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MRI based Morphometric analysis of tibial Plateau in Pakistani population: A cross sectional survey

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How to site this: Iram Zakria, Maleeha Zafar, Rabia Waseem, Salma Ambreen Shahab, Asma Hafeez, Iram Tassaduq. MRI based Morphometric analysis of tibial Plateau in Pakistani population: A cross sectional survey PAMS 2025; 1(1):08-18
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Abstract

Objective: Rationale of the study was to offer a basis for individualized implant/prosthesis adjustment, to assess the anthropometric data of the proximal tibial plateau in the Pakistani population using magnetic resonance imaging (MRI). Our hypothesis is that currently available tibial components in the market do not meet the requirements of our population and there is need of newly designed tibial component to match the needs of local population.

Methods: Magnetic resonance imaging is used to take anthropometric data from the proximal tibia. Data is taken from 121 knees (28 women and 93 men) in Pakistani subjects. Among the measured parameters were, "*Mediolateral, middle anteroposterior, medial and lateral anteroposterior dimensions and the aspect ratio of the resected proximaltibial surface"*. All morphological data were compared with the dimensions of four contemporary tibial implants, including *asymmetric and symmetric design* types.

Results: The dimensions of the tibial plateau of Pakistani knees demonstrated significant differences in AP, ML, MAP, LAP, CM & CL according to gender ($P < 0.05$). Pearson coefficient correlation test revealed significant negative correlation (-0.7) between AR and AP dimension of tibial specimens irrespective of gender. However huge proportion of tibial implants this study tend to overhang or under hang mediolaterally.

Conclusion: We found that the morphological measurements of tibial components didn't match with the local tibial specimens, once compared with tibial components of commonly used TKR implants. Our data could provide the basis for designing the optimal tibial component for this population, required for best fit.

Keywords: *Total knee arthroplasty (TKA), total knee replacement (TKR), tibial plateau anthropometry, Tibial component, Magnetic resonance imaging (MRI)*

Introduction

The primary functions of the human lower limbs are movement and weight transmission. In addition to maintaining an erect, ambulatory standing position, these functional requirements have made the inferior extremities stronger and more stable. They have also changed the mechanical and functional requirements of all skeletal structures in comparison to the superior extremities[1].Humans may bear more weight when

their knees are extended. It is widely known how the anteroposterior and mediolateral dimensions of the main tibial sections relate to the various weight-bearing scenarios.[2] Knee injuries and arthritis are rather prevalent and are often treated with surgery. An in-depth anatomical research of this pertinent surgical sector would aid in the design of necessary interventions in a variety of pathological and degenerative disorders of the knee joint, as knee joint surgeries are technically challenging and quickly changing procedures.[3]

For severe knee osteoarthritis, knee arthroplasty is the recommended surgical option for pain alleviation and function restoration. A successful total knee arthroplasty (TKA) requires maximum tibial bone coverage with the right implant size, precision bone cutting, and proper soft tissue balancing.[4]

Direct and indirect approaches are typically employed for the morphometric analysis of knee joints. The direct method measures dry cadaveric bone with Vernier calipers and rulers. The indirect approach also makes use of three-dimensional (3D) models, magnetic resonance imaging (MRI), and computed tomography scans (CT) images. The benefit of the latter approach is that it is carried out digitally, which spares the specimen from damage. Additionally, we may obtain the patient's demographic information, which is not feasible when using dry cadaveric bones. Nowadays, morphometric studies of the knee joint frequently use 3D models.[5]

TKA usage is probably becoming more common in most populations worldwide.[6] However, currently no published information is available about proximal tibias anthropometric measurements for our population, and no research has assessed whether commercially available tibial components fully meet our population's needs. In order to offer a basis for individualized implant/prosthesis adjustment, the current study is directed to make a fair assessment of the proximal tibial plateaus anthropometric data from the Pakistani population by employing the magnetic resonance imaging (MRI).

Methodology

This is MRI based, retrospective, cross sectional descriptive study which was carried out in Iqbal Memorial Hospital Jhang in collaboration with Hitec Institute of Medical Sciences. All the patients who required MRI due to knee pain, uncertain history, and physical examination according to scientific indications with normal MRI report within the age range of 18-60 years were enrolled in the present study. Morphologic data from the proximal tibia of 121 knees (28 women and 93 men) were analyzed, wherein one knee of each subject was studied (left or right, as chosen randomly).

MRI Measurements

MRI images of each knee were obtained using a 0.3 Tesla Hitachi Airis 2 comfort. Knee was scanned after being relaxed and stabilized in the extended position in the leg holder with the subject in supine position. In order to reduce the chance of errors in measurement the leg holder is used to keep the leg in extended position throughout scanning, as limb rotations might affect the measurements.

MRI sections were taken in axial, coronal and sagittal planes through the resection level of proximal tibia and the epicondylar axis of the femur were obtained. Digital radiological system (Hitachi Airis 2 comfort) is employed to take simulated proximal tibial resections and then radiological measurements were taken virtually on each subject.Digital radiological system is used to get multislice images, further simulated resection levels and cutting thickness were determined, and the simulated axial slices were taken perpendicular to the mechanical axis of the tibia with a 7° posterior slope from 8 mm below the highest point of lateral tibial plateau (Fig.1).

Proximal tibial dimensions were measured using a standardized protocol. The ML and AP dimensions were taken for a selected slice to assess the gross size of proximal tibial surface. “The ML dimension is a line drawn in the axial plane to the tibial cut surface, which is parallel to the epicondylar axis of the femur and is the longest mediolateral distance of the proximal tibia” (Fig. 2) “It is formed by a line between the lateral epicondylar prominence and the medial sulcus of the medial epicondyle”, as described by Karimi et al., 2019, according to which a set of morphological metrics were calculated as follows:[7]

Mediolateral (ML) width

The ML dimension was taken as the “longest ML width of the resected proximal tibial surface, drawn

parallel and collinear to the surgical epicondylar axis of the femur".

Anteroposterior (AP) length

"The AP dimension was taken as the length of a line drawn perpendicular and passing through the midpoint of the ML line."

Medial anteroposterior (MAP) and lateral anteroposterior (LAP)

"The MAP dimension and LAP dimension were defined as the longest lines drawn parallel to the AP line and perpendicular ML lines that connect the most anterior and the most posterior parts in the medial and lateral compartments in the resected tibial surface, respectively."

- Medial to center distance (CM) and lateral to center distance (CL): "The MAP and LAP distances to the central point are called CM and CL," respectively
- Aspect Ratio: The resected tibial plateau aspect ratio has been defined as "ML/AP ratio, and for each compartment (compartment aspect ratio) it has been calculated as MAP/ML and LAP/ML in the medial and lateral compartments, respectively."

All the measurements were recorded in millimeters using the "Hitachi imaging software version 5.0"

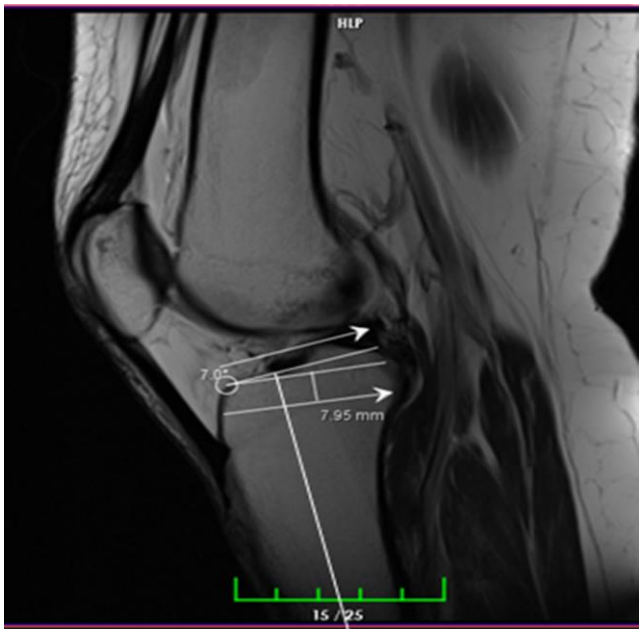

Fig 1: "MRI section in the sagittal plane used for drawing a 7° posteriorslope from 8 mm below the highest point of the lateral "tibial Plateau"

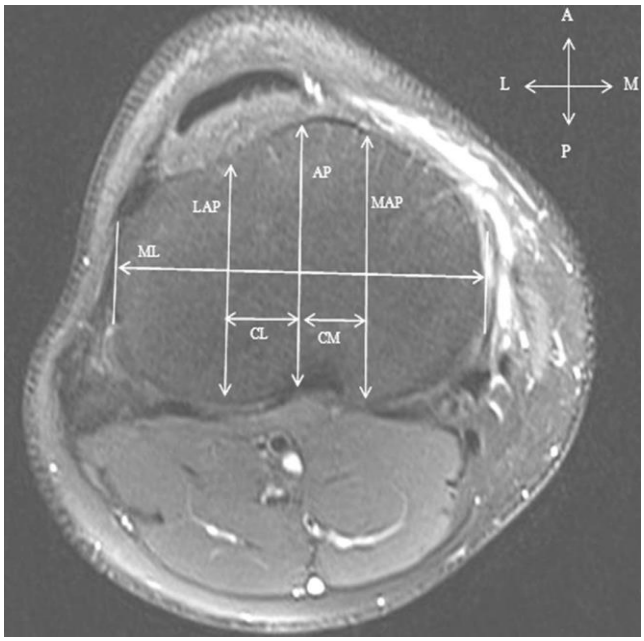

Fig 2: Schematic representation of the "proximal tibial" resected surface showing the measurement methods used in the MRI analysis.

Tibial component designs

"The symmetric tibial components of Zimmer, Nexgen, Biomet and Vanguard were used. The AP and ML dimensions of these components were obtained from the manufacturers, and all the available sizes of each component design were used in the analysis. According to the manufacturers' manuals, the medial or lateral AP diameters were taken into account for implants".

Statistical analysis

The data was statistically analyzed using SPSS software (version 28). Descriptive statistics were applied to measure the variables and age. In a comparison between the genders, the independent sample T test was performed. Person's correlation was recruited to study the correlation between simulated

bone cut and dimensions of prostheses used in TKA surgery. "P-value less than 0.05 was considered statistically significant."

Results

Gender based comparison was done within tibial specimens. Moreover, tibial specimens were compared tibial implants used for prosthesis.

Proximal Tibial measurement in study

Measurements of proximal tibial dimensions are summarized in Table 1. The mean scores of AP length and ML width, as well as the aspect ratio of tibial bone, in all subjects were 46.8±5.57mm, 74.0±5.06mm, and 1.60 ±0.33, respectively. The mean values of MAP and LAP were 49.9±3.9and 48.9±5.07 mm, respectively. AP, ML, MAP, LAP, CM & CL were significantly higher in males (P<0.05). Other ratios like ML/AP, MAP/ LAP, MAP/ML, and LAP/ML were non-significant between males and females. The distance of the MAP (CM) and LAP (CL) lines from the AP line was also taken into account, and MAP was found to be closer to the AP than LAP by an average of 0.5 mm in males and 0.7 mm in females which was not significant. These results confirm the symmetric shape of the proximal tibial surface at the resection level in the Pakistani population.

Table 1 "Average values of the measured data from the subjects"

parameters	male	female	total	P Value
	Mean ± SD			
Age (Yrs.)	34.61 ± 13.0	35.93±9.5	34.92±12.34	0.96
Dimensions (mm)				
AP	48.2 ± 5.5	42.4± 2.7	46.8±5.57	<0.001
ML	75.8±4.0	67.8±2.6	74.0±5.06	<0.001
MAP	50.1± 3.5	45.1±2.4	49.9±3.9	<0.001
LAP	47.6±3.57	42.6±3.69	48.9±3.94	<0.001
CM	15.6±1.9	14.4±1.8	15.36±2.06	0.005
CL	15.8±1.9	14.5±2.1	15.56±2.06	0.002
Aspect Ratio				
ML/AP (AR)	1.6±0.3	1.6±0.1	1.60±0.33	0.9
MAL/LAP (AR-1)	1.0±0.06	1.0±0.04	1.01±0.06	0.8
MAP/ML (AR-2)	0.6±0.04	0.6±0.02	0.66±0.04	0.4
LAP/ML (AR-3)	0.6±0.04	0.6±0.03	0.66±0.04	0.7
MAP-LAP Diff	2.5±3.4	2.5±1.9	2.5±3.11	0.8

SD: standard deviation.
AR: Aspect Ratio

Comparison between Tibial specimens and implants

"For both genders, the AP sizes of all tibial implants tended to overhang or under hang for the given AP dimensions. In other words, the tibial components that matched properly with the AP dimension overhanged or underhanged mediolaterally. The comparisons of the dimensions of the tibial components and of the average tibial dimensions of males and females are shown in Figs 1 2 & 3. The data set of the study population was found to be relatively somewhat consistent with the dimensions of Biomet prostheses compared to others." No statistically significant difference was noted between the median ARs of females and males. However, the measurements demonstrated a progressive decline in the AR with an increase in the AP dimensions for both males and females (fig 4). Through the comparison of the tibial components, we found that all prostheses followed a similar horizontal pattern with a minimal decrease in the AR, irrespective of gender.

Correlation between AP diameter and proximal tibial aspect ratio of study population

Pearson coefficient correlation test revealed significant negative correlation (-0.7) which indicated that there is significant decrease in AR with increase in AP size irrespective of gender. The shapes of tibial specimens illustrating a progressive decrease in AR with an increasing AP dimension are shown in Fig. 4.

Correlation between proximal Tibial components of study population with Tibial implants

Pearson coefficient correlation test was performed to find the correlation between proximal tibial measurements among the Pakistani population and tibial prostheses. A non-significant positive correlation was found between AP diameters of tibial specimens & NexGen (0.36) and Zimmer (0.50). However, ML diameters of tibial specimens revealed non-significant positive correlation with those of Venguard (0.36). Moreover, when this test was applied on overall aspect ratios it revealed a non-significant positive correlation between aspect ratios of Tibial Specimens and Biomet (0.52).

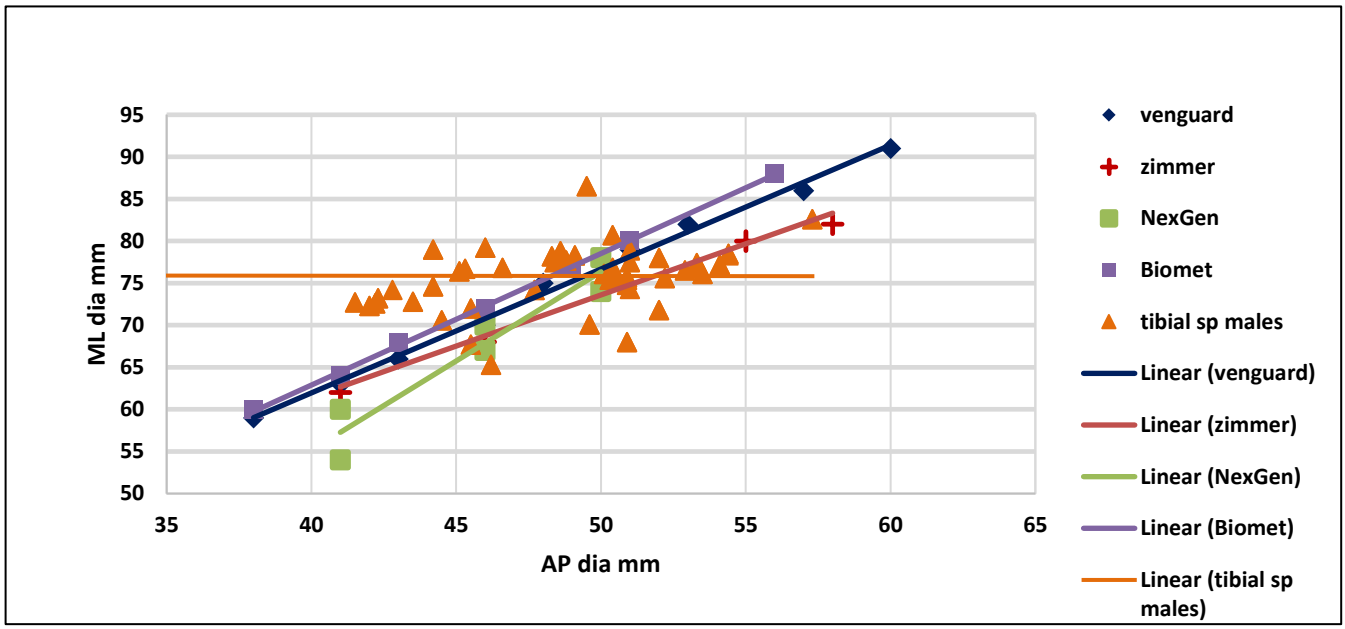

Fig 1: "Proximal tibial ML and AP dimensions of male subjects compared with the dimensions in four conventional tibial prostheses. This graphic demonstrates that tibial components tended to be small or large for Pakistani males for a given AP dimension. Among these prostheses, Venguard design followed the population data most consistently compared to the others".

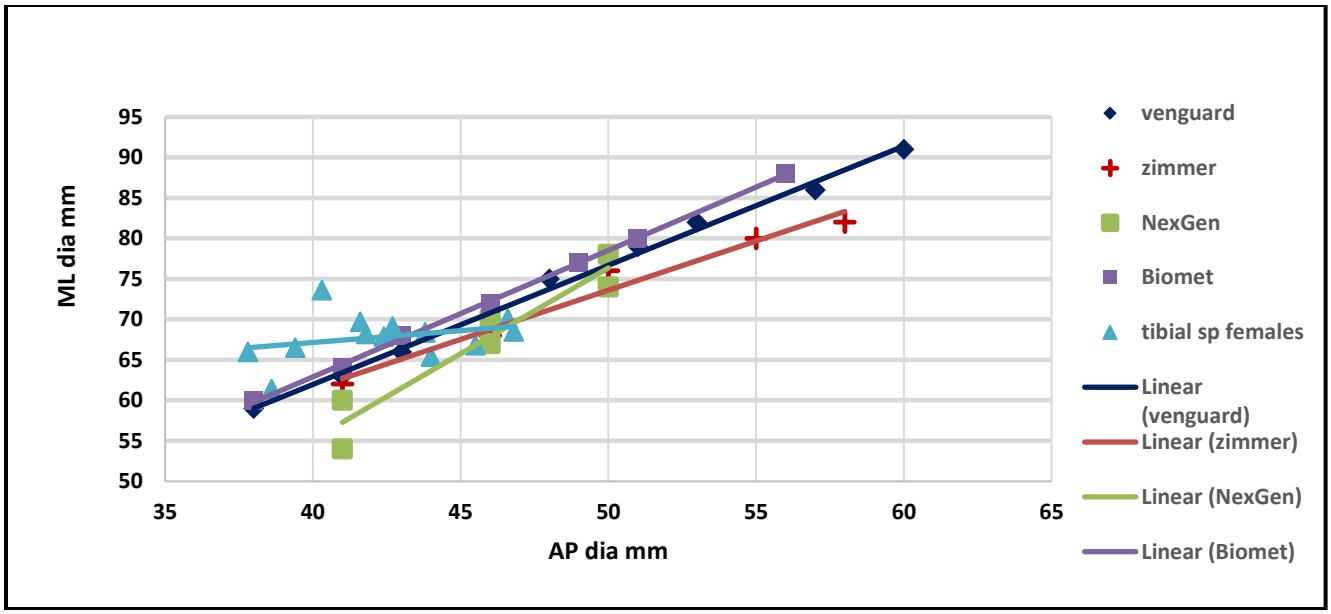

Fig 2: "Proximal tibial ML and AP dimensions of female subjects compared with the dimensions in four conventional tibial prostheses. This graphic demonstrates that tibial components tended to be too small or too large for Pakistani females for a given AP dimension."

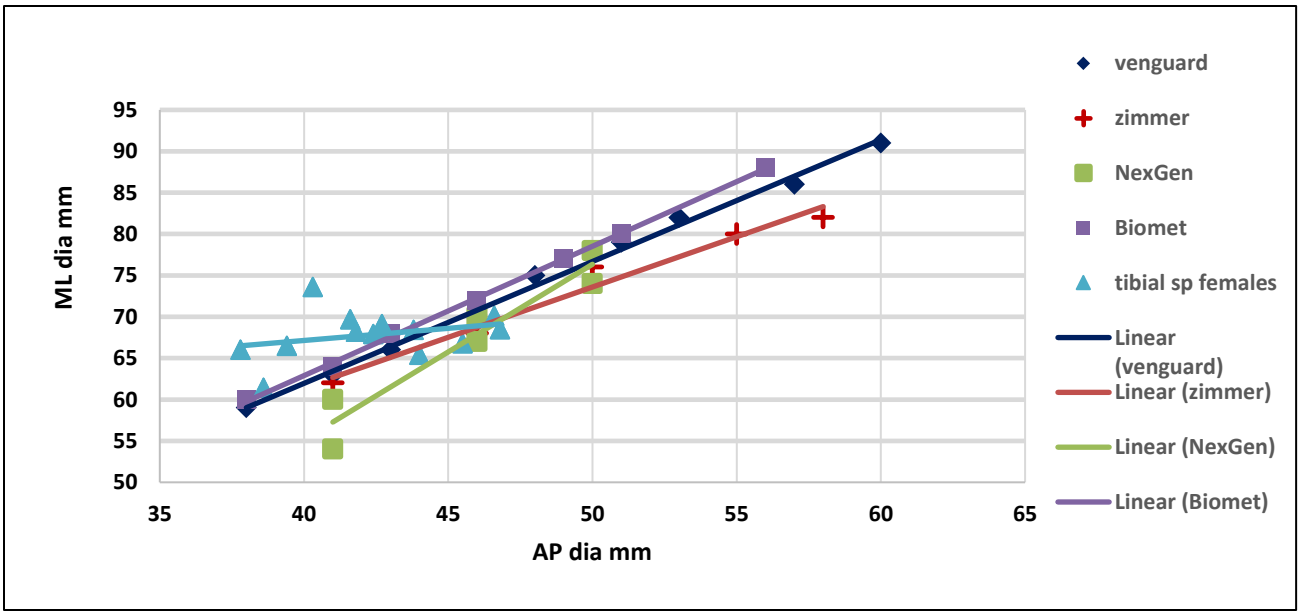

Fig 3. Correlations of resected tibial mediolateral width and anteroposterior length in 121 knees of study population in comparison with dimensions in four current tibial prostheses.

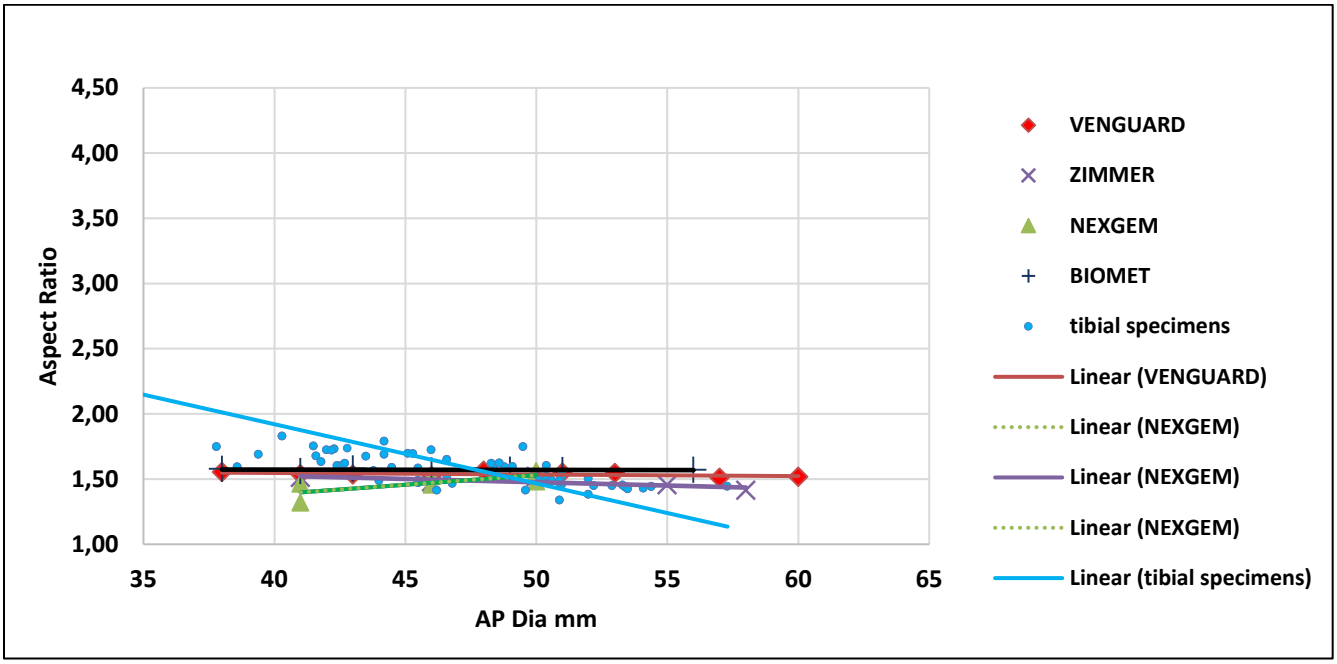

Fig 4 "Proximal tibial aspect ratio and the AP dimension of tibial specimens compared with the dimensions of four conventional tibial prostheses. The line represents the median values for the population. The population data show a significant decrease in the aspect ratio with the increasing AP size of the knee,(significant negative correlation -0.7) whereas most of the prostheses show a relatively constant aspect ratio."

SD: standard deviation.

Aspect ratios of the specimens and various implants

Specimen/implant	Average aspect ratio
Tibial specimens	1.58
Zimmer	1.48
NexGen	1.47
Biomet	1.57
Venguard	1.53

Discussion

Researchers should look for ways to increase the prosthesis' durability and retention because TKA is on the rise. Creating prosthetics that fit the anthropometry of any population is one of these techniques. Most of the components are made to conform to the physical characteristics of Westerners. Furthermore, the findings of several research show that Asian and Western societies differ in the morphological and anatomical traits of the lower limbs[5]. While the physique and size of Pakistanis are comparable to those of other Asians.[8] However, there are anthropometric variations within

this population. Numerous studies have examined Asian knee morphology and contrasted it with Chinese and Western knees.[9,10,11] To the best of our knowledge, this is the first report on the anthropometry of the proximal tibia in the Pakistani population. Data on this subject have not yet been published. This investigation produced a number of conclusions.

Women's proximal tibial anatomic forms and dimensions were smaller than those of men, according to the research population's measurements. This discrepancy is consistent with earlier reports and was anticipated.[7,12] Comparing our measurement data with previously published data revealed that the AP and ML lengths were almost identical to those of the Turkish[7] and Thai populations[5], but smaller than those of the Western population. The ML length of Chinese males and females was estimated by Zhang et al., 2019 to be 75.59 ± 2.8 mm and 62.89 ± 2.77 mm, respectively, which corresponded to 75.8±4.0 mm and 67.8±2.6 mm in our study[11]. The majority of women in this study (20 of 28) had AP diameters between 41 and 47 mm, while the majority of men (60 of 93) had AP diameters between 47 and 58 mm. Given that 80% of knees fall within this range, the ML dimensions of the tibial component should concentrate on a length of 66–70 mm for women and 71–80 mm for males. This indicates that a tibial component that varies in size between 66 and 80 mm in ML length and 41 and 58 mm in AP length is appropriate for most of the Pakistani population.

A vital factor that affects joint stability, range of motion, and implant design is aspect ratio, which is calculated by dividing mediolateral width (ML) by anteroposterior length (AP).[13] According to Zang et al. (2019), the Northeast Chinese male and female populations had ML/AP ratios of 1.71 and 1.77, respectively.[11] In our population, there was no gender variance ($p = 0.9$), despite the fact that the same index for Caucasian males and females was 1.75 and 1.76. Additionally, our study's aspect ratio (1.60) was lower than that of our Chinese and Caucasian counterparts.[14,15]

At first, it was determined that a larger knee had a reduced aspect ratio. Though the aspect ratio of the tibia plateau may not be enough to direct the design of tibial prostheses, it could be used as a reference given the larger knee size and higher aspect ratio of the Caucasian population.[3, 15, 16]

The symmetry of the proximal tibial cut was examined in this study in order to align the geometry of the tibial prosthesis's components with the bone surface. The average LAP and MAP measurements were 48.70±5.35 mm and 50.12±4.88 mm, respectively. Moreover, the study population had asymmetric proximal tibia, as evidenced by the mean CL and CM scores of 17.09±6.83 and 13.40±6.17 mm, respectively. The majority of the commonly available complete knee implants have symmetric tibial baseplates, despite the fact that certain authors have suggested that asymmetric tibial components will fit better in the bone surface.[7,17,18]

However, certain studies have shown that, in comparison to the usage of asymmetric tibial base plates, the symmetric component's tibial coating was better because the tibial plateau was more widely covered.[19] However, despite the fact that an asymmetric tibial component seems to be advantageous in theory for optimizing tibial surface coverage, there has been no convincing proof of the functional benefit of utilizing asymmetric components.[20] According to recent research, the amount of tibial bone covering offered by symmetric and asymmetric base plate designs was comparable.[21, 13]

As the AP size increased, the aspect ratio of the tibial specimens in the present study gradually decreased. In contrast, the majority of prostheses exhibit a comparatively constant aspect ratio as the AP dimension increases, which causes oversizing issues with the proximal tibia's growing AP dimensions in this population. Our current data indicates that certain biomet designs fit the proximal tibia better than others as the aspect ratio of our tibial specimen is close to that of biomet designs.[22]

The tibial AR of the majority of the implants used for comparison was lower than the aspect ratio (AR=ML/AP) of the current study group. Additionally, this suggests that the sizes of the implants utilized in the study did not match the proximal tibial morphology (for a given AP length, the implants' ML dimension was less than the knee's ML diameter), which could result in undercoverage. This indicates that the four prosthesis stated above do not meet the needs of this group and are currently on the market.

Our study showed that the aspect ratio of Pakistani population having asymmetrical tibial base plates is greater than the aspect ratio of most of knee models which are used in total knee arthroplasty. This is in accordance with the findings mentioned by Singh et al., 2016[19].

Conclusion

Pakistanis have proximal tibia dimensions that are different from those of other populations. The majority of the implants' dimensions did not closely match those of the local tibia specimens, according to a comparison with tibial components of commonly used TKR implants.

Recommendations:

1. The results may not be applicable to patients with degenerative arthritis who are candidates for total knee arthroplasty (TKA), as the participants in this study were relatively young and had healthy knees. Therefore, future research in Pakistan should include a more balanced sample, consisting of both younger and older individuals, to provide more relevant insights.

2. Since height and weight were not analyzed as separate factors in the proximal tibia measurements in this study, additional research is needed to investigate how these variables might influence the findings.

CONFLICT Of INTEREST: None.

GRANT SUPPORT AND FINANCIAL DISCLOSURE: None.

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Authors Contribution:

Dr Iram Zakria: Substantial contributions to study design, acquisition of data; manuscript writing; has given final approval of the version to be published;agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Dr. Maleeha Zafar: Substantial contributions to study design, acquisition of data; manuscript writing;has given final approval of the version to be published; agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Dr Rabia Waseem: Substantial contributions to analysis and interpretation of data; critical review; has given final approval of the version to be published ;agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Dr Salma Ambreen Shahab: Substantial contributions to concept, study design ; critical review; has given final approval of the version to be published; agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Dr Asma Hafeez: Substantial contributions to concept, study design ; critical review; has given final approval of the version to be published ;agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Dr Iram Tassaduq: Substantial contributions to concept, study design; critical review; has given final approval of the version to be published; agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Submitted for Publication August 05, 2025
Accepted for Publications August 28, 2025
IRB ethical approval #41/IRB/Anatomy dated 01.12.2020