

Evaluation of Patellar Indices in the South Indian Population using Magnetic Resonance Imaging: A Retrospective Observational Study

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ABSTRACT

Introduction: Being placed subcutaneously, the patellofemoral joint carries a lot of significance and is also prone to a higher risk of trauma. Developmental and degenerative changes in patella are very common, sometimes warranting surgical intervention as well. Surgical procedures like total knee arthroplasty which are being performed across different age groups worldwide, mandating a study to evaluate the morphometric analysis of patella and its indices in different population.

Aim: To estimate the various patellar indices like Patellar Angle (PA), Patellar Relative Thickness (PRT), Patellar Facet Thickness (PFT), Patellar Lateral Facet Ratio (PLFR) and Patellar Medial Facet Ratio (PMLR) across both genders and also to compare and contrast them within the same gender by broadly classifying the cohorts into two different age groups.

Materials and Methods: A retrospective observational study was conducted in the Department of Radiology over four months, including 324 MRI. Patellar parameters such as height, width,

thickness, angle, lateral facet width, medial facet width and indices like PA, PRT, PFT, PLFR and PMLR were measured, and statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) Statistics software, version 22.0.

Results: The MRI of 162 males and 162 females were categorically classified into two groups: between 20-40 years and above 40 years. Across genders, strong statistical significance was observed for all parameters, including patellar height, width, angle, thickness, and facet thickness. Type 2 of Wiberg patellar variant was found to be the most commonly observed of the three types: 30 (37%) in females of the 20-40 years group, 45 (56%) in females > 40 years group, 43 (53%) in males of 20-40 years group and 49 (61%) in males >40 years group.

Conclusion: It was notable that almost all the parameters were statistically significant across the genders, while the significance was notably less when compared across the different age groups.

Keywords: Forensic applications, Knee surgeries, Morphometry, Patella, Prosthesis

INTRODUCTION

The patellofemoral joint is an articulation between the femoral trochlea and patella. The joint permits primarily translation from superior to inferior and also from lateral to medial sides [1]. Among the various sesamoid bones, the patella is particularly significant, being the largest of its kind. Being placed subcutaneously, it is highly susceptible to trauma in conditions involving the knee joint. Its fracture can also be easily confused with improper formation or degenerative changes, especially when osteochondral fragments lie within the joint cavity [2-6]. Critical surgeries such as total knee replacement and patellofemoral arthroplasty are performed widely [7,8]. Prosthesis manufacturing is mostly based on the requirements of the Caucasian population, whose morphometry differs markedly from that of the Indian population [9-11]. Various factors must be considered before constructing a prosthetic implant, including its 3D structure and angle. Dimensions also vary between genders within the same population [10,11]. The bone, apart from its surgical significance, also poses importance in the forensic platform with regards to identification of the age, gender, and population to which a person belongs [12-14].

The MRI has become the gold standard for visualising the patella, its central cartilaginous lesions (if any), its alignment with the femoral trochlea, any associated pathology, developmental defects, etc., in detail [15]. Therefore, the present study involves exploring the patellar indices in South Indian demographics.

MATERIALS AND METHODS

A retrospective observational study was conducted in the Department of Radiology at Chettinad Hospital and Research

Institute, Chettinad Academy of Research and Education from November 2021 to February 2022. The Institutional Human Ethics Committee approved the study protocol, ensuring adherence to ethical standards (Ref. no. IHEC-I/0226/21). The study analysed a dataset of 324 MRI of normal patellae, comprising equal numbers of male (162) and female (162) subjects.

Inclusion criteria: Images involving adult knee joints (>18 years of age) with normal morphology from both genders were used for the study.

Exclusion criteria: Subjects with congenital knee abnormalities, knee surgery or severe trauma, knee joint tumours, rheumatoid arthritis, acquired deformities, evident infective pathology, acute patellar dislocation, knees with degenerative changes, or patellar fractures. Additionally, those with poor-quality MR images, those in the paediatric age group, extensive bone erosions, significant bone density loss, and patients who underwent prior knee joint surgery or had any pathological changes were excluded from the study.

Study Procedure

Eleven patellar parameters were then measured from the mid-axial and sagittal MR images, where the maximal diameters of the patella were visible, as listed in [Table/Fig-1] and illustrated in [Table/Fig-2,3].

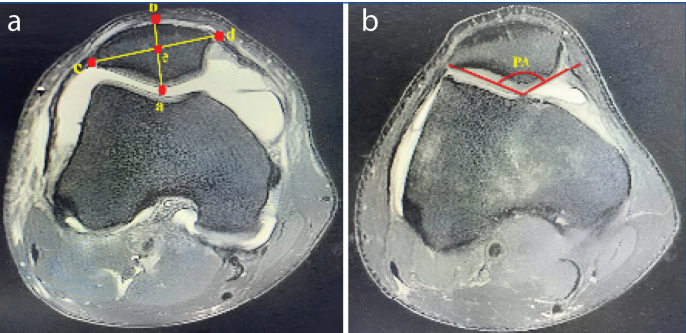
The patellae were categorised by morphology using the Wiberg classification system, which defines three main types:

Wiberg Type-I - Centrally located patellar ridge.

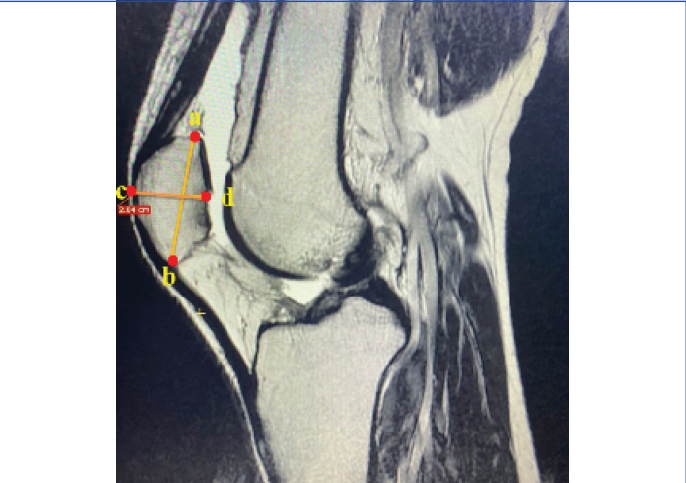
Wiberg Type-II - The patellar ridge is slightly medial, resulting in a smaller medial facet compared to the lateral facet.

Indices	Measurements	
	From	To
Patella Height (PH)	Tip of patellar apex	Base of patella
Patellar Width (PW)	Most medial ends of the patella	Most lateral ends of the patella
Patella Thickness (PT)	Patellar central ridge	Patellar anterior point
Patellar Facet Thickness (PFT)	Central ridge point	Central point of patella
Patellar Lateral Facet Width (PLFW)	Central point of patella	Most lateral point of patella
Patellar Medial Facet Width (PMFW)	Central point of patella	Most medial point of patella
Indices	Angle/Ratios	
Patella Angle (PA)	Angle between medial and lateral patellar facets with the point of patellar central ridge as the zenith	
Patellar Relative Thickness	PRT=PT/PW	
Patellar Facet Thickness Ratio (PFTR)	PFTR=PFT/PT	
Patellar Lateral Facet Ratio (PLFR)	PLFR=PLFW/PW	
Patellar Medial Facet Ratio (PMFR)	PMFR=PMFW/PW	

[Table/Fig-1]: The measured parameters of the patella from MRI images.



[Table/Fig-2]: Representative image of Magnetic Resonance Imaging (MRI) right knee T2 axial section illustrating (a). The landmarks: a- base of patella, b- patellar anterior point, c- most lateral point, d- most medial point, e- patellar central point, and indices including ab- patellar thickness, cd- patellar width, ae- patellar facet thickness, ce- patellar lateral facet width, ed- patellar medial facet width, (b). Patella angle.



[Table/Fig-3]: Representative image of Magnetic Resonance Imaging (MRI) knee T2 section illustrating. The landmarks a- point of the patellar central ridge, b-Tip of patellar apex, c- Most anterior point, d- Most posterior point, and indices including ab- patellar height, cd- patellar facet thickness.

1. Male participants aged 20-40 years (n=81)
2. Female participants aged 20-40 years (n=81)
3. Male participants aged ≥ 40 years (n=81)
4. Female participants aged≥ 40 years (n=81).

The 40-year age threshold was selected based on preliminary findings showing negligible differences in patellar measurements within each age category, facilitating a targeted analysis of sex- and age-related differences in patellar morphology.

STATISTICAL ANALYSIS

Data analysis was performed using IBM SPSS Statistics for Windows, version 22.0. The normality of parametric data was assessed using the Kolmogorov-Smirnov test. Continuous data were summarised as mean ± standard deviation. Statistical significance was set at a level of 0.05. Two distinct groups were compared for parametric variables using Student's t-test.

RESULTS

It was notable that almost all the parameters were statistically significant across the genders while the significance was notably less when compared across the different age groups [Table/Fig-4,5].

Patellar indices from MRI images	Male 20-40 years (mean±SD)	Male ≥40 years (mean±SD)	t-value	p-value
Patella height	5.18±0.43	5.31±0.49	1.73	0.043
Patella angle	134.59±3.86	133.70±1.98	1.84	0.034
Patella width	4.54±0.19	4.53±0.170	0.39	0.348
Patella thickness	2.07±0.08	2.01±0.12	3.32	<0.001
Patellar relative thickness	0.45±0.02	0.44±0.03	2.46	0.007
Patella facet thickness	1.21±0.04	1.16±0.01	10.73	<0.001
Patellar facet thickness ratio	0.58±0.03	0.57±0.03	1.52	0.066
Patella lateral facet width	2.48±0.24	2.46±0.28	0.51	0.307
Patellar lateral facet ratio	0.54±0.05	0.54±0.06	0.29	0.384
Patella medial facet width	2.11±0.27	2.09±0.25	0.41	0.341
Patellar medial facet ratio	0.46±0.05	0.46±0.056	0.26	0.399

Patellar indices from MRI images	Female 20-40 years (mean±SD)	Female ≥40 years (mean±SD)	t-value	p-value
Patella height	3.94±0.08	3.98±0.08	2.95	0.001
Patella angle	130.92±2.72	129.05±3.27	3.95	<0.001
Patella width	3.92±0.14	3.94±0.14	1.01	0.158
Patella thickness	1.83±0.10	1.74±0.15	4.26	<0.001
Patellar relative thickness	0.46±0.03	0.44±0.04	3.31	<0.001
Patella facet thickness	1.014±0.04	0.96±0.02	9.64	<0.001
Patellar facet thickness ratio	0.58±0.05	0.52±0.03	8.08	<0.001
Patella lateral facet width	2.32±0.20	2.34±0.32	0.50	0.309
Patellar lateral facet ratio	0.59±0.05	0.59±0.08	0.14	0.443
Patella medial facet width	1.88±0.21	1.94±0.23	1.48	0.071
Patellar medial facet ratio	0.48±0.05	0.49±0.06	1.15	0.125

[Table/Fig-4]: Age-specific differences in patellar indices observed in MRI images.

Patellar indices from MRI images	Male 20-40 years (mean±SD)	Female 20-40 years (mean±SD)	t-value	p-value
Patella height	5.18±0.43	3.94±0.08	25.13	<0.001
Patella angle	134.59±3.86	130.92±2.72	6.98	<0.001
Patella width	4.54±0.19	3.92±0.14	22.79	<0.001
Patella thickness	2.07±0.08	1.74±0.15	16.85	<0.001
Patellar relative thickness	0.45±0.029	0.44±0.042	2.11	0.018
Patella facet thickness	1.21±0.04	1.01±0.04	30.48	<0.001

Wiberg Type-III - Significantly medial patellar ridge, leaving minimal space for the medial facet [1].

Atypical - Patellae that do not conform to these types are considered atypical [16].

The present study aimed to quantify sex and age variations in patellar measurements by examining 324 patellar MR images, stratified into four distinct cohorts based on age and sex:

Patellar facet thickness ratio	0.58±0.03	0.59±0.05	0.51	0.306
Patella lateral facet width	2.48±0.24	2.32±0.20	4.61	<0.001
Patellar lateral facet ratio	0.54±0.05	0.59±0.05	5.06	<0.001
Patella medial facet width	2.11±0.27	1.88±0.21	5.85	<0.001
Patellar medial facet ratio	0.46±0.05	0.48±0.05	1.82	0.035
Patellar indices from MRI images	Male >40 years (mean±SD)	Female >40 years (mean±SD)	t-value	p-value
Patella height	5.31±0.49	3.98±0.08	23.93	<0.001
Patella angle	133.70±1.98	129.05±3.27	10.94	<0.001
Patella width	4.53±0.17	3.94±0.14	23.88	<0.001
Patella thickness	2.01±0.12	1.83±0.10	10.46	<0.001
Patellar relative thickness	0.46±0.03	0.44±0.03	3.86	<0.001
Patella facet thickness	1.16±0.01	0.96±0.02	76.31	<0.001
Patellar facet thickness ratio	0.57±0.03	0.52±0.03	9.54	<0.001
Patella lateral facet width	2.46±0.28	2.34±0.32	2.58	0.005
Patellar lateral facet ratio	0.54±0.06	0.59±0.08	4.14	<0.001
Patella medial facet width	2.09±0.25	1.94±0.23	4.13	<0.001
Patellar medial facet ratio	0.46±0.05	0.49±0.06	3.12	<0.001

[Table/Fig-5]: Sexual differences in patellar indices observed in MRI images.

Patellar type: Among the different morphologies of patella according to the Wiberg classification system, the Type 2 patella was apparently the one with the highest incidence in all four cohorts taken into consideration, consequently making the Type 2 patella the most common among the South Indian population [Table/Fig-6,7].

Wiberg type of patella	Females 20-40 years (n=81)	Females > 40 years (n=81)
	n (%)	n (%)
Type 1	22 (27)	10 (12)
Type 2	30 (37)	45 (56)
Type 3	27 (33)	23 (28)
Atypical	2 (3)	3 (4)

[Table/Fig-6]: Wiberg classification of the patella showing distribution in female between 20-40 years of age above 40 years of age.

Study	Population	Publication year	PH	PA	PW	PT
Sah SK et al., [17]	Nepal	2021	M: 36.23±4.20 F:33.53±4.80	-	M: 37.15±6.09 F:34.53±6.07	M: 17.00±1.87 F:16.00±1.95
Olateju OI et al., [18]	South Africa	2013	43.73±3.65	-	45.14±3.96	R: 23.85±2.18 L:24.10±2.06
Shang P et al., [19]	China	2014	R: 39.98±3.55L: 39.90±3.85	-	R: 44.12±3.98L: 44.15±3.99	R:22.65±1.83 L: 22.79±1.82
Katchy AU et al., [20]	Nigeria	2020	46.1±4.7	-	46.9±0.9	26.6±1.5
Maia Medeiros JP et al., [21]	Brazil	2021	-	-	42.64	-
Yoo JH et al., [22]	Korean	2007	-	-	M: 47 F: 41.2	M: 23.1 F: 21.2
Mzimela N et al., [23]	South Africa	2024	M: 41.98±3.18F: 37.35±2.71	-	M: 42.96±3.77F: 39.35±3.10	M:20.52±1.78F: 18.67±1.49
Sakaue K [12]	Japan	2008	M: 41.1F: 36.6	-	M: 43.5 F: 39.1	M:19.4 F: 17.7
Peckmann TR et al., [13]	Spain	2016	M:42.90F:37.89	-	M: 44.62 F: 40.30	M:20.34 F:18.13
Jan SS [24]	India- North	2023	R:3.99±0.33 L:4.10±0.45	-	R:4.10±0.38 L:4.11±0.36	R:2.02±0.14L: 2.00±0.20
Kumar R et al., [10]	India- West	2020	-	-	M: 44.42±3.59, F: 39.11±2.53	M:19.37±2.33, F:17.74±1.28
Muhammed R et al., [11]	India- South	2017	-	M:127±4.60, F: 125.01±2.87	M: 42.21±2.03, F: 36.07±1.49	M: 20.30±0.89, F:16.24±0.92

Wiberg type of patella	Males 20-40 years (n=81)	Males > 40 years (n=81)
	n (%)	n (%)
Type 1	17 (21)	26 (32)
Type 2	43 (53)	49 (61)
Type 3	15 (18)	6 (7)
Atypical	6 (8)	0

[Table/Fig-7]: Wiberg classification of the patella showing distribution in male between 20-40 years of age above 40 years of age.

Bipartite patella: Bipartite patella was observed in four images (1.23%) of the 324 MR images studied [Table/Fig-8].



[Table/Fig-8]: Bipartite patella - inferior type.

DISCUSSION

Following an extensive literature review, authors compared and contrasted patellar morphometry data across regions worldwide [Table/Fig-9a,b] [10-13,17-24].

Patella thickness is an index that demonstrates sexual dimorphism, with males exhibiting greater thickness compared to females. This difference was statistically significant in both age groups. The increased patellar thickness in males may be related to higher bone density and greater mechanical load-bearing capacity. Hudelmaier M et al., reported patellar cartilage thickness to be lower in asymptomatic women than in men, consistent with the present study [25].

Present study 20-40 years	India- South	2026	M: 5.18±0.43, F: 3.94±0.08	M: 134.59±3.86, F: 130.92±2.72	M: 4.54±0.19, F: 3.92±0.14	M: 2.07±0.08, F: 1.83±0.10
Present study≥ 40 years	India- South	2026	M: 5.31±0.49, F: 3.98±0.08	M: 133.70±1.98, F: 129.05±3.27	M: 4.53±0.170, F: 3.94±0.14	M: 2.01±0.12, F: 1.74±0.15

[Table/Fig-9a]: Comparative analysis of morphometry of patella across different population [10-13,17-24].
Abbreviations: PH: Patellar height; PA: Patellar angle; PW: Patellar width; PT: Patellar thickness

Study	Population	Year	PRT	PFT	PFTR	PLFW	PLFR	PMFW
Sah SK et al., [17]	Nepal	2021	-	-	-	M: 23.84±2.57 F:18.53±3.01	-	M: 20.46±1.76 F:15.69±2.09
Kafa B et al., [7]	Turkey	2024	2.10±0.15	10.89±1.33	0.56±0.06	25.65±3.35	-	20.19±2.35
Baldwin JL and House CK [9]	USA	2005	-	-	-	-	-	27.5
Olateju OI et al., [18]	South Africa	2013	-	-	-	26.02±2.68	-	20.38±3.36
Shang P et al., [19]	China	2014	-	-	-	R: 25.21±2.88 L:25.06±2.68	-	R: 18.92±2.20L: 19.15±2.24
Katchy AU et al., [20]	Nigeria	2020	-	-	-	27.7±1.8	-	25.5±1.8
Maia Medeiros JP et al., [21]	Brazil	2021	-	-	-	24.17±0.31	-	18.47±0.36
Yoo JH et al., [22]	Korean	2007	-	-	-	-	-	-
Mzimela N et al., [23]	South Africa	2024	-	-	-	M: 26.50±2.33F: 23.65±1.85	-	M:21.11±1.95F: 19.03±1.61
Sakaue K [12]	Japan	2008	-	-	-	M: 27.5 F: 24.5	-	M: 21.5 F: 19.3
Peckmann TR et al., [13]	Spain	2016	-	-	-	M:24.83F:22.47	-	M:19.19 F:17.02
Jan SS [24]	India-North	2023	-	-	-	R:2.40±0.20 L:2.45±0.24	-	R:2.12±0.20 L:2.02±0.27
Kumar R et al., [10]	India-West	2020	M:0.44±0.06, F: 0.45±0.04	M: 11±1.20, F: 10.56±1.07	M: 0.57±0.06, F: 0.60±0.05	M:25.05±2.88, F: 22.21±2.08	M: 0.50±0.04, F: 0.57±0.05	-
Muhammed R et al., [11]	India-South	2017	M:0.48±0.03, F: 0.45±0.04	M: 12.21±0.77, F: 10.26±0.99	M: 0.60±0.05, F: 0.63±0.05	M: 22.59±1.99, F: 19.47±1.11	M:0.53±0.05, F:0.54±0.04	-
Present study 20-40 years	India-South	2026	M: 0.45±0.02, F: 0.46±0.03	M: 1.21±0.04, F: 1.014±0.04	M: 0.58±0.03, F: 0.58±0.05	M: 2.48±0.24, F: 2.32±0.20	M: 0.54±0.05, F: 0.59±0.05	M: 2.11±0.27, F: 1.88±0.21
Present study≥ 40 years	India-South	2026	M: 0.44±0.03, F: 0.44±0.04	M: 1.16±0.01, F: 0.96±0.02	M: 0.57±0.03, F: 0.52±0.03	M: 2.46±0.28, F: 2.34±0.32	M: 0.54±0.06, F: 0.59±0.08	M: 2.09±0.25, F: 1.94±0.23

[Table/Fig-9b]: Comparative analysis of morphometry of patella across different population 7,9-13,17-24].
Abbreviations:PRT: Patellar relative thickness; PFT: Patellar facet thickness; PFTR: Patellar facet thickness ratio; PLFW: Patellar lateral facet width; PLFR: Patellar lateral facet ratio; PMFW: Patellar medial facet width

In the present study, most patellae were Type 2, which was similar to the other studies mentioned in [Table/Fig-10] [1,7,21,23].
The present study could be further improved with a larger sample size, whose findings could be imperative in the forensic field and advance prosthetic design modelling.

Study	Population	Type 1 (%)	Type 2(%)	Type 3(%)
Kafa B et al., 2024 [7]	Turkey	7.73	64.88	27.38
Wiberg G 1941 [1]	Sweden	12	84	4
Maia Medeiros JP et al., [21]	Brazil	15.2	84.8	-
Mzimela N et al., [23]	South Africa	1.9	59.7	38.3

[Table/Fig-10]: Comparison of Wiberg types across different population [1,7,21,23].

Limitation(s)

The study had certain limitations. Being a retrospective, single-centre study, the sample may not fully represent the diversity within the South Indian population. Further studies involving a larger multicentric approach would be more fruitful.

CONCLUSION(S)

This study estimated various patellar indices in the South Indian population using MRI, and in doing so, revealed marked sexual dimorphism across nearly all parameters. On comparing the same indices within the same gender across two age groups, the differences were far less pronounced, suggesting that patellar morphometry is influenced more strongly by sex than by age beyond early adulthood. This emphasises on the need to account for sex

and population based variations in patellar morphometry while designing prosthetic implants and also while considering these indices for forensic age and sex estimation.

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Authors’ contribution: All authors have contributed to the study in conceptualising and designing it, collecting data, analysing it, writing and reviewing the manuscript.

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