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Morphology of proximal tibia in Iranian population and its correlation with available prostheses

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Abstract

Background: Total knee arthroplasty is a complex procedure aiming to relieve pain and improve function. It is critical to select prosthesis that best cover the bone surfaces. Ethnicity may affect fitness of the components mainly designed for Caucasian populations. This study aimed to evaluate morphometric features of proximal tibia in Iranian population.

Methods: During 2013, 150 consecutive patients (96 males and 54 females) form orthopedics department of Rasoul-Akram hospital with knee CT scan were randomly enrolled. We entered cases with apparent normal extremity alignment and bone maturity. Cases with history of fracture or conditions affecting knee profile were excluded. Standard cuts were simulated on CT scan. Anteroposterior (AP), mediolateral (ML) and aspect ratio (ML/AP) were measured for general morphology. Medial and lateral AP distance of tibia and their distance to tibial center were measured for checking symmetry.

Results: Mean age was 43.0± 10.4 years (rang 11-80). Males showed significantly larger values in ML dimension and aspect ratio than females under a given AP value ($p<0.001$). However, the aspect ratio was suggestive of similar configuration of proximal tibia profiles among genders. Totally, close correlations were observed among simulated cuts and size-matched tibial components of the prostheses. However, better coverage was provided by some brands via designing interchangeable components for a given dimension. Medial and lateral condyles of tibia were almost symmetrical.

Conclusion: Our findings indicated that some alterations in the shape of the components are needed to provide optimal coverage in Iranian population. We propose symmetrical configuration in designing tibial components as well.

Keywords: Proximal tibia, morphometry, Total knee arthroplasty, computed tomography, Iranian.

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Introduction

Total knee arthroplasty (TKA) is a highly complex and accurate procedure aims to relieve pain and improve function. To achieve this, it is critical to select a prosthesis that best fit the sizes of the resected surfaces of the distal femur and proximal tibia. Any mismatch or malposition may result in a number of severe complications such as soft tissue imbalance, impaired movement and implant loosening (1, 2).

Prosthetic components currently available on the market are mainly designed based on Caucasian population. Asian ethnicities are supposed to have smaller knees based on their small statures (3-10). Therefore, modification of current prostheses may be needed to fulfill the requirements of these anthropometrically smaller ethnic groups (4-8). Moreover, differences between male

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and female sizing and necessity of gender specific prostheses have been an issue of debate (11-15). Recently, some studies have focused on more detailed points such as designing asymmetrical tibial baseplate for better fit (5, 6, 16-18).

Anthropometric characteristics of the knee joint from many Asian countries are presently available mainly from Asian-pacific countries (4-10). Some significant criticism can be made regarding the studies' methodology that puts comparability of the results into trouble. To our knowledge, such surveys were rarely performed in middle-east countries.

We conducted this study to evaluate proximal tibia morophometrical characteristics of Iranian ethnicity based on CT imaging. Furthermore, correlation with three available prostheses (NEXGEN, Scorpio, and GENESIS) was assessed. We also tried to examine symmetry of proximal tibia based on simulated cuts.

Methods

Sample selection

During 2013, a cross-sectional study was conducted at the outpatient ward of orthopaedics department of Rasoul Akram hospital. Patients were randomly recruited based on their documents' code available in digital imaging database.

The selection criteria were defined as ages after maturity, normal apparent lower limb alignment. Patients with severe osteoarthritis, any rheumatoid condition, gross congenital anomaly or deformity and patients with concomitant hip or spine deformities were excluded from the study. Informed consents were obtained from all participants of the study and the study proposal was approved by the institutional review board of Iran University of Medical Sciences (IUMS).

Imaging protocol

A computerized tomography (CT) scan of the knee was obtained using a helical CT scanner with 1-3 millimeter of slice thickness. Patients were instructed to be relaxed in supine position with both lower limbs in extension and neutral rotation (i.e. with patellae parallel to the ceiling). Using scout views, the scan direction was aligned to be in the plane perpendicular to the mechanical axis of the tibia in the frontal plane. The data were reconstructed in three conventional planes in MacoPacs program. Cut simulations were performed as follow:

Simulated proximal tibia bone cut was made following the standard TKA surgical technique with 10-mm thickness from the higher side of the tibial plateau with roughly 7 degrees of posterior slope. Almost consistently performed in all studies, the AP and ML length of the resected proximal tibia was measured as described by Uehara et al (5). The ML width was defined as the longest value of the resected proximal tibia parallel to anatomical trans-epicondyar axis (TEA) of the distal femur. A line perpendicular and through the midpoint of this line was drawn, and the length was regarded as the AP size of the tibia.

The medial anteroposterior (MAP) and lateral anteroposterior (LAP) dimensions were taken as the length of line drawn parallel to the middle anteroposterior line (AP) in the longest value throughout the tibia plateaus. The distances of the MAP and LAP lines from the central point (intersection of AP and ML lines) were measured as CM and CL, respectively. These variables were exploited as indicators of tibial condyles symmetry.

In addition, a characterization of the aspect ratio (the ML width divided by the AP length) was made for both simulated cuts. The equation to define aspect ratio is applied reversely in some other studies. Therefore it should be considered while interpreting the results.

All measurements were recorded in millimeters. The osteophytes surrounding the cut surfaces, if any, were excluded from the measurements. The measured dimensions were correlated to the sizing of three available tibial components in Iran, including NexGenLPS-Flex (Zimmer), Genesis II (Smith & nephew) and Scorpio (Stryker).

Table 1. Descriptive statistics of subject demographics variables

Parameter	Total (N=150)	Male (N=96)	Female (N=54)
	Mean±SD (range)	Mean±SD (range)	Mean±SD(range)
Age (year)	43.0± 17.18(17-80)	41.8± 17.11(18-80)	45.6±16.86(17-78)
Height (cm)	168.7±7.57(150-175)	171.8±8.11(152-175)	156.8±5.85(150-170)

Table 2. Descriptive statistics of proximal tibial dimensions.

Parameters	Total	Male	Female	p
	Mean±SD (range)	Mean±SD	Mean±SD	
Resected AP length (mm)	48.6±4.50(39-57)	51.0±2.77	44.2±3.51	<0.001
Resected ML width (mm)	74.6±5.90(62-89)	78.0±3.81	68.5±3.83	<0.001
Aspect ratio (ML/AP)	1.5±0.07(1.35-1.75)	1.5±0.07	1.5±0.07	0.073
Medial AP	50.5±4.39(41-60)	52.7±3.26	46.5±3.21	<0.001
Lateral AP	48.9±5.00((38-58)	51.9±3.22	43.5±2.87	<0.001
CM	13.2±2.40(8-20)	13.9±2.32	11.9±1.80	<0.001
CL	13.0±2.35(9-20)	13.7±2.32	11.8±1.86	<0.001

Statistical analysis

The SPSS and GraphPad Prism 6 softwares were used for statistical analysis. Descriptive statistic was used for demographics and bone dimension measurements. Comparative statistical analyses between genders were made using the t-test.

Correlation analysis was performed to compare simulated resected bones with size-matched components of total knee prosthetic systems. In analyzing the morphometrical data, scatter plots along with a best-fit line were represented (α: 0.02).

Results

A total of 150 patients were included, comprising 96 males (64%) and 54 females (36%) aging 17-80 years. No statistical difference was observed among ages and genders (p=0.063). The demographic data are shown in Table 1.

Proximal tibia profile

After simulation of resected proximal tibia, parameters were measured (Table 2). Mean±SD of AP length and ML width were 48.6±4.50 mm and 74.6±5.90 mm, respectively. Medial and lateral AP lengths valued similar amounts (50.5±4.39 Vs 48.9±5.00 mm). Moreover, their distances from the central AP line were similar (CM: 13.1±2.40 and 13.0±2.35 mm). These approximately define a symmetrical shape for tibial condyles at resection site. All parameters revealed significantly higher values in men than women. The difference for aspect ratio was not statistically significant (p=0.073).

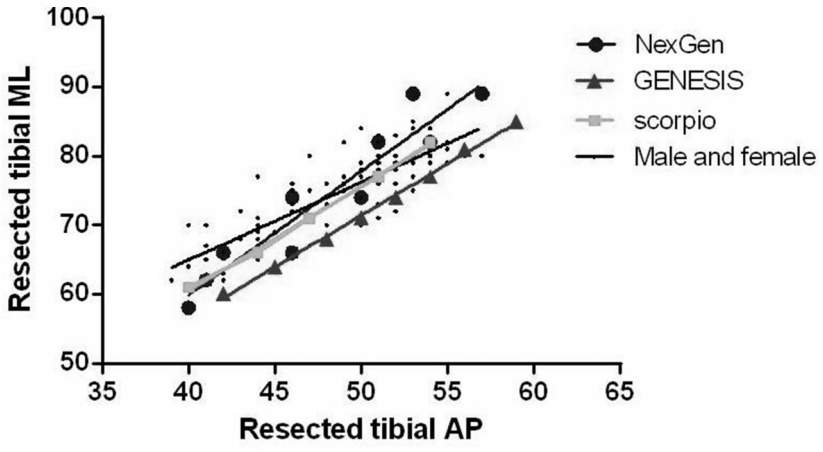

Fig. 1. Graphs demonstrating correlations among resected tibial AP length and ML width and four prosthetic systems

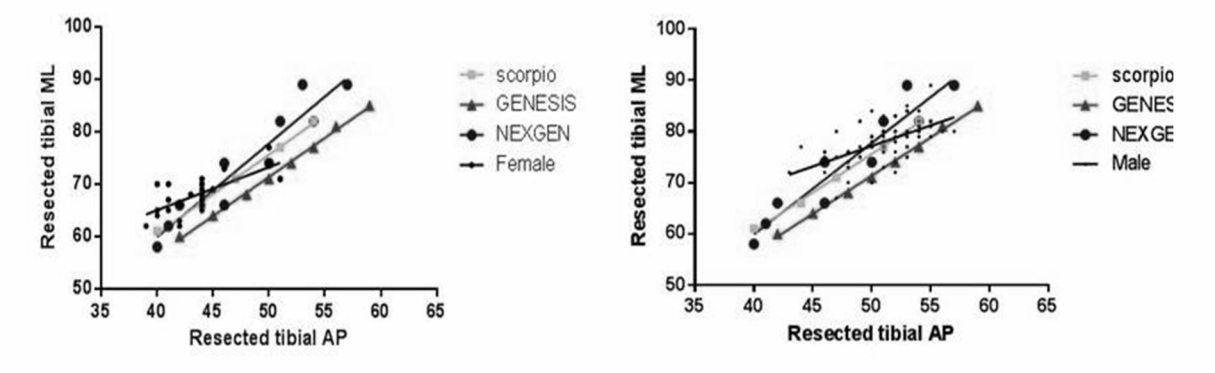

Fig. 2. Graphs demonstrating correlations among resected tibial AP length and ML width and four prosthetic systems in males and females

Correlations of current prostheses and the resected tibial condyle

Analyses showed a high correlation among size-matched tibial component of NexGenand resected proximal tibia in our subjects. However, for size-matched of smaller AP values, Scorpi and GENESIS II components were mainly undersized. The versatile fitness of NexGen seemed to be specially originated from its interesting design that made two alternatives of ML sizes available for a given AP dimension and vice versa (Fig. 1).

Evaluation of prostheses fitness among genders for Scorpi and GENESIS II, was suggestive of sizing mismatch at smaller and larger AP values. In simple words, these components are undersized for smaller knees and overhang for larger knees (Fig. 2).

Evaluation of tibial aspect ratios among genders and compared prostheses disclosed interesting points (Fig. 3). The slopes of correlation lines suggest similar downward trends among males and females. Thus, smaller knees enjoy higher aspect ratio. On contrary, the aspect ratios of prostheses remain approximately the same through different sizes.

Discussion

Besides precise surgical techniques in TKA, proper sizing of the prosthesis is mandatory for a successful and long-life outcome (1). Any mismatch in the form of overhanging or undersizing of the components can lead to altered soft-tissue tensioning and impaired patello-femoral tracking.

In order to enhance the quality of the fitness yielded by prostheses, morphometric studies from diverse ethnicities are mandatory. Some surveys demonstrated that Asian populations enjoy smaller knee compared with Caucasians (2- 4). This has posed the need for alteration in sizing and configuration of current prostheses to best fit them. To our knowledge, anthropometric surveys from China, Korea, Japan, India, Malaysia and Thailand were conducted to construct Asian knee profile (4-10,16).

Table 3. Proximal tibia dimensions reported from different studies

		Thai[3]	Korean[6] (by Kwak)	Korean[7] (by Lim)	Japanese[5]	Iranian	Chinese (by Cheng)	Chinese[11] (by Yue)	White's[11]
AP length (mm)	Total	46.04±4.4	45.7±3.8	53.4 & 49.2	48.3±5.4	48.6±4.5	48.8±3.4		
	Male	50.15±3.09	48.2±3.3	59.5 & 52.7	53.8±6.6	51±2.77	51.3±2.0	41.5 ± 2.1	45.0 ± 2.8
	Female	43.23±2.57	43.2±2.3	47.7 & 45.7	46.6±3.6	44.18±3.51	45.7±1.9	37.3 ± 2.8	39.3 ± 2.6
ML width (mm)	Total	68.8±5.8	71.9±5.6	75.1±7.01	74.3±6.6	74.6±5.9	73.0±4.6		
	Male	74.44±3.44	76.1±4.0	80.6±6.31	83.0±6.2	78±3.81	76.4±2.8	75.2±3.6	78.7 ± 5.4
	Female	64.95±3.45	67.6±3.1	70.0±3.45	71.7±4.0	68.5±3.83	68.8±4.6	66.2±2.1	69.0 ± 4.2
Aspect ratio (ML /AP)	Total	1.47		1.4 & 1.51		1.53±0.07	1.49		
	Male	1.48		1.35 & 1.52		1.53±0.07	1.49	1.82±0.07	1.75±0.11
	Female	1.47		1.47 & 1.52		1.55±0.07	1.50	1.78±0.10	1.76±0.08

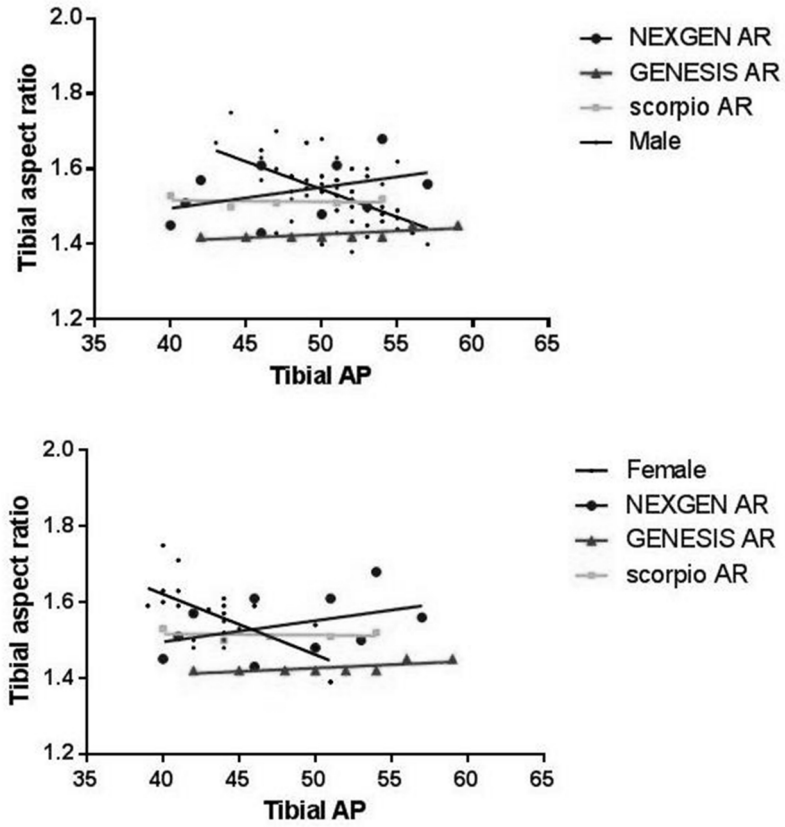

Fig. 3. Graphs demonstrating correlations among resected tibial aspect ratio and four prosthetic systems in males and females

There were delicate discrepancies in methodology and results of these studies that can affect the outcome of TKA in a different manner from Western population.

To avoid misinterpretation, it should be first delineated from what stance we are viewing the results: whether clinically or anatomically. For example, a glance to an anatomical study conducted by Mahfouz et al shows that they defined most of their anthropometrical parameters based on the longest length of them (3). However, in clinical studies like most of the works related to arthroplasty, the same parameters were defined based on some different considerations. On the other hand, within the same population either Caucasian or Asian, sometimes all the available studies are not fully scrutinized before coming up with a conclusion. These should be regarded while comparing the results.

We evaluated knee dimensions corresponding to standard cuts of proximal tibia during TKA. Based on our findings, morphological parameters were significantly larger in males comparing to females. However, aspect ratios did not show such difference. It can be inferred that shape configuration of resected cuts seemed to be maintained with knee enlargement. These ratios were reported to be different among genders in some studies (6, 7, 9, 13). Distribution of measured values depicts that for a given AP size there is variety of ML sizes. This dissipation also was a matter of concern in other population (6, 8, 16-19). To overcome probable mismatches, availability of several or at least two ML sizes for the same AP size of prostheses is proposed to provide better coverage.

In comparison of tibia dimensions among studies (Table 3), we believe that assumption of smaller knee size (as correlated with arthroplasty) is more evident for Thai and Indian population. However, dimensions represented from other Asian ethnicities

along with Iranians do not seem to have significant difference from white populations. Minor discrepancies may have resulted from longer height and different imaging techniques.

On the tibial side, all prostheses were undersized for small knees (ML sizes were too small for the same AP value) and oversized for larger knees. This was also mentioned in Chinese, Korean and Thai population (7, 9, 16). Our data along with these studies demonstrated a decreasing aspect ratio as AP size rises. However, most implants had a relatively constant aspect ratio. This implies a need for alteration in prostheses shape in addition to their sizing; especially considering this point that most candidates of TKA in Asian countries need smaller or medium sized components (4, 6, 8). On the other hand, interesting versatile designing of components such as NexGen is a good strategy that made two alternatives available for a given AP or ML dimension.

In order to further match the geometry of the tibial component, symmetry of proximal tibial cuts was debated in recent studies (17-20). Again, the locations for measuring related values were a matter of controversy that complicates their comparison. Besides this variability, almost all of them reported larger medial AP than lateral and larger CL than CM values that implies asymmetry of proximal tibia (5, 7). However, our findings were more indicative of symmetric profile and observed minor differences were not significantly meaningful. Although some authors have reported substantially better fit for asymmetric tibial components (17, 18), definite statement is not yet represented (5, 6, 9). This was mainly because of two reasons. No outcome study has compared tibial component survival rates between asymmetric and symmetric baseplate designs. On the other hand, asymmetric TKA designs mandate doubling the inventory and stock for the operating room.

The limitation of our analysis is relatively younger age of the selected sample. This may be more approximate to normal morphology rather osteoarthritic knees. Further studies are advised to cover cuts with different depths and combine imaging measurement with corresponding surgical results. Other confounding factors such as age, height, severity of osteoarthritis and lower extremity alignment should also be adjusted.

Conclusion

We tried to evaluate anthropometric data of Iranian population in order to improve current designs of TKA prostheses. Data from mismatches between sizes and shapes (aspect ratio) of the components may be taken into account by manufacturing companies. We propose symmetric configuration in designing tibial components as well.

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