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Cross-sectional Study

Evaluation of patellar dimension and Bristol Index in Asian population: An MRI study

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ABSTRACT

Background: Restoration of patellar thickness is pivotal during a total knee arthroplasty (TKA). Several studies showed there are differences in the knee measurements between Asian and Western population.
Purpose: This study aims to evaluate the patellar dimension and Bristol Index of patellar width to thickness (BIPWiT) using magnetic resonance imaging (MRI) in Asian population.
Study design: This is a descriptive epidemiology study.
Methods: 101 MRI scans of young adult patients with normal patellofemoral joint (PFJ) age 17–40 were evaluated from January 2019 to December 2020. Exclusion criteria included patella-femoral pathology and degenerative joint disease. Data of gender, body height and weight were obtained from physical examination, while patella height, width and thickness were obtained using MRI measurement. Descriptive analysis was used to get the mean and standard deviation of patella dimension, whereas correlation between patella thickness with patella width and length were analyzed using Pearson correlation and BIPWiT ratio was obtained by dividing the patellar width and patellar thickness.
Results: Mean patellar length was 30.06 ± 2.94 (29.48–30.64); patellar width was 44.13 ± 4.44 (43.26–45.01); and patellar thickness was 23.89 ± 2.33 (23.43–24.35). Patellar dimension in male were significantly larger compared to female ($P < 0.001$). However, there was no difference in cartilage thickness between male and female ($P = 0.305$). There was strong correlation between patellar width and patellar thickness ($r = 0.66$; $P < 0.001$) with BIPWiT ratio of 1.85 ± 0.15.
Conclusion: BIPWiT of 1.8:1 between patellar width and patellar thickness was recommended as a guide for patellar thickness restoration during TKA. There is no difference of patellar dimension between Asian and Western population in a healthy knee.
Clinical relevance: The result of BIPWiT ratio found in this study may aid upon pre-operative planning prior TKA for surgeons in order to achieve optimal patellar thickness and avoid patellofemoral problem.
What is known about the subject: Currently there are raising concerns about the different sizes of knee measurements between Asian and Western population which will affect techniques during TKA to achieve optimum result.
What this study adds to the existing knowledge: This study not only prove that there is no difference between patellar dimension of Asian and Caucasian but also found a similar BIPWiT ratio for patellar resection during TKA with previous literature.
Level of evidence: Level III.

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1. Introduction

A successful patellar resurfacing or replacement in a total knee arthroplasty (TKA) highly depends on the appropriate sizing of patella [1]. In a patellar resurfacing surgery, patella which is too thick will lead to a lateral patellar subluxation, increased lateral condyle pressure, increased compression forces and decrease flexion capability which lead to function worsening [2,3]. However, patellar which is too thin will have poor strain characteristics needing greater quadriceps power to generate the force needed hence leading to early failure [4,5]. Hence it is generally assumed to resurface the patella as its original thickness [6] and maintain 16 mm of bony thickness [7].

Knowledge of patellar dimension is pivotal during pre-operative surgical planning. Thickness, height/width ratio will affect surgical technique and implant selection. Kim et al., 2008 observed that Korean knee were thinner and smaller hence it is difficult to achieve that criteria [1]. However, despite those challenging scenario, data regarding patella dimension for Asian population is limited.

Sullivan et al., in 2014 discovered that patellar thickness correlate with its width which is the Bristol Index of patellar width to thickness (BIPWiT) of 1.8:1 [8]. The ratio can be used as a guide in patellar resection to restore the thickness. However, to date no data regarding the BIPWiT index in Asian population.

Hence, our study aimed to obtain the patellar dimension using MRI study and evaluate the BIPWiT in our population.

2. Methods

This was a retrospective cross-sectional study conducted according to STROCCS guideline [9]. A total of 226 patients with acute knee pain who came to the knee and sport clinic of a tertiary hospital and underwent MRI of their knees between January 2019 until December 2020. All patients were examined by senior orthopaedic knee consultant in our hospital. Exclusion criteria were age under 17 and over 40; degenerative joint disease and patellofemoral pathology (125 patients). This study has been registered at the clinicaltrials.gov with registration number NCT05112978 and conducted in accordance with Declaration of Helsinki. Ethical clearance was unnecessary due to evaluation of medical records unrelated to direct patient examination.

The knee MRI scans included in this study were 101 which were reviewed using Carestream Vue Motion (Carestream Health Inc, Rochester, NY) for measurements. All imaging studies were performed on a 3.0-T magnet MRI Magnetom Skyra (Siemens Medical Solutions, Malvern, PA, USA). The following protocols were used: proton density-weighted sagittal image (thickness, 3.0 mm; time of repetition, 1300 ms; time to echo, 15–17 ms), T2-weighted axial images (thickness, 3.0 mm; time of repetition, 4000 ms; time to echo, 100–110 ms), and sagittal proton density-weighted images (thickness, 3.0 mm; time of repetition, 1300 ms; time to echo, 15–17 ms).

There were 73 males and 28 females with an average age of 30 (range 17–40). The measurements recorded were patellar thickness (with and without cartilage), patellar width at its widest point and patellar articular length according to Sullivan et al., 2014 (Fig. 1) [8].

2.1. Patellar thickness

On an extended knee, patellar thickness was obtained at the thickest point of axial MRI slice drawn in a line perpendicular to the medial/lateral axis. Afterwards, the thickness without cartilage was also recorded.

2.2. Patellar width

The width of patella was measured using an axial MRI cut in which the widest medial to lateral point of the patellar was recorded.

2.3. Patellar length

A proximal to distal patellar articular cartilage length was measured using sagittal MRI slice.

2.4. Statistical analysis

All data were collected and analyzed using SPSS software version 23. Descriptive statistics were calculated for all variables. One Way ANOVA was used to compare the differences between gender and physical characteristics.

All significance level was set at $P < 0.05$. Intra- and interobserver reliability of the patellar measurements on MRI was analyzed with an intraclass correlation coefficient (ICC) which strength of agreement may range from 0 to 1 (0.80 is good; 0.60–0.79 is moderate; 0.59 is poor).

Pearson rank correlation was used to evaluate the association between patellar thickness and patellar width, and between thickness and articular cartilage length. The strength of the correlation was indicated by the coefficient −1 to +1. When the relationship of one variable decreases while the other increases the coefficient is negative but greater than −1; when both variable increases the coefficient is positive but less than +1; and when a relationship is random or non-existent, the coefficients are nearly zero. Simple linear regression was used to estimate the association between patellar width and articular length with patellar thickness with and without articular cartilage thickness.

3. Results

A total of 101 cases (73 men, 28 women) were enrolled in this study. The participants had a mean age of 30.51 ± 5.65 (range 17–40 years), a mean height of 169.21 ± 7.9 (range 149–186 cm), a mean weight of 76.36 ± 15.00 (43.0–132.2 kg), a mean BMI of 26.60 ± 4.62 (range 28.57–41.7 kg/m^2). Height and weight were measured on the day of the MRI.

The physical characteristics of the patients are shown in Table 1, and for each characteristic, the values were significantly larger in males than

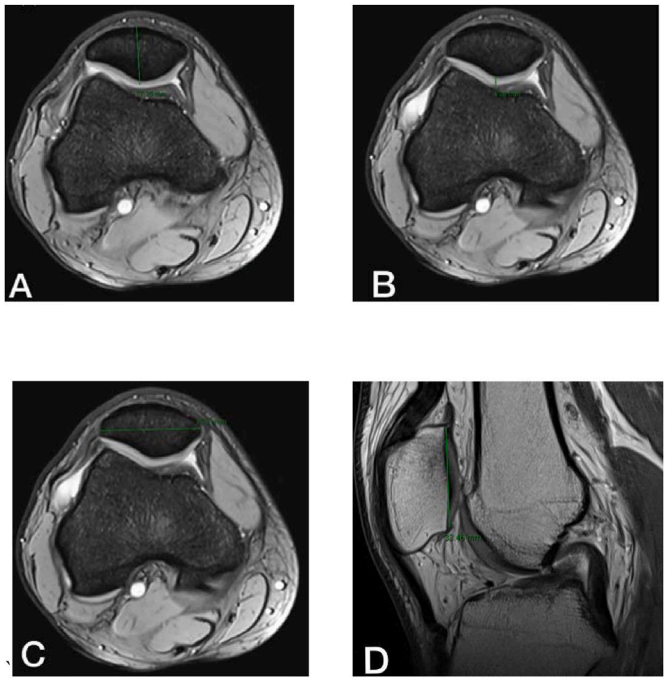

Fig. 1. Images from Carestream Vue illustrating the measured patellar dimensions. (a) Patellar thickness with cartilage. (b) Patellar cartilage thickness. (c) Patellar width. (d) Patellar articular length.

Table 1
Physical characteristics of the participants.

	Height (cm ± SD)	Weight (kg ± SD)	BMI (kg/m^2)
Total	169.21 ± 7.9	76.36 ± 15.00	26.60 ± 4.62
Male	171.98 ± 0.06	81.20 ± 12.75	27.44 ± 4.00
Female	162.00 ± 0.09	63.76 ± 13.08	24.41 ± 5.44
P value[a]	<0.0001	<0.0001	0.003

Data were given in mean ± standard deviation.
BMI Body mass index (kg/m^2).
[a] P value: comparison of values between males and females.

in females.

Patellar articular length mean ± standard deviation (95% confidence interval, 95% CI) was 30.06 ± 2.94 (29.48–30.64); patellar width was 44.13 ± 4.44 (43.26–45.01); patellar cartilage 3.64 ± 0.63 (3.52–3.77); patellar thickness with cartilage 23.89 ± 2.33 (23.43–24.35) and patellar thickness without cartilage 20.25 ± 2.26 (19.81–20.70). The ICC for intraobserver reliability was 0.912 in patellar thickness with and without cartilage ($P < 0.001$) and 0.871 in patellar width ($P < 0.0001$).

There were significant differences of all patellar dimensions in male and female ($P < 0.001$) except for articular cartilage thickness ($P = 0.305$). Male patella was significantly larger in the patellar articular cartilage length, width and thickness with and without cartilage (Table 2). However, there were no significant differences between patellar width and length with patellar thickness with and without cartilage (Table 2).

There were a moderate correlation between patellar width and patellar thickness with cartilage ($r = 0.66$, $P < 0.001$) with ratio of 1.85 ± 0.15 (1.82–1.88) (Fig. 2) and patellar width and patellar thickness without cartilage ($r = 0.62$, $P < 0.001$) with ratio of 2.19 ± 0.20 (2.15–2.23) (Fig. 3).

Meanwhile, patellar thickness with and without cartilage showed poor correlation with patellar articular length ($r = 0.58$ and $r = 0.55$) (Figs. 4 and 5).

4. Discussion

Our study is the first study evaluating patellar dimension using MRI in a healthy non-arthritic knee. The aim was to aid surgeons achieving the anatomic native patella size during patellar resurfacing or replacement in TKA. Several literatures (Table 3) found female Asian patellae

Table 2
Comparison results male vs. female.

Dimension	Male	Female	P value*
	Mean ± SD (95% CI) (mm)	Mean ± SD (95% CI) (mm)	
Articular cartilage length	30.81 ± 4.68 (CI 30.20–31.42)	28.12 ± 2.88 (CI 27.00–29.23)	P < 0.001
Patellar width	45.66 ± 3.41 (CI 44.87–46.46)	40.15 ± 4.39 (CI 38.44–41.85)	P < 0.001
Cartilage thickness	3.68 ± 0.67 (CI 3.52–3.84)	3.54 ± 0.51 (CI 3.34–3.73)	P = 0.305
Thickness with cartilage	24.56 ± 1.75 (CI 24.15–24.97)	22.16 ± 2.75 (CI 21.10–23.23)	P < 0.001
Thickness without cartilage	20.87 ± 1.70 (CI 20.48–21.27)	18.63 ± 2.71 (CI 17.57–19.68)	P < 0.001
Ratio width:thickness with cartilage	1.86 ± 0.14 (CI 1.83–1.90)	1.82 ± 0.15 (CI 1.76–1.88)	P = 0.190
Ratio width:thickness without cartilage	2.20 ± 0.20 (CI 2.15–2.24)	2.18 ± 0.21 (CI 2.10–2.26)	P = 0.633
Ratio length:thickness with cartilage	1.26 ± 0.11 (CI 1.23–1.28)	1.28 ± 0.13 (CI 1.23–1.32)	P = 0.442
Ratio length:thickness without cartilage	1.48 ± 0.14 (CI 1.45–1.51)	1.53 ± 0.18 (CI 1.46–1.59)	0.187

Data were given in mean ± standard deviation (95% confidence interval).
BMI Body mass index (kg/m^2).
a P value: comparison of values between males and females.

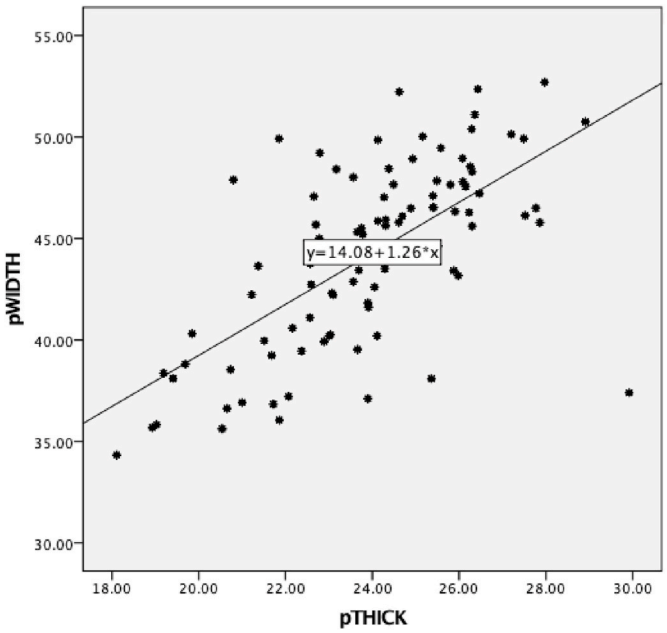

Fig. 2. Chart showing the strong, positive correlation between patellar thickness with cartilage and patellar width. r = 0.66.

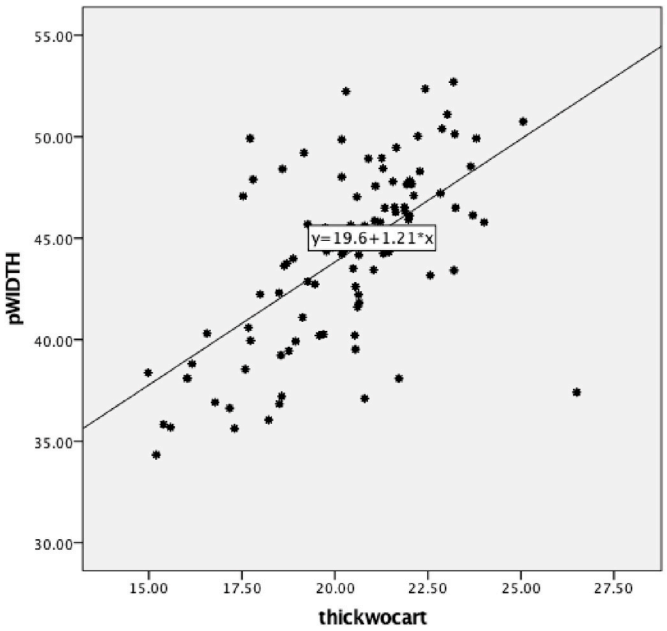

Fig. 3. Chart showing the strong, positive correlation between patellar thickness without cartilage and patellar width. r = 0.62.

were significantly smaller compared to Caucasian's [1,12,13]. However, our finding showed similar dimension between Asian and Caucasian patellae. This might be due to the difference method of measurement. Previous studies measured the patella using caliper in arthritic knee during TKA, meanwhile our study measured healthy patella using MRI. Loures et al., 2017 showed that MRI is a more reliable imaging to measure knee anthropometry similar with direct measurement [14].

The most significant finding in this study was that we obtained a ratio of 1.8:1 for patellar width and patellar thickness in Asian population. This result was similar to the study in Caucasian patient by Sullivan et al., 2014 [8]. Iranpour et al., 2008 [10] measured a ratio of 2 : 1 for patellar width: patellar thickness but did not account for articular

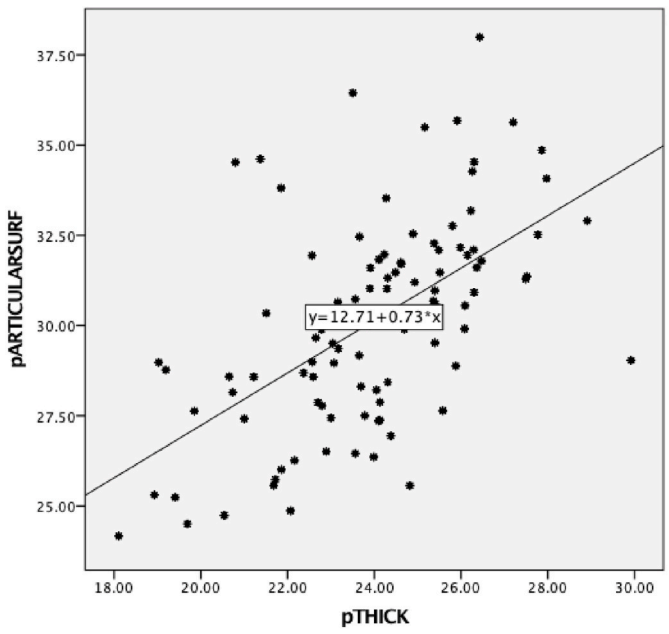

Fig. 4. Chart showing the strong, positive correlation between patellar thickness with cartilage and patellar articular surface. r = 0.58.

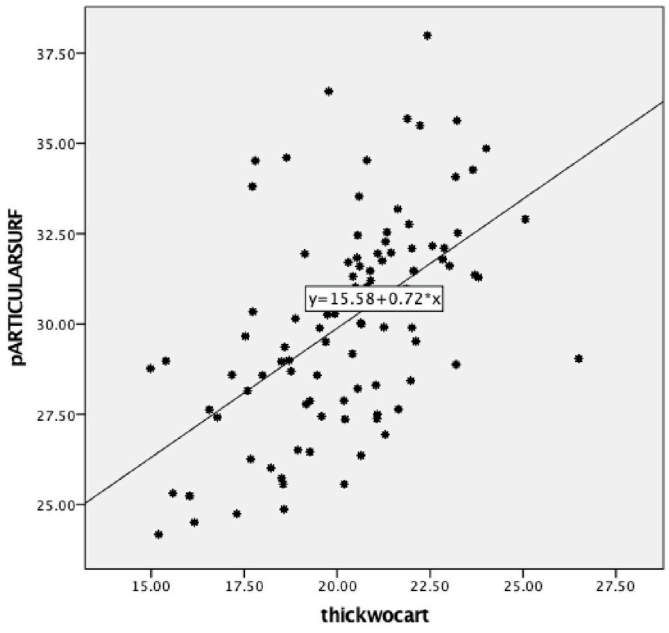

Fig. 5. Chart showing the strong, positive correlation between patellar thickness without cartilage and patellar width. r = 0.55.

cartilage thickness. In our study, if we reduce the patellar cartilage thickness we obtained the ratio of 2.19 : 1 with a weaker correlation. However, this would not reflect the normal 'chondral covering' of the patellar thickness in a normal situation.

We found that male patella was significantly larger of all measurement of patella except patellar cartilage which is consistent with other literatures [11,13–15]. Hence, this will need a consideration during a patellar resurfacing or replacement.

This study also showed similar patellar thickness measurement in healthy Asian and Caucasian knee [8]. However, patellar thickness in arthritic knee is slightly smaller than healthy knee using all methods [1,6,12], and evaluation using conventional radiograph [14] could show significantly smaller size compared to MRI or CT-3D [10]. A study by Jain et al., 2018 mentioned that patellar dimension in Indian population is smaller than Caucasian rendering the need to use special design patellar replacement [14]. However, this study was conducted using conventional X-ray which might be due to the different ratio used with MRI. Therefore during TKA, we recommend using ratio BIPWiT of 1.8:1 as a guide for patellar resurfacing or replacement to prevent patellofemoral joint pain after TKA.

4.1. Limitation of study

First of all this is a retrospective study of knee MRI with acute pain. Although we have excluded patients with patellofemoral disorder however, there might still be chances that the other pathology could influence the results since these are not 'normal' knee MRI. Further study comparing the BIPWiT ratio using other radiographic methods are recommended to evaluate the precision of this index.

5. Conclusion

BIPWiT of 1.8:1 between patellar width and patellar thickness was recommended as a guide for patellar thickness restoration during TKA. There is no difference of patellar dimension between Asian and Western population in a healthy knee.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Ethical approval

Not Required since study did not involve direct patients intervention but only the medical record data.

Consent

Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal on request.

Author statement

LAP contributed to perform the operation, data collection, analysis and interpretation, manuscript drafting, revising, and approval for publishing;

IHD contributed to assist the data collection, analysis and interpretation, manuscript drafting, revising, and approval for publishing.

AJR contributed to assist the operation, data collection, analysis and interpretation, manuscript drafting, revising, and approval for publishing;

WW contributed to assist the operation, data collection, analysis and interpretation, manuscript drafting, revising, and approval for publishing;

REPH contributed to data collection, analysis and interpretation of analysis, manuscript drafting, revising, and approval for publishing;

JF contributed to data collection, analysis and interpretation of analysis, manuscript drafting, revising, and approval for publishing.

Registration of research studies

1. Name of the registry: clinicaltrials.gov
2. Unique Identifying number or registration ID: NCT05112978
3. Hyperlink to your specific registration (must be publicly accessible and will be checked): https://register.clinicaltrials.gov/prs/app/act

Table 3
Comparison of patellar measurement in several literatures.

Study	Race	Nature of Knee	Method of Study	PatLength (mm)	PatWidth (mm)	PatThick (mm)
This study (n = 101)	Asian	Healthy	MRI	30.06 ± 2.94	44.13 ± 4.44	23.89 ± 2.33
Female (n = 28)				28.12 ± 2.88	40.15 ± 4.39	22.16 ± 2.75
Male (n = 73)				30.81 ± 4.68	45.66 ± 3.41	24.56 ± 1.75
Sullivan et al. (n = 75) [8]	Caucasian	Healthy	MRI	32.00 ± 3.30	44.70 ± 3.80	24.50 ± 2.00
Kim et al. [1] (n = 752)	Korean	Arthritic	Caliper	n/a	n/a	n/a
Female (n = 713)				33.1(23–43)	41.0(25–51)	21.2(17–26)
Male (n = 39)				36.2(31–52)	45.6(36–52)	23.1 (20–26)
Chmell et al. [12] (n = 198)	Caucasian	Arthritic	Caliper	n/a	n/a	n/a
Female (n = 123)				n/a	n/a	22.6(17.5–28)
Male (n = 75)				n/a	n/a	26.1(20–33)
Jain et al. [14] (n = 200)	Indian	Healthy	Xray	41.67 ± 4.01	43.35 ± 4.10	19.22 ± 2.19
Baldwin et al. [6] (n = 92)	Caucasian	Arthritic	Caliper	35.70(28–47)	46.10(36–65)	22.60(18–30)
Female (n = 57)				35.0(28–43)	42.7(32–50)	21.8(18–27)
Male (n = 35)				39.4(34–45)	49.5(44–64)	23.9(20–30)
Murugan et al. [15] (n = 65)	Indian	Healthy	Caliper	38.07 ± 3.79	38.58 ± 3.81	18.29 ± 1.73
Iranpour et al. [10] (n = 37)	Caucasian	Healthy	3D CT Scan	34.30 ± 3.80	44.80 ± 4.80	22.40 ± 2.30

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Guarantor

LAP is the guarantor of this study.

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None.

Declaration of competing interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amsu.2021.103072.

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