



Anthropometric measurements of patella and its clinical implications

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Abstract

Introduction Early patellar failures in tricompartmental total knee arthroplasty (TKA) have been related to universal designing of implants. Establishing the appropriate patellar bone–prosthesis composite thickness is one of the important steps in ensuring functional success in arthroplasty. Since there is a paucity of data concerning the anthropometric measurements of Indian patella, the objective of this study was to obtain anatomic information of the patella of the northern Indian population and to analyze how it differs from western patellae that will improve patellar component design and implantation in TKA.

Materials and methods A total of 266 consecutive knee radiographs were evaluated. All data were collected by a single doctor using X-ray console, where height (mm) and breadth (mm) were taken in anteroposterior views and thickness (mm) in lateral view.

Results The mean, standard deviation, 95% confidence interval and *P* value of the measurements were calculated. It was found that Indians had thinner and smaller patella as compared to westerners and also males had significantly ($P < .001$) larger patella as compared to females.

Conclusion Anthropometric patellar dimensions can influence implant design and surgical outcomes and can be used as a guideline for future designing of more regional and gender-specific patellar component and patellar plate.

Keywords Patella · Anthropometry · Arthroplasty · TKR

Introduction

There is a paucity of data concerning the anthropometric measurements of Indian patella. Information regarding anthropometric patellar dimensions can play an important role during the design of the patellar prosthesis and implants [1]. A disproportional implant of the patellofemoral joint would result in an ineffective lever support, limitation of motion, excessive wear and instability of patella with associated knee pain [2]. In patellar resurfacing, it is desirable that the final thickness of the resurfaced patella following TKA matches the native patellar thickness. While overstuffing of the patella femoral joint can reduce the range of motion, predispose to lateral patellar subluxation and increase patella femoral compression force, a thin patella can reduce the contact force and potentially result in fracture and anteroposterior instability [3, 4]. There is a difference in the patella of

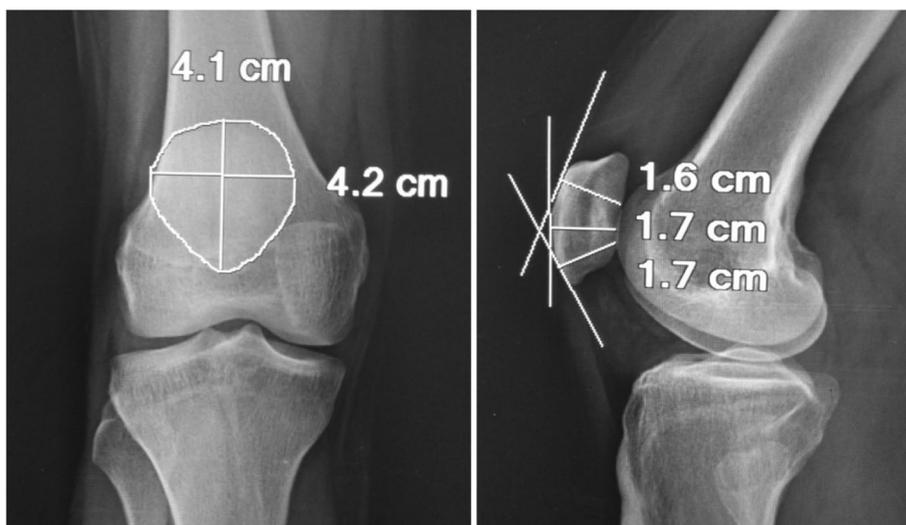
Asian and western population [5–7]. Most of the prostheses currently available in the market are designed based on the measurements from Caucasians which may not be suitable for Asian patients [6, 8–10]. There is a lack of data about the Asian knee joint to determine whether the oversized component could cause poor clinical results after TKA [11]. It is thus necessary to design regional and gender-specific patellar implants based on anthropometric studies. Another promising surgical technique is the use of minifragment locking plate fixation with appropriate size lag screw depending on the dimension of patella for fractures that have comminution or for revision of failed patellar fixation.

The objective of this study was to obtain the anthropometric data of the patella for the northern Indian population. These data can be used for designing patellar component and patellar implants. We hypothesized that there is a difference between male and female patellar measurements, and anthropometric measurements of patella for the northern Indian population tended to be smaller than measurements for western population based on data from the previous studies.

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Fig. 1 Description on measurements of patella



Materials and methods

A total of 266 consecutive knee radiographs of the patients that underwent X-rays for minor soft tissue injury or pain were evaluated. The inclusion criteria were normal X-rays without any radiological evidence of arthritis or any old diseases. Two hundred knee radiographs fulfilling the inclusion criteria of which 113 belonged to males and 87 females were taken in this study. The mean age was 35.13 years (range 18–60). All data were collected by a single doctor using X-ray console, where height (mm) and width (mm) were taken in anteroposterior views and thickness (mm) in lateral view. The software used was FCR console software version 8.3, in which the obtained values remain the same and are not affected by changes made in the size of the image. A standing AP (weight-bearing) radiograph was obtained with the knee extended, the cassette behind the knee and the central X-ray beam perpendicular to the cassette. The height of the patella (H) was measured from the superior border to apex. Patellar width (W) was measured from medial to the lateral border. Patellar thickness (T) was the one decimal mean of three different measurements from anterior to posterior facet drawn as perpendicular to three tangents across the anterior surface of patella in the lateral view (Fig. 1).

Student's t-test was used to compare patellar dimensions between male and female patients. Significance was considered at the *P* value less than 0.05. The mean, standard deviation and 95% confidence interval (CI) were calculated and tabulated using SPSS software, and data were verified for normal distribution. To determine whether Indian and western patients differed in terms of anthropometric dimensions, we compared our results with the published values. The study was approved by our institutional review board.

Table 1 Descriptive statistics of patellar dimensions

Parameter	Mean	SD	95% Confidence interval	<i>P</i> value
<i>Height (H) mm</i>				
Male (<i>n</i> = 113)	43.78	3.41	43.15–44.42	
Female (<i>n</i> = 87)	38.91	2.92	38.29–39.54	
Both (<i>n</i> = 200)	41.67	4.01	41.11–42.22	< .001
<i>Width (W) mm</i>				
Male (<i>n</i> = 113)	45.44	3.40	44.80–46.07	
Female (<i>n</i> = 87)	40.63	3.26	39.93–41.32	
Both (<i>n</i> = 200)	43.35	4.10	42.77–43.92	< .001
<i>Thickness (T) mm</i>				
Male (<i>n</i> = 113)	20.15	2.05	19.77–20.54	
Female (<i>n</i> = 87)	18.00	1.73	17.63–18.36	
Both (<i>n</i> = 200)	19.22	2.19	18.91–19.52	< .001

Table 2 Distribution of subjects according to height and width

Dimensions (mm)	Frequency (%)	
	Height	Width
30–39	63 (31.5%)	31 (15.5%)
40–49	134 (67.0%)	154 (77.0%)
50–59	3 (1.5%)	15 (7.5%)

Results

Descriptive statistical analysis for all subjects is presented in Tables 1, 2 and 3 and Fig. 2.

It was observed that the male patellae had larger dimension than female patellae, and it was found to be statistically significant (*P* < .001) for all three measured dimensions. Levene's test for equality of variance showed that

Table 3 Statistical analysis of data

Parameter	Male		Female	
	Skewness	Kurtosis	Skewness	Kurtosis
Height	.182 (SE .227)	.023 (SE .451)	.269 (SE .258)	.170 (SE .511)
Width	.648 (SE .227)	.850 (SE .451)	.164 (SE .258)	.371 (SE .511)
Thickness	.007 (SE .227)	.620 (SE .451)	.371 (SE .258)	.007 (SE .511)

variance in height ($P = .089$), width ($P = .652$) and thickness ($P = .120$) is equal in all probabilities. Frequency of patella with height 40–49 mm was 67% and width 40–49 mm was 77%. It was also observed that mediolateral width of patella was larger than its height. Mean thickness was 19.22 mm with 76% falling between 17 and 21 mm. A Shapiro–Wilk's test ($P > .05$), visual inspection of histograms, normal Q–Q Plots, box plots and skewness and kurtosis as indicated by Z value falling between -1.96 and $+1.96$, suggests that the data for height, width and thickness were approximately normally distributed for both males and females [12, 13].

Discussion

The patella is an important component in the extensor mechanism of the knee joint. It reduces the work of quadriceps by displacing the lever arm from the trochlea pivot point [14]. The method of measurements can be divided into direct and indirect measurements. Direct measurement is with dried bone, skeletal remains or intraoperative measurements performed by surgeon using a caliper [1, 5]. It is difficult to procure a sufficient quantity of dry bones or patients needing TKA for research analysis. Indirect measurement is to measure radiographic images. In this study, we adopted the indirect method using X-ray images. This was a quick, inexpensive and noninvasive way to get patellar dimensions [15]. The final bone–prosthesis composite thickness should match the native patellar thickness. However, this may be difficult if patella is affected by advanced degenerative change, severe deformation or erosion, all of which will invariably distort the surface anatomy. Ideally, one should aim to preserve approximately 15 mm (12–15 mm) of patellar bone during patellar resurfacing [16]. In the current study

of normal patella unaffected by erosive disease, we found mean height, width and thickness to be 41.67 mm (SD 4.01), 43.35 mm (SD 4.10) and 19.22 mm (2.19), respectively. This was comparable to another study from southern Indian population by Murgan et al. [17], who reported mean height, width and thickness of 38.07 mm, 38.58 mm and 18.29 mm, respectively. Peng et al. [15] in their study of 80 normal patella reported that male patella had larger dimensions than female patella. Western studies reported large patellar dimension. Baldwin et al. [1] in their study of 92 subjects from Oregon, USA, reported mean thickness of 21.8 mm in females and 23.9 mm in males. Mean height and width were 38.6 mm and 50.3 mm in males, and 33.9 mm and 43.5 mm in females, respectively. Similar trend was seen in a study by Iranpour et al. [2] in 37 subjects from London, UK, with mean width, thickness and length of 44.8 mm, 22.4 mm and 34.3 mm, respectively. Olategu et al. [18] in his study of 46 South African cadavers of European ancestry found mean thickness of 23.9 mm and mean patellar height and width to be 43.7 mm and 45.1 mm, respectively (Table 4). The data show that Indians have a narrow patella compared with westerners.

The major limitation of this study was that the mean thickness calculated from this study does not take into account the thickness of the patellar cartilage. The patellar cartilage thickness is approximately 4 mm, although there is progressive thinning after the age of 50 years [19–21]. However, if one considers the ideal thickness of the cement mantle and the fact that cartilage is more compressible than the prosthesis, it may be more practical to restore native bone thickness [20]. However, further studies measuring cartilage thickness with MRI and its progressive thinning with age in Indian population are warranted. Also in abnormal patella secondary to trochlea dysplasia, restoring native patellar thickness is to be further proven.

In conclusion, we can say that patellar dimension using indirect method showed that Indian patella is thinner and smaller as compared to that of westerners, so most of the currently available prosthesis based on the measurements from Caucasians may not be suitable. Also males have larger patella as compared to females. Thus, anthropometric patellar dimensions play an important role in the design of patellar prosthesis. The results of this study will provide fundamental data for future designing of regional and gender-specific patellar component and patellar implant. Also the results can be used in forensic anthropometric studies when other long bones, skull and pelvis are not available.

Fig. 2 Box plot of height **a**, width **b** and thickness **c** shows data are approximately symmetrical with a very few outliers

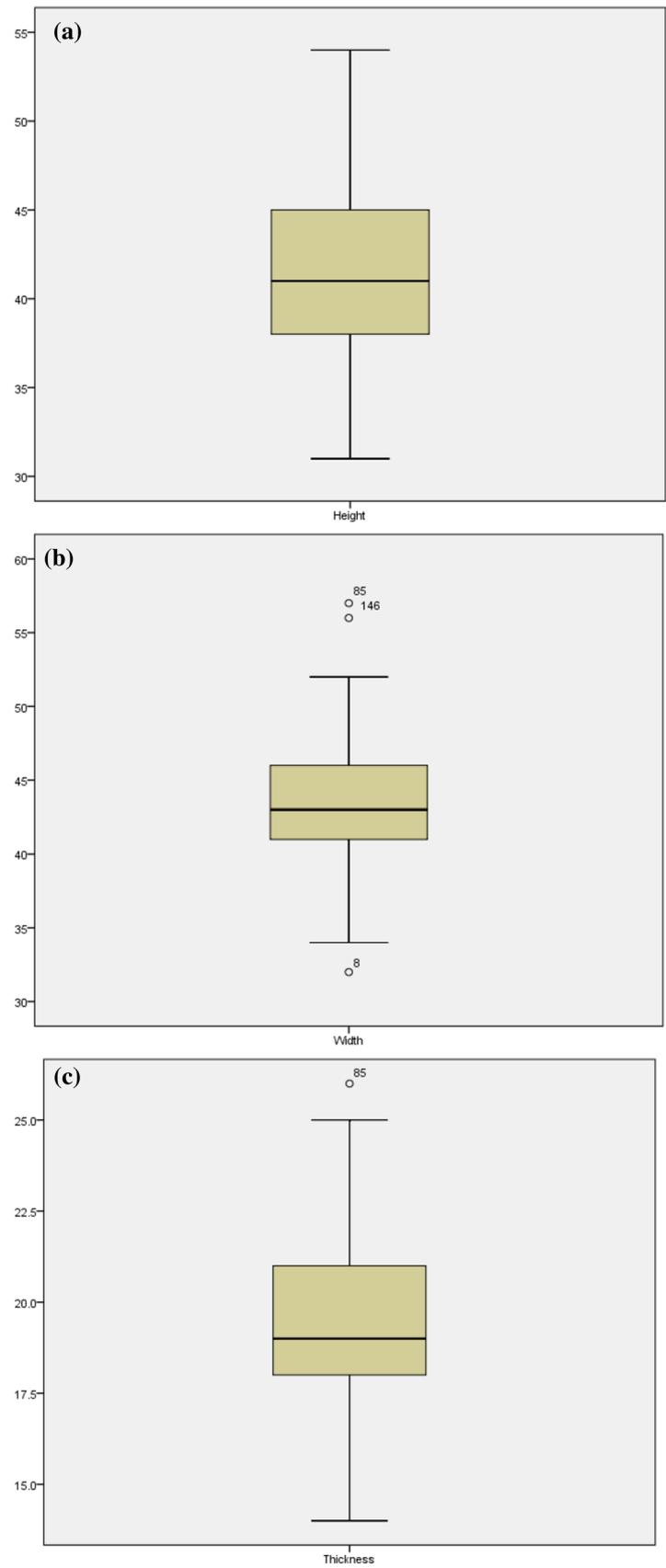


Table 4 Comparison of means of anthropometric dimensions of patella

Study	Mean height (mm)	Mean width (mm)	Mean thickness (mm)
Murugan et al. [17] (Southern Indian) (<i>n</i> = 65)	38.07 (SD 3.79)	38.58 (SD 3.81)	18.29 (SD 1.73)
Baldwin and House [1] (Oregon, USA)			
Female (<i>n</i> = 57)	33.90 (28–38)	43.50 (36–51)	21.80 (18–27)
Male (<i>n</i> = 35)	38.60 (32–47)	50.30 (45–65)	23.90 (20–30)
Total (<i>n</i> = 92)	35.70 (28–47)	46.10 (36–65)	22.60 (18–30)
Iranpour et al. [2] (London, UK) (<i>n</i> = 37)	34.30 (SD 3.80)	44.80 (SD 4.80)	22.40 (2.30)
Olateju et al. [18] (South African cadavers of European ancestry)			
Female (<i>n</i> = 25)	41.05 (SD 2.18)	42.71 (SD 2.52)	22.89 (SD 1.50)
Male (<i>n</i> = 21)	46.94 (SD 2.11)	48.03 (SD 3.41)	25.55 (SD 1.69)
Current study			
Female (<i>n</i> = 87)	38.91 (SD 2.92)	40.63 (SD 3.26)	18.00 (SD 1.73)
Male (<i>n</i> = 113)	43.78 (SD 3.41)	45.44 (SD 3.40)	20.15 (SD 2.05)
Total (<i>n</i> = 200)	41.67 (SD 4.01)	43.35 (SD 4.10)	19.22 (SD 2.19)

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

- Baldwin JL, House CK (2005) Anatomic dimensions of the patella measured during total knee arthroplasty. *J Arthroplasty* 20:250–257
- Iranpour F, Merican AM, Cobb JP, Amis AA (2008) The width: thickness ratio of the patella: an aid in knee arthroplasty. *Clin Orthop Relat Res* 466:1198–1203
- Hsu HC, Luo ZP, Rand JA, An KN (1996) Influence of patellar thickness on patellar tracking and patellofemoral contact characteristics after total knee arthroplasty. *J Arthroplasty* 11:69–80
- Oishi CS, Kaufman KR, Irby SE, Colwell CW Jr (1996) Effects of patellar thickness on compression and shear forces in total knee arthroplasty. *Clin Orthop Relat Res* 331:283–285
- Kim T, Chung B, Kang Y, Chang C, Seong S (2009) Clinical implications of anthropometric patellar dimensions for TKA in Asians. *Clin Orthop Relat Res* 467:1007–1014
- Vaidya SV, Ranawat CS, Aroojis A, Laud NS (2000) Anthropometric measurements to design total knee prostheses for the Indian population. *J Arthroplasty* 15:79–85
- Uehara K, Kadoya Y, Kobayashi A, Ohashi H, Yamano Y (2002) Anthropometry of the proximal tibia to design a total knee prosthesis for the Japanese population. *J Arthroplasty* 17:1028–1032
- Ho WP, Cheng CK, Liao JJ (2006) Morphometrical measurements of resected surface of femurs in Chinese knees: correlation to the sizing of current femoral implants. *Knee* 13:12–14
- Kwak DS, Surendran S, Pengatteeeri YH, Park SE, Choi KN, Gopinathan P et al (2007) Morphometry of the proximal tibia to design the tibial component of total knee arthroplasty for the Korean population. *Knee* 14:295–300
- Lim HC, Bae JH, Yoon JY, Kim SJ, Kim JG, Lee JM (2013) Gender differences of the morphology of the distal femur and proximal tibia in a Korean population. *Knee* 20:26–30
- Sharkey PF, Hozack WJ, Rothman RH, Shastri S, Jacoby SM (2002) Why are total knee arthroplasties failing today? *Clin Orthop Relat Res* 404:7–13
- Doane DP, Seward LE (2011) Measuring skewness: A forgotten statistic? *J Stat Educ* 19(2):1–18
- Razali NM, Wah YB (2011) Power comparison of Shapiro–Wilk, Kolmogorov–Smirnov, Lillifors and Anderson–Darling tests. *J Stat Mod Anal* 2(1):21–23
- Sullivan NPT, Robinson PW, Ansari A, Hassaballa M, Robinson JR, Porteous AJ et al (2014) Bristol index of patellar width to thickness (BIPWIT): a reproducible measure of patellar thickness from adult MRI. *Knee* 21(6):1058–1062
- Peng S, Linan Z, Zengtao H, Xueling B, Xin Y, Zhaobin X et al (2014) Morphometric measurement of the patella on 3D model reconstructed from CT scan images for the southern Chinese population. *Chin Med J* 127(1):96–101
- Berry DJ, Rand JA (1993) Isolated patellar component revision of total knee arthroplasty. *Clin Orthop Relat Res* 268:110–115
- Murugan M, Ambika S, Nim VK (2017) Knee cap: a morphometric study. *Int J Anat Res* 25(1):3556–3559
- Olateju OL, Philander I, Bidmos MA (2013) Morphometric analysis of the patella and patellar ligament of South Africans of European ancestry. *S Afr J Sci* 109(9/10):1–5
- Cohen ZA, Mow VC, Henry JH, Levine WN, Ateshian GA (2003) Templates of the cartilage layers of the patellofemoral joint and their use in the assessment of osteoarthritic cartilage damage. *Osteoarthr Cartil* 11:569–579
- Hardy PA, Nammalwar P, Kuo S (2001) Measuring the thickness of articular cartilage from MR images. *J Magn Reson Imaging* 13:120–126
- Meachim G, Bentley G, Baker R (1977) Effect of age on thickness of adult patellar articular cartilage. *Ann Rheum Dis* 36:563–568

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