a major contributor to the onset and progression of osteoarthritis.[24] The morphology of an arthritic knee, especiallyone with varus or valgus deformity, may be different from that of a normal knee.

Therefore, one should be cautious about applying the results of this study to patients with severe knee deformity. Naturalized implants according to the individualare the best in giving long-term results, but they may not be cost effective [25].

Limitation

The limitations of our study were that the landmarks on computed tomography imaging scans are not as clearly defined as those on MRI scans in defining the patellar tendon and this could have affected the measurements. However, the reproducibility of our measurements was demonstrated to be acceptable and the relationship between the tibial shaft axis and the center of the tibial plateau was not influenced. We did not measure the medial and lateral tibial anteroposterior distance separately, so we are not able to compare and analyze the asymmetry of both the tibial condyles. Another limitation was that our study subjects who were having a clinical condition and comorbidity cannot be identified. we were not able to clinically examining the patient for comparing the varus /valgus abnormality.

CONCLUSION

In conclusion, we have described the morphology of the proximal part of the tibia as measured on computed tomography, we observed a large variation and mostly the tibial shaft axis is inoffset from the tibial plateau. The tibial shaft axis was located anterior to the center of the tibial plateau in a majority of our Indian subjects. Accordingly, an anterior offset tibial keel or stem seems to be a more suitable choice for Indian patients undergoing primary or revision total knee arthroplasty. In the case of medial-lateral offset, we need both medial and lateral offset stemmed implant as the medial offset is seen in 86 knees and the lateral offset is seen in 39 kneesalmost ¼ th of the study subjects.

REFERENCES

[1] Pachore JA, Vaidya SV, Thakkar CJ, Bhalodia HKP, Wakankar HM. ISHKS joint registry: A preliminary report. Indian J Orthop. 2013;47(5):505–9.

[2] Schroer WC, Berend KR, Lombardi AV, Barnes CL, Bolognesi MP, Berend ME, et al. Why are total knees failing today? Etiology of total knee revision in 2010 and 2011. J Arthroplasty. 2013 Sep;28(8 Suppl):116–9.

[3] Lee RW, Volz RG, Sheridan DC. The role of fixation and bone quality on the mechanical stability of tibial knee components. Clin Orthop. 1991 Dec;(273):177–83.

[4] Bourne RB, Finlay JB. The influence of tibial component intramedullary stems and implant-cortex contact on the strain distribution of the proximal tibia following total knee arthroplasty. An in vitro study. Clin Orthop. 1986 Jul;(208):95–9.

[5] Nagamine R, Miura H, Bravo CV, Urabe K, Matsuda S, Miyanishi K, et al. Anatomic variations should be considered in total knee arthroplasty. J Orthop Sci Off J Jpn Orthop Assoc. 2000;5(3):232–7.

[6] Hicks CA, Noble P, Tullos H. The anatomy of the tibial intramedullary canal. Clin Orthop. 1995 Dec;(321):111–6.

[7] Yoo JH, Kang YG, Chang CB, Seong SC, Kim TK. The relationship of the medially-offset stem of the

tibial component to the medial tibial cortex in total knee replacements in Korean patients. J Bone Joint Surg Br. 2008 Jan;90(1):31– 6.
[8] Tang Q, Zhou Y, Yang D, Xu H, Liu Q. The offset of the tibial shaft from the tibial plateau in Chinese people. J Bone Joint Surg Am. 2010 Aug 18;92(10):1981–7.
[9] Yun X-D, An L-P, Jiang J, Mao J-J, Wang C-F, Wang J, et al. The offset of the tibia plateau of osteoarthritis patients: a single-center study. Int J Clin Exp Med. 2015;8(9):16907–13.
[10] Danzig LA, Newell JD, Guerra J, Resnick D. Osseous landmarks of the normal knee. Clin Orthop. 1981 May;(156):201–6.
[11] Kwak DS, Surendran S, Pengatteeri YH, Park SE, Choi KN, Gopinathan P, et al. Morphometry of the proximal tibia to design the tibial component of total knee arthroplasty for the Korean population. The Knee. 2007 Aug;14(4):295–300.
[12] Hitt K, Shurman JR, Greene K, McCarthy J, Moskal J, Hoeman T, et al. Anthropometric measurements of the human knee: correlation to the sizing of current knee arthroplasty systems. J Bone Joint Surg Am. 2003;85-A Suppl4:115–22.
[13] Insall JN, Scott WN, Diduch DR, Iorio R, Long WJ, Elsevier (Amsterdam). Insall & Scott Surgery of the knee. Vol. 1 Vol. 1. Philadelphia: Elsevier; 2018.
[14] Medda S, Kundu R, Sengupta S, Pal AK. Anatomical variation of posterior slope of tibial plateau in adult Eastern Indian population. Indian J Orthop. 2017;51(1):69–74.
[15] Pangaud C, Laumonerie P, Dagneaux L, LiArno S, Wellings P, Faizan A, et al. Measurement of the Posterior Tibial Slope Depends on Ethnicity, Sex, and Lower Limb Alignment: A Computed Tomography Analysis of 378 Healthy Participants. Orthop J Sports Med [Internet]. 2020 Jan 24
[16] Khattak MJ, Umer M, Davis ET, Habib M, Ahmed M. Lower-limb alignment and posterior tibial slope in Pakistanis: a radiographic study. J Orthop Surg Hong Kong. 2010 Apr;18(1):22–5.
[17] Pal CP, Singh P, Chaturvedi S, Pruthi KK, Vij A. Epidemiology of knee osteoarthritis in India and related factors. Indian J Orthop. 2016 Sep;50(5):518– 22.
[18] Kumar H, Pal CP, Sharma YK, Kumar S, Uppal A. Epidemiology of knee osteoarthritis using Kellgren and Lawrence scale in Indian population. J Clin Orthop Trauma. 2020 Feb;11(Suppl 1):S125–9.
[19] March L, Smith EUR, Hoy DG, Cross MJ, Sanchez-Riera L, Blyth F, et al. Burden of disability due to musculoskeletal (MSK) disorders. Best Pract Res ClinRheumatol. 2014 Jun;28(3):353–66.
[20] Vaidya SV, Ranawat CS, Aroojis A, Laud NS. Anthropometric measurements to design total knee prostheses for the Indian population. J Arthroplasty. 2000 Jan 1;15(1):79–85.
[21] Gandhi S, Singla RK, Kullar JS, Suri RK, Mehta V. Morphometric Analysis of Upper End of Tibia. J Clin Diagn Res JCDR. 2014 Aug;8(8):AC10–3.
[22] Mahfouz M, Abdel Fatah EE, Bowers LS, Scuderi G. Three-dimensional Morphology of the Knee Reveals Ethnic Differences. Clin Orthop. 2012 Jan;470(1):172–85.
[23] Hashemi J, Chandrashekar N, Gill B, Beynnon BD, Slauterbeck JR, Schutt RC, etal. The geometry of the tibial plateau and its influence on the biomechanics of the tibiofemoral joint. J Bone Joint Surg Am. 2008 Dec;90(12):2724–34.
[24] Miyatake N, Sugita T, Aizawa T, Sasaki A, Maeda I, Kamimura M, et al. Comparison of intraoperative anthropometric measurements of the proximal tibia and tibial component in total knee arthroplasty. J Orthop Sci Off J Jpn Orthop Assoc. 2016 Sep;21(5):635–9.
[25] Incavo SJ, Ronchetti PJ, Howe JG, Tranowski JP. Tibial plateau coverage in total knee arthroplasty. Clin Orthop. 1994 Feb;(299):81–5.