

Morphometry of the Patella and Patellar Ligament for Bilateral Variation and Sexual Dimorphism: A Cadaveric Study from Chennai, India

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ABSTRACT

Introduction: The patella and ligamentum patellae together form a complex structure in front of the knee joint to stabilise it. The patella is a dense, thick bone and is covered by a compact lamina, which helps delay putrefaction or decomposition after death. This characteristic feature significantly affects the estimation of sex, age, and racial features. Variations in patellar and ligament dimensions aid knee replacement surgery, implant design, reconstruction procedures, and sex differentiation.

Aim: To evaluate the patella and ligamentum patellae morphometry to assess the differences between the sides and genders and to classify the patellar articular facet according to the Koyuncu classification.

Materials and Methods: This cross-sectional morphometric study was carried out at the Department of Anatomy, Saveetha Medical College and Hospital (SIMATS), Thandalam, Chennai, Tamil Nadu, India, from June 2025 to November 2025 on 32 human cadavers (16 males and 16 females) comprising 64 patellae in total. The dimensions such as height, width, thickness, central ridge length, medial and lateral articular facets of the patella, and the length, thickness, proximal and distal width of the ligamentum patellae were measured and compared between the sides and genders. Patellar facets were categorised as per Koyuncu's categories. A p-value <0.05 was

considered statistically significant. An Independent t-test or Mann-Whitney U test was used for continuous variables based on normality using the Shapiro-Wilk test, and the Chi-square test was used for categorical variables.

Results: A significant side difference was observed with only one bony parameter (length of the medial articular facet), and all other bony parameters showed no significant difference between the sides (p-value >0.05). The length, thickness and distal width of ligamentum parameters differed significantly between the sides (p-value >0.05). Significant side differences were observed for all measured ligamentum patellae parameters (p<0.05), with higher values on the right side. Most patellar and ligamentum patellae parameters showed significantly higher values in males than females. As per Koyuncu's classification, predominance in Type B (82.81%) morphology was noted, followed by Type C (12.50%) and Type A (4.69%).

Conclusion: All the patella and ligamentum patellae dimensions showed significant sexual differentiation with unilateral imbalance in specific dimensions like the medial articular facet and all ligament parameters. The most prevalent Type B patellar articular facets ensure the importance of population-specificity in implant design, anterior cruciate ligament repair (ACL repair or reconstruction), and forensic tools in sexual differentiation.

Keywords: Articular facets, Cadavers, Morphometry; Knee joint, Sex differentiation

INTRODUCTION

The patella is the largest sesamoid bone (kneecap) wrapped by the quadriceps tendon in front of the knee joint, forming the patellofemoral complex and attached distally to the tibial tuberosity, forming the ligamentum patellae. This complex bony-ligamentous structure maintains the integrity of patellofemoral joint biomechanics and enhances the ability of the quadriceps femoris tendon over the knee joint for effective extension, force transmission and joint stabilisation [1,2]. The dense cortical structure in the patella helps to sustain resistance during post-mortem degradation, which makes it one of the best single bones in forensic research for multiple purposes such as age estimation, sexual differentiation, and also for racial documentation of population-specific skeletal remains [3]. Hence, patellar morphometric data may be the guide for multiple orthopaedic procedures such as arthroplasty, implant design, and reconstructive procedures [2,4]. Ligamentum patellae is commonly used as an autograft in anterior cruciate ligament repair (ACL reconstruction), hence, patellar morphometry is likely a tool for successful graft harvesting and surgical planning [5].

Multiple studies have reported the patellar significance in sexual dimorphism, with larger dimensions in males than females [6,7].

Patellar characterisation in sexual differentiation has been explored for gender determination in unknown bodies through radiological methods or discriminant functional analysis [8,9]. Consistency of patellar morphometry in racial specificity (population-specific) is reported by previous literature [7,10].

Patella has also been investigated for its bilateral specificity in addition to sexual dimorphism. The majority of the patellar parameters show bilateral symmetry, with the exception of certain articular facet dimensions and ligament-related parameters which are asymmetrical between the sides. This may be due to factors such as age, gender, mechanical load (lifestyle) and age-related changes [11,12].

The differential facet morphology has a direct impact on patellofemoral biomechanics, joint stability, and prosthetic compatibility. Koyuncu classified relative differential patterns between the medial and lateral patellar articular facets as type A, B, and C, with type B being the most common pattern in the South Indian population, which is characterised by a wider lateral facet than the medial facet [13].

Numerous dry patellar morphometric studies have been reported, but the morphometric data integrating wet patellae and ligamentum patellae in both bilaterality and sexual differentiation in human

cadavers remain limited [6,7,14,15]. Hence, the present study aimed to analyse the morphometry of the wet patella and ligamentum.

MATERIALS AND METHODS

This cross-sectional morphometric study was carried out at the Department of Anatomy, Saveetha Medical College and Hospital (SIMATS), Thandalam, Chennai, Tamil Nadu, India, from June 2025 to November 2025. Ethical approval for the study was obtained from the institute Ethics Committee (IEC) of Saveetha Medical College and Hospital, Chennai, Tamil Nadu, India (Approval number SMC/IEC/2025/02/056 dated February 20, 2025).

Inclusion criteria: Human cadavers with intact and anatomically preserved patellae were included for morphometric and statistical analysis in the study.

Exclusion criteria: Human cadavers with a history of trauma to the knee joint, osteoarthritis, and those that underwent any kind of orthopaedic procedure such as arthroscopy, knee surgeries, knee replacement, anterior and posterior cruciate ligament etc., were excluded from the study.

Sample size estimation: Consecutive sampling was used. All adult human cadavers fulfilling the predefined eligibility criteria and available during the study period were included. A total of 32 cadavers, comprising 16 males and 16 females, yielded 64 patellae.

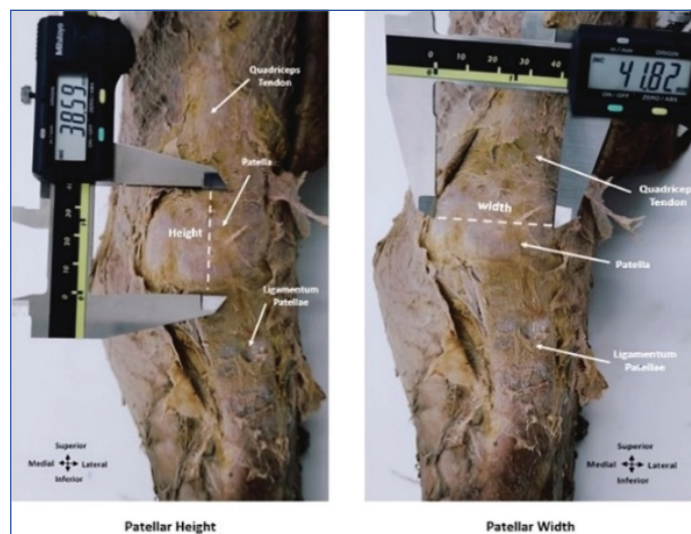
Study Procedure

The study was conducted on human cadavers utilised for routine lower limb dissection as part of regular undergraduate MBBS anatomy teaching sessions. During the scheduled knee joint dissection, the anterior aspect of the knee region was explored for the patella and ligamentum patellae. After reflection of the skin, superficial, and deep fascia, the connective tissue around the patella and ligamentum patellae was carefully removed. The quadriceps tendon superior to the patella and the ligamentum patellae extending from the apex of the patella to the tibial tuberosity were fully exposed. The patella was then carefully isolated from surrounding soft tissues while maintaining its anatomical integrity, and the following morphometric measurements of the patella and ligamentum patellae were obtained using a digital Vernier calliper (Mitutoyo digital Vernier calliper with sensitivity to 0.1 mm),

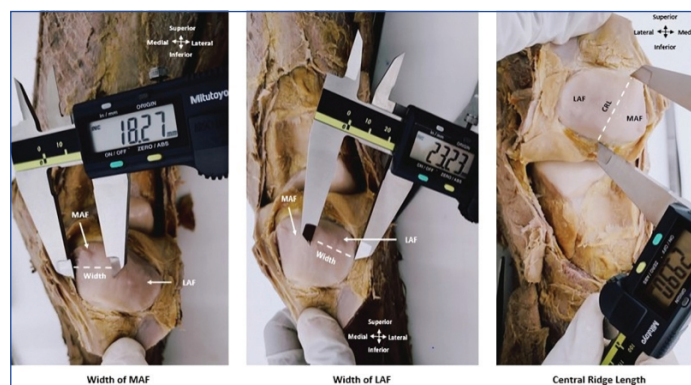
1. Height of the patella (PH) – Linear distance from the superior border to the apex of the patella [13].
2. Width of the patella (PW) – Maximum distance between the medial and lateral borders of the patella [13].
3. Thickness of patella (PT) - Distance between the maximum convexities from the anterior surface to the median ridge on the posterior surface [13].
- 4a. Length of lateral articular facet (LLAF) – Maximum length from the superior to inferior border of the lateral articular facet [13].
- 4b. Width of lateral articular facet (WLAF) - Maximum width from the lateral border to the median ridge of the patellae [13].
- 5a. Length of medial articular facet (LMAF) – Maximum length from the superior to inferior border of the medial articular facet [13].
- 5b. Width of medial articular facet (WMAF) - Maximum width from the medial border to the median ridge of the patellae [13].
6. Central ridge length (CRL) – Maximum length from the superior to inferior pole of the central ridge [13].
7. Length of ligamentum patellae (LLP) – Distance from the tip of the patellar apex to the tibial tuberosity [3].
8. Proximal width of ligamentum patellae (PWLP) – Linear distance distal to the apical attachment of ligamentum patellae [3].
9. Distal width of ligamentum patellae (DWLP) – Linear distance proximal to the tibial tuberosity attachment of ligamentum patellae [3].

10. Thickness of ligamentum patella (TLP) – Distance from anterior to posterior surface at the middle of ligamentum patellae [3].

Each parameter was measured thrice in millimetres (mm) by 3 different observers, and the mean value was documented for the statistical analysis to reduce the inter-observer variability. [Table/ Fig-1-3] show the measurement of multiple dimensions in the wet patella, patellar articular facets and ligamentum patellae using a Mitutoyo digital Vernier calliper with a sensitivity to 0.1 mm.

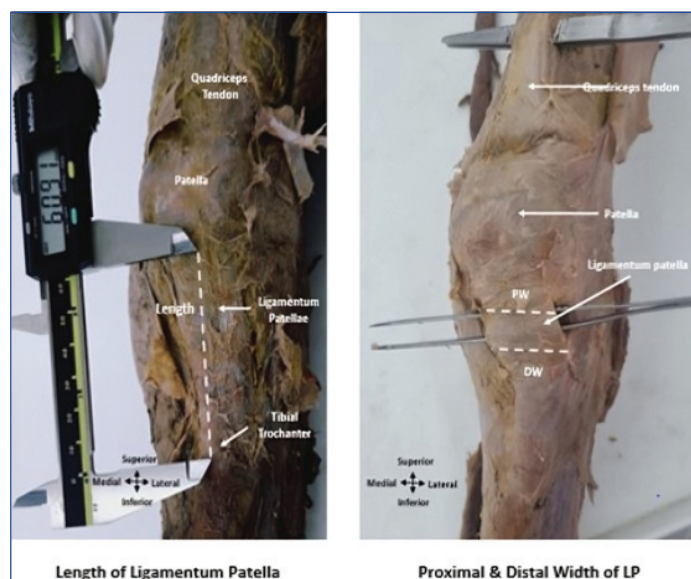


[Table/Fig-1]: Patellar length and width.



[Table/Fig-2]: Central ridge length, width of the medial and lateral articular facets of patella.

MAF: Medial articular facet, LAF: Lateral articular facet, CRL: Central ridge length



[Table/Fig-3]: Length, proximal and distal width of ligamentum patellae.

PW: Proximal Width, DW: Distal width

Koyuncu's classification: Koyuncu's classified the patella into three categories (A, B, C) with reference to the width of the medial

and lateral articular facets of the patella. In this classification, class A refers to the same or equal width in both articular facets, class B refers to the lateral articular facets being larger in width than the medial articular facets, and class C refers to the medial articular facets being larger in width than the lateral articular facets [16]. The present study also observed the type of patellae based on Koyuncu's classification.

STATISTICAL ANALYSIS

Microsoft Excel for Microsoft 365 (Microsoft Corporation, Redmond, WA, USA) was used for entering the measurements of all patellar parameters, and IBM Statistical Package for Social Sciences (SPSS) Statistics for Windows, Version 32.0 (IBM Corp., Armonk, NY, USA) was used for the purpose of statistical analysis. Normally distributed continuous variables were compared using the paired t-test for right-left comparisons and the Independent-samples t-test for male-female comparisons. The Wilcoxon signed-rank test and Mann-Whitney U test were used for non normal distributed paired and independent observations, respectively.

RESULTS

A total of 32 adult human cadavers, comprising 16 males and 16 females, were included in the present study, yielding 64 wet patellae for morphometric assessment. The patellar and ligamentum patellae parameters were measured bilaterally, and the findings were analysed with respect to sexual dimorphism and bilateral differences.

Most patellar morphometric parameters were not statistically significant between the right and left sides ($p>0.05$), indicating strong bilateral symmetry [Table/Fig-4]. Key dimensions such as patellar height, width, thickness, and lateral facet measurements were comparable on both sides. However, significant differences were observed in the length of the medial articular facet and all measured parameters of the ligamentum patellae ($p=0.001$). These findings indicate side-specific variations in the above parameters. This suggests that while the overall bony morphology is symmetrical, certain articular and ligamentous components exhibit side-specific variation.

S. No.	Parameters	Right side (32) Mean±SD (mm)	Range (mm)	Left side (32) Mean±SD (mm)	Range (mm)	p-value *
1.	Height of the patella	38.59±3.84	32.57 – 47.49	38.66±3.92	32.6 – 47.7	0.897
2.	Width of the patella	39.67±3.60	34.54 – 47.84	40.19±3.71	35.12 – 47.81	0.324
3.	Thickness of the patella	21.85±2.11	19.04 – 24.92	21.35±2.25	17.42 – 25.81	0.325
4.	Length of the lateral articular facet	28.13±3.03	21.7 – 37.23	28.87±2.99	21.61 – 35.2	0.295
5.	Width of the lateral articular facet	23.40±2.08	19.11 – 28.48	23.03±2.51	18.56 – 30.22	0.386
6.	Length of the medial articular facet	24.00±2.42	20.53 – 28.5	25.45±2.82	20.05 – 31.31	0.001 *
7.	Width of the medial articular facet	21.45±1.9	18.65 – 25.7	21.82±2.09	17.98 – 26.32	0.443
8.	Central ridge length	32.70±3.20	25.00 – 39.0	32.70±4.60	25.00 – 40.0	0.971
9.	Length of ligamentum patellae	49.90±2.20	45.10 – 54.7	47.70±1.90	45.10 – 52.6	0.001 *

10.	Proximal width of ligamentum patellae	35.00±2.90	30.90 – 39.7	33.20±1.80	30.70 – 38.4	0.001 *
11.	Distal width of ligamentum patellae	25.80±3.00	22.40 – 30.9	23.20±1.70	20.50 – 27.6	0.001 *
12.	Thickness of ligamentum patellae	5.96±0.47	5.28 – 6.57	5.77±0.49	5.14 – 6.44	0.001 *

[Table/Fig-4]: Comparison of the patellar morphometric parameters between the right and left side.

*p-value less than 0.05 was considered as statistically significant.

The statistically significant sexual dimorphism in all measured patellar parameters ($p<0.05$) is shown in [Table/Fig-5]. Male patellae showed consistently higher values than females for height, width, thickness, articular facet dimensions, central ridge length, and ligamentum patellae measurements. This clearly shows that the males are with larger and robust patella with the reliability of patellar parameters for sexual differentiation, especially during implant design.

S. No.	Parameters	Male (32) Mean±SD (mm)	Range (mm)	Female (32) Mean±SD (mm)	Range (mm)	p-value *
1.	Height of the patella	41.10±3.74	32.6 – 47.7	36.16±1.87	32.57 – 41.91	0.001 *
2.	Width of the patella	42.39±3.27	35.49 – 47.84	37.47±1.94	34.54 – 40.81	0.001*
3.	Thickness of the patella	22.48±1.92	17.42 – 25.81	20.72±2.08	17.76 – 24.56	0.001 *
4.	Length of the lateral articular facet	29.59±3.64	21.61 – 37.23	27.41±1.62	24.89 – 31.78	0.004 *
5.	Width of the lateral articular facet	24.43±2.33	19.32 – 30.22	22.00±1.49	18.56 – 26.87	0.001 *
6.	Length of the medial articular facet	26.19±2.83	20.05 – 31.31	23.26±1.54	21.11 – 25.87	0.001*
7.	Width of the medial articular facet	22.44±2.21	18.65 – 26.32	20.83±1.36	17.98 – 23.65	0.001 *
8.	Central ridge length	35.40±2.40	29.00 – 40.0	29.90±3.30	25.00 – 35.0	0.001 *
9.	Length of Ligamentum patellae	49.90±2.10	45.10 – 54.7	47.60±1.90	45.10 – 52.4	0.001 *
10.	Proximal width of ligamentum patellae	36.10±2.20	32.40 – 39.7	32.20±2.01	30.70 – 33.6	0.001*
11.	Distal width of ligamentum patellae	26.50±2.50	22.80 – 30.9	22.50±1.09	20.50 – 23.9	0.001 *
12.	Thickness of ligamentum patellae	6.33±0.14	6.04 – 6.57	5.40±0.17	5.14 – 5.69	0.001*

[Table/Fig-5]: Comparison of the patellar morphometric parameters between male and female.

*p-value less than 0.05 was considered as statistically significant.

A consistent sexual dimorphism was observed on both the right and left sides, with males showing significantly higher values than females in most patellar and ligamentum patellae parameters ($p<0.05$) [Table/Fig-6,7]. On the right side, a few parameters, such as patellar thickness and medial facet width, did not show significant differences, indicating selective variation. On the left side, almost all parameters were significantly different except the length of the lateral articular facet. Gender-related differences were observed for most parameters on both sides, although selected measurements did not reach statistical significance.

S. No.	Parameters	Male (16) Mean±SD (mm)	Female (16) Mean±SD (mm)	p-value *
1.	Height of the patella	41.19±3.59	35.99±1.8	0.001 *
2.	Width of the patella	41.72±3.56	37.62±2.27	0.001 *
3.	Thickness of the patella	22.22±1.74	21.48±2.43	0.333
4.	Length of the lateral articular facet	29.51±3.67	26.74±1.17	0.010 *
5.	Width of the lateral articular facet	24.74±1.87	22.05±1.27	0.001 *
6.	Length of the medial articular facet	25.23±2.63	22.77±1.37	0.002 *
7.	Width of the medial articular facet	21.98±2.35	20.92±1.17	0.118
8.	Central ridge length	34.40±0.24	30.90±3.10	0.001 *
9.	Length of Ligamentum patellae	51.00±1.70	48.80±2.00	0.002 *
10.	Proximal width of ligamentum patellae	37.70±1.20	32.40±1.02	0.001 *
11.	Distal width of ligamentum patellae	28.60±1.30	23.00±1.60	0.001 *
12.	Thickness of ligamentum patellae	6.41±0.90	5.50±1.20	0.001 *

[Table/Fig-6]: Comparison of the right patellar morphometric parameters between males and females.

*p-value less than 0.05 was considered as statistically significant.

S. No.	Parameters	Right (16) Mean±SD (mm)	Left (16) Mean±SD (mm)	p-value *
1.	Height of the patella	41.19±3.59	41.01±4.01	0.852
2.	Width of the patella	41.72±3.56	43.05±2.91	0.117
3.	Thickness of the patella	22.22±1.73	22.74±2.13	0.449
4.	Length of the lateral articular facet	29.51±3.67	29.67±3.74	0.902
5.	Width of the lateral articular facet	24.74±1.87	24.12±2.74	0.373
6.	Length of the medial articular facet	25.23±2.63	27.16±2.78	0.003 *
7.	Width of the medial articular facet	21.98±2.35	22.89±2.03	0.292
8.	Central ridge length	34.40±2.40	36.40±1.90	0.026*
9.	Length of Ligamentum patellae	51.00±1.70	48.80±1.90	0.003 *
10.	Proximal width of ligamentum patellae	37.70±1.20	34.40±1.70	0.001 *
11.	Distal width of ligamentum patellae	28.60±1.30	24.40±1.30	0.001 *
12.	Thickness of ligamentum patellae	6.41±0.90	6.24±1.20	0.001 *

[Table/Fig-8]: Comparison of the right and left patellar morphometric parameters in males.

*p-value less than 0.05 was considered as statistically significant.

S. No.	Parameters	Male (16) Mean±SD (mm)	Female (16) Mean±SD (mm)	p-value *
1.	Height of the patella	41.01±4.01	36.32±1.99	0.001 *
2.	Width of the patella	43.05±2.91	37.32±1.59	0.001 *
3.	Thickness of the patella	22.74±2.13	19.97±1.33	0.001 *
4.	Length of the lateral articular facet	29.67±3.74	28.08±1.76	0.135
5.	Width of the lateral articular facet	24.12±2.74	21.94±1.72	0.011*
6.	Length of the medial articular facet	27.16±2.78	23.75±1.57	0.001 *
7.	Width of the medial articular facet	22.89±2.03	20.74±1.56	0.002 *
8.	Central ridge length	36.40±1.90	28.90±3.30	0.001 *
9.	Length of Ligamentum patellae	48.80±1.90	46.50±1.03	0.001 *
10.	Proximal width of ligamentum patellae	34.40±1.70	32.00±1.01	0.001 *
11.	Distal width of ligamentum patellae	24.40±1.30	21.90±1.03	0.001 *
12.	Thickness of ligamentum patellae	6.24±1.02	5.30±1.05	0.001 *

[Table/Fig-7]: Comparison of the left patellar morphometric parameters between male and female.

* p - value less than 0.05 was considered as statistically significant.

S. No.	Parameters	Right (16) Mean±SD (mm)	Left (16) Mean±SD (mm)	p-value *
1.	Height of the patella	35.99±1.8	36.32±1.99	0.655
2.	Width of the patella	37.62±2.27	37.32±1.59	0.636
3.	Thickness of the patella	21.48±2.43	19.97±1.33	0.033*
4.	Length of the lateral articular facet	26.74±1.17	28.08±1.76	0.066
5.	Width of the lateral articular facet	22.05±1.27	21.94±1.71	0.821
6.	Length of the medial articular facet	22.77±1.37	23.75±1.57	0.091
7.	Width of the medial articular facet	20.92±1.17	20.74±1.55	0.681
8.	Central ridge length	30.90±3.10	28.90±3.30	0.182
9.	Length of Ligamentum patellae	48.80±2.00	46.50±1.32	0.001 *
10.	Proximal width of ligamentum patellae	32.40±1.02	32.00±1.43	0.120
11.	Distal width of ligamentum patellae	23.00±1.19	21.90±1.90	0.001 *
12.	Thickness of ligamentum patellae	5.50±1.20	5.30±1.50	0.001 *

[Table/Fig-9]: Comparison of the right and left patellar morphometric parameters in females.

*p-value less than 0.05 was considered as statistically significant.

In males, most patellar morphometric parameters did not differ significantly between the right and left sides, indicating overall bilateral symmetry [Table/Fig-8]. Parameters such as patellar height, width, thickness, and lateral facet measurements were comparable ($p > 0.05$). However, significant differences were observed in the central ridge length, length of the medial articular facet and ligamentum patellae dimensions ($p < 0.05$). This suggests localised asymmetry, particularly in articular and ligament-related components. Overall, male patellae exhibit predominant symmetry with specific functional variations, as evident by differences in particular surface dimensions.

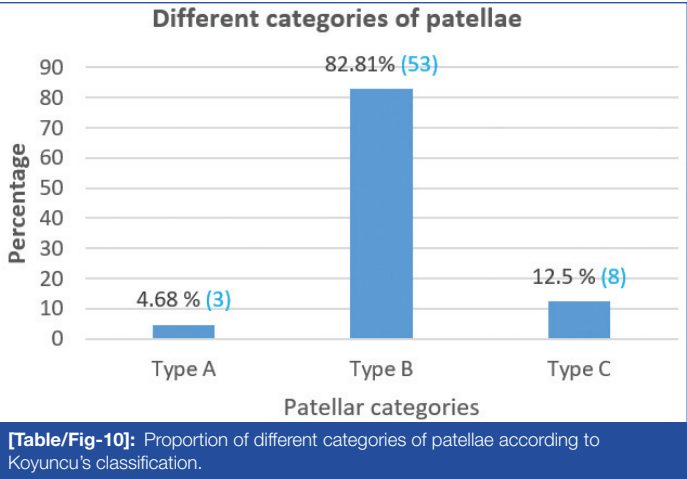
In females, most patellar morphometric parameters did not significantly differ between the right and left sides, indicating strong bilateral symmetry [Table/Fig-9]. Measurements such as patellar height, width, articular facet dimensions, and central ridge length

were comparable ($p > 0.05$). However, significant differences were observed in patellar thickness, length, distal width, and thickness of the ligamentum patellae ($p < 0.05$). This suggests that asymmetry is mainly confined to ligament-related parameters rather than bone; otherwise, female patellae exhibit greater symmetry with limited functional variation.

Based on Koyuncu's classification, the present study observed that 53 (82.81%) patellae were in the type B category, 8 (12.5%) patellae were in the type C category, and 3 (4.68%) patellae were in the type A category. The percentage distribution of different categories of patellae are shown in [Table/Fig-10].

DISCUSSION

The present study analyses patellar morphometry and its ligament between the sides and gender. Mostly, the key bony parameters



were similar between sides ($p>0.05$), except that the length of the MAF and all ligament parameters were significantly different ($p<0.05$). This highlights symmetry of the bony patella, but dimensions of the patellar ligament and specific articular components may express their functional and biomechanical adaptation between the sides. Significant male dominance over all dimensions of bony and ligament parameters ($p<0.05$). Side-wise subgroup analyses also demonstrated sexual dimorphism, reinforcing the primary role of patellar and ligament morphometry in sex differentiation. However, certain dimensions showed significant differences in males between the sides (length of MAF and all ligamentum patellae); and in females (PT, length and thickness of ligamentum patellae). This shows localised asymmetry despite overall bilateral symmetry in both sexes. According to Koyuncu, the predominant type B (82.81%) followed by type C (12.5%) and type A (4.68%) were observed, highlighting a dominant lateral over medial facet as a result of lifestyle pattern.

The present study observed insignificant differences in most of the patellar dimensions between the sides except PH, PW, PT, and LAF, which were comparable on both sides, suggesting consistent structural morphology. Balanced biomechanical stress at the knee would be the reason for symmetrical patellar dimensions between sides [1,11], however, minimal side differences were reported by Taj S et al., which is similar to observations in the present study, emphasising localised asymmetry (length of MAF and all ligament parameters) [13]. This localised asymmetry may reflect adaptive remodelling due to limb dominance and quadriceps load [12,17]. Sex-specific subgroup analysis showed minor side-to-side variations in males, indicating greater bilateral consistency than in females as a result of hormones, pelvic anatomy and Q-angle [2]. Overall, the present study illustrates selective asymmetry (medial facet length and all ligament parameters) with bilateral symmetry in all parameters. These side-specific variations warrant attention in surgical and implant design during knee arthroplasty [1,4].

Most patellar and ligament parameters were significantly larger in males, indicating clear sexual dimorphism. Previous studies reported consistent dominance by males (PH, PW, PT, and facet dimensions), making them dependable indicators for sexual differentiation [6,7,10,18]. High androgen levels, muscle mass and mechanical load (Q angle formation by MAF) in males result in enhanced bone

remodelling and highlight the hormonal importance over patellar pathology [12,19,20]. Similarly, the present study demonstrated the significant sexual difference (male dominance) in wet patellae and ligament dimensions. This could be considered before graft selection (ACL repair) and joint reconstruction procedures [2,5].

In the present study, significant male preponderance in side differentiation was seen in parameters like length of MAF and CRL, supported by certain biomechanical studies with reasons like differential loading patterns between dominant and non dominant limbs [8,12,17]. In contrast, minimal side differentiation was observed in females, except that PT showed significance ($p<0.05$), as a result of hormonal factors may express balanced mechanical load, leading to uniform bony morphology [4].

Unlike bone morphometry, all ligamentum parameters showed significant bilateral differences in both gender, indicating localised asymmetry. Length, distal width, and thickness were significantly greater on the right side, while proximal width remained comparable in females [2]. This pattern of ipsilateral (dissimilar) in males and contralateral (similar) in females will aid in implant design and knee reconstruction.

In the current study, the patellar dimensions were significantly larger in males than females on both sides, indicating that sexual dimorphism is consistent and independent of laterality, and a CT-based study stating minimal influence of side in terms of sexual identification [2,21]. In contrast, Nguyen TT et al., noted minor side-related variations in sexual dimorphism, with dominant male's dimensions than females, possibly due to biomechanical loading differences [17]. Previous studies have reported variable accuracies for patellar sex estimation using discriminant analysis and machine-learning approaches, depending on population, measurements and modelling strategy [18,22-24].

The present study demonstrates that ligament parameters on both sides are consistently greater in males than females, consistent with patellar tendon [25,26]. The biomechanical study measured the stiffness, mechanical strength and cross-sectional area of the patellar tendon using MRI and found a significant male preponderance [15]. Despite gender-related differences in tendon dimensions, their intrinsic mechanical properties may remain comparable [26].

Overall, findings of the current study show unique, consistent sexual differences with minimal side-related variation, reinforcing the utility of patellar morphometry as a reliable marker for gender identification and surgical and forensic applications.

Type B patellae predominated (82.81%), consistent with Taj S et al., (92%), with 4% each in type A and C [13]. Greater load transmission through lateral facet may explain its consistent morphology [1,4,5,13,17]. These patterns may influence patellofemoral articulation, mal-tracking, and implant fit, warranting further investigation. Comparison of the present study with global studies regarding objectives, conclusions, sample sizes, and parameters used [3,4,6,13,14,17,20] [Table/Fig-11].

The present study integrated the analysis of symmetry with dimorphism in a similar population background (in both patellae and patellar ligament) and observed that sexual dimorphism

S. No	Authors name and Year	Place of study	Sample size	Objective	Parameters assessed	Conclusion
1.	Aithal Padur A et al., 2021 [3]	Karnataka, India	50	To analyze the morphometry of the patella and patellar ligament for patellar tendon graft applications.	All patellae dimensions and length, width, thickness of ligamentum patellae	Morphometric data are useful in ACL repair and graft harvesting.
2.	Taj S et al., 2022 [13]	Chennai, India	50	To study the dry patellar morphometry.	All bony patellar morphometry	Morphometric data aids prosthesis design and forensic identification.
3.	Ahmed DA et al., 2022 [4]	Mansoura, Egypt	200	To evaluate age and gender related variations in patellar morphometry.	Length, width, thickness of patellae, lateral facet width and facet thickness	Parameters measured by MRI demonstrated significant sexual dimorphism.

4.	Peckmann TR & Meek S, 2017 [6]	Halifax, Canada	200	To derive population specific discriminant function equation for sexual dimorphism.	Length, width, thickness of patellae, height and width of medial and lateral facets.	Patellar morphometry could be used to develop discriminant function equation for sexual differentiation.
5.	Bidmos MA et al, 2005 [20]	Johannesburg, South Africa	120	To derive population-specific equations for sex estimation using patellar measurements	Length, width, thickness of patellae, height and width of medial and lateral facets.	maximum height and maximum breadth can be used to estimate sex in South African White skeletal remains.
6.	Michiue T et al., 2018 [14]	Osaka, Japan	220	To assess sex differences by patellar morphometry using CT image	Patellar bone mass volume and mean CT density, 3D patellar morphometry.	Bone mass volume was most useful parameter to differentiate the sex.
7.	Nguyen TT et al., 2024 [17]	Hue, Vietnam	280	To evaluate the influence of gender and age on patellar morphology.	All patellar and its facets dimensions, Insall-salvati ratio, Patellar articular angle.	Patellar morphology showed significant variation with sex and age, with greater dimensions in males
8.	Present study, 2026	Chennai, India	64	To evaluate the morphometry of wet patellae and its ligament for sexual dimorphism and bilaterality.	Length, width, thickness of wet patellae and its ligament.	All patellar and its ligament dimensions showed sexual difference with unilateral imbalance in medial articular facet and all ligament parameters.

[Table/Fig-11]: A comparison of parameters used in this study with the studies done in different population worldwide

is independent of laterality. Male and female subgroups both demonstrated predominantly bilateral symmetry, with selected parameters showing significant side differences, selective asymmetry in the lateral facet, and high prevalence of Type B patella (population-specific morphology).

Limitation(s)

The present study is limited by its modest sample size and restricted population diversity. Age, ethnicity, and physical activity were not assessed, which may influence patellar morphology. Future studies should include larger, diverse populations, advanced CT/3D modelling, and longitudinal designs to evaluate precise morphological changes with ageing and activity.

CONCLUSION(S)

The present study demonstrated sexual dimorphism in most measured patellar and patellar ligament dimensions, with generally greater values in male cadavers. Most bony parameters showed bilateral symmetry, whereas selected articular and ligament parameters demonstrated significant side differences. Type B patellar morphology was predominant in the present sample. Larger multicentre studies incorporating age and other relevant biological and functional variables are required to validate these findings and determine their applicability to forensic and clinical settings.

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