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### RESEARCH ARTICLE

#### A MORPHOMETRIC STUDY OF PATELLA IN LUCKNOW REGION

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#### Abstract

**Background:** Patella is the largest sesamoid bone which develops in the tendon of Quadriceps femoris muscle and protects the front of knee joint. It has gained anatomical, clinical & forensic significance due to its vital role in patellofemoral mechanics and its property of resistance to post mortem changes.

**Aims and Objectives:** Our study aims to measure the various dimensions of left and right human patella which can be useful for the manufacture of patellar prosthesis, better suited to Indian population, in contrast to already available prosthesis which are mostly based on the western anthropometric measurements.

**Methods:** The study involves 100 dry human patellae, 50 each from left and right sides. Total patellar height, maximum height of articular surface, maximum width, maximum thickness, shape, width of medial and lateral articular facets of patella were measured using digital Vernier calipers. Mean and standard deviation were calculated for each parameter for left and right sides and the data was analyzed using SPSS.

**Results:** The mean of patellar width on left side came out to be  $41.65 \pm 2.78$ , while for right side, the mean of patellar width was observed to be  $42.83 \pm 3.02$ . A statistically significant difference was observed in patellar width of left and right sides ( $p = 0.044$ ).

**Conclusion:** Anthropometric study of patella in India can thus be helpful in designing femoropatellar prosthesis for our population leading to better post-operative outcome.

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#### Introduction:-

The patella, also referred to as knee cap, is the largest sesamoid bone, embedded in the tendon of Quadriceps femoris. It has three borders- superior, lateral & medial and two surfaces-anterior & posterior. The superior border of patella is called base and is thicker compared to the medial & lateral borders, which converge at the apex distally. The posterior surface comprises upper articular part and lower non-articular part. The articular part is divided by a smooth vertical ridge, into medial and lateral facets; lateral usually being larger. Each facet can further be divided by faint horizontal lines into equal thirds.<sup>[1]</sup> Another facet is separated by a narrow strip along the medial border of the patella which comes in contact with the medial femoral condyle in complete flexion.<sup>[2]</sup>

Patella increases the angle at which quadriceps femoris muscle acts, thus enhancing its leverage and protecting the front of the joint. Patella is involved in various postures like sitting and squatting. So depending on cultural & ethnic practices, several modifications can be observed in this sesamoid bone.<sup>[3]</sup>

On the basis of width and convexity of medial and lateral articular facets (MAF & LAF), Wiberg divided patella into 3 categories. Type I patella is defined as a patella whose MAF and LAF widths are concave and equal. Type II patella, which is the most common type, is one in which the width of the MAF is flat or slightly convex and smaller than the width of the LAF. In Type III patella the width of the MAF is convex and considerably smaller than the width of the LAF. Another classification was proposed by Koyunku et al. according to which, patella with equal width of MAF & LAF belonged to Class A, patella with WMAF smaller than WLAF belonged to Class B and patella with WMAF greater than WLAF belonged to Class C. [4]

Depending on the variation in their position, patella can be named as patella alta (if placed higher) or patella baja (if placed lower). The former carries risk for dislocation or subluxation of patella while the latter is more susceptible for tendon rupture or neuromuscular disorder. [5]

Patella has gained anatomical, clinical & forensic significance due to its vital role in patellofemoral mechanics and its resistance towards post mortem changes. For accurate sex determination from skeleton, ideally complete skeleton should be available. However, in most of the cases, it is not possible and in such cases, patella can be useful for sex determination. [6] It has been observed that patella is resistant to post-mortem changes, due to which it can be used for personal identification. Measuring the dimensions of patellae can be useful for the determination of the size of a patellar implant. [1] The knowledge of patellar thickness for example could be a guide for surgeons in estimating the extent of depth of resection in total knee replacement. [2]

The patellar prostheses used currently in India are based on the anthropometric measurements of Western population, due to which they are not perfectly suitable for Indian people. Measuring the anthropometric dimensions of patella of Indian population from different regions can enable us to manufacture patellar prosthesis with better accuracy leading to better post-operative results. [7] Our present study, conducted in Lucknow region of Uttar Pradesh, is an attempt to contribute to this endeavour.

### Material and Methods:-

Our study included 100 dry human patella bones (Left patellae=50, Right patellae=50), obtained from Department of Anatomy of the institute. The side determination of these bones were done by keeping each of them on a plane surface, in its anatomical position and observing the side to which its lateral articular facet rests. Seven parameters of each patella were measured using Digital Vernier calipers, namely Total patellar height (H1), Maximum height of articular surface (H2), Patellar width (PW), Patellar thickness (PT), Width of medial articular facet (WMAF), Width of lateral articular facet (WLAF) and Shape of patella. Description of these parameters has been provided in **Table 1**. Left and right sided patellae were measured separately for these seven parameters, followed by the calculation of maximum, minimum, mean and standard deviation of patellae of each side.

We have applied Statistical Package for Social Science (SPSS) version 21.0 for statistical analysis of the data and to find out if any significant difference exists between right & left sided patellae.

### Observation & Result:-

Total 100 dry patellae were taken and the above mentioned seven parameters were measured using digital Vernier calipers separately for right & left sides as shown in **Fig. 1, 2 & 3**. **Table 2** represents the comparative analysis of maximum, minimum, mean and standard deviation of different parameters of right & left patellae. The mean of total patellar height in left and right sided patella came out to be  $40.02 \pm 2.68$  and  $40.21 \pm 2.93$  respectively. The calculated mean for maximum height of articular surface was  $30.69 \pm 1.65$  in left sided &  $31.26 \pm 3.17$  in right sided patella. The mean for patellar width on left side was calculated as  $41.65 \pm 2.78$  while  $42.83 \pm 3.02$  on right side. This difference in patellar width was found to be statistically significant ( $p = 0.044$ ) by t-test. In left sided patella, mean for patellar thickness was  $20.14 \pm 1.51$  and in right sided patella it was  $20.31 \pm 1.49$ . For width of medial articular facet, the mean on left & right sides were  $21.88 \pm 1.52$  &  $22.38 \pm 1.77$  respectively. Similarly, for width of lateral articular facet, the calculated mean on left & right sides were  $25.78 \pm 1.94$  &  $25.87 \pm 2.32$  respectively.

**Table 3** shows the left & right patellae divided into three types according to Koyunku's classification. Out of 50 left patellae, six (12%) belonged to type A, i.e. width of their MAF & LAF were almost equal, 43 (86%) belonged to type B, i.e. their WMAF were observed to be smaller than WLAF and one (2%) belonged to type C, i.e. WMAF greater than WLAF, as represented by a pie chart in **Fig. 4**.

Out of 50 right patellae, five (10%) belonged to type A, 42 (84%) belonged to type B and three (6%) belonged to type C according to Koyuncu's classification, as represented by a pie chart in **Fig. 5**.

In **Fig. 6(a)**, width of medial and lateral articular facets are almost equal in patella, hence represents type A patella. In **Fig. 6(b)**, first two patellae represent type B ( $WMAF < WLAF$ ) while latter two patellae represent type C ( $WMAF > WLAF$ ).

In **Table 4**, we have classified the patellae based on their shape as triangular, rounded or irregular. Out of 50 right sided patellae, 30 (60%) were triangular, 15 (30%) were rounded and five (10%) were found to be irregular. Out of 50 left sided patellae, 37 (74%) were triangular, 10 (20%) were rounded and three (6%) were irregular in shape. **Fig. 7** represents different shapes of patellae included in the study.

### Discussion:-

In India, the patellar prostheses used are mostly based on the anthropometric measurements of Western population, due to which they are not perfectly suitable for Indian people. Manufacturing patellar prosthesis based on Indian anthropometric measurements can lead to better results.<sup>[7]</sup> In this study, we have attempted to understand the morphometry of patella in Lucknow population of India by measuring its various dimensions and compare it with similar studies done in different population.

Most of the studies conducted on various populations in India were in view that Indian population has smaller patellar dimensions as compared to those of Western or African population.<sup>[7], [8]</sup> The present study is also in agreement with this view as represented by the comparative analysis with different ethnic populations in **Table 5**.

In our study, the mean patellar width on left side was  $41.65 \pm 2.78$  and  $42.83 \pm 3.02$  on right side. The values were in accordance with the studies conducted by Kayalvijhi et al.<sup>[9]</sup> ( $42.1 \pm 3.1$ ) and Jain et al.<sup>[10]</sup> ( $43.35 \pm 4.10$ ) on North Indian population. This was slightly less compared to the studies conducted by Shang Peng et al.<sup>[11]</sup> ( $44.13 \pm 3.96$ ) in 2014 on Southern Chinese population, Olateju et al.<sup>[4]</sup> ( $45.14\text{mm}$ ) in 2013 on South African population and markedly lesser compared to the study conducted by Baldwin et al.<sup>[12]</sup> ( $50.30 \pm 5.65$ ) in 2005 on American population.

In the present study, the mean of WMAF on left & right sides were found to be  $21.88 \pm 1.52$  and  $22.38 \pm 1.77$  respectively which was slightly higher than the studies conducted on Chinese, Koreans & Western population (19.03mm, 18.4mm and 18.8mm respectively). But it was in accordance with the study conducted by Chapparwal et al. on the population of Madhya Pradesh, where WMAF was found to be 20.69 mm. However, the mean of WLAF according to our study was  $25.78 \pm 1.94$  and  $25.87 \pm 2.32$  for left & right sides respectively, which was comparable with previous studies: 25.1mm in Chinese, 23.3mm in Koreans and 25.3mm in Western population respectively.<sup>[1]</sup>

Chapparwal et al. in their study on population of Madhya Pradesh, observed 82% patella as triangular (R: 80% & L: 84%), 12% rounded (both R & L) and 6% irregular in shape (R: 8% & L: 4%).<sup>[3]</sup> A study done on Brazilian dry patella by Borges et al. in 2016 found 67.6% patellae were triangular, 21.6% oblong and 10.81% were irregular.<sup>[13]</sup> These findings were almost similar to that of ours where among the right patellae, 60% were triangular, 30% were rounded & 10% were irregular and among left patellae, 74% were triangular, 20% were rounded & 6% were irregular in shape.

According to a study conducted by Koyuncu et al. in Turkey, 19.5% patellae belonged to Type A ( $WMAF = WLAF$ ), 50% belonged to Type B ( $WMAF < WLAF$ ) and 30.5% patellae belonged to Type 3 ( $WMAF > WLAF$ ).<sup>[14]</sup> However in our study, among the right sided patellae, 10% were of Type A, 84% were of Type B and 6% belonged to Type C variety. Similarly, among the left sided patellae, 12% were of Type A, 86% belonged to Type B and 2% belonged to Type C variant of patella.

In the present study, we have not classified the patellae as male or female but few previous studies have realised the significance of this sesamoid bone in sexual dimorphism. Akhlagi et al. conducted a prospective study on 113 patellae (57 male & 56 female) collected from fresh cadavers of Iranian population and observed that all the dimensions were larger in males than females, confirming the high accuracy of using patellar dimensions for sex determination in case of unavailability of other useful skeletal sample, like in cases of mass disasters.<sup>[15]</sup> Similar finding was reported by Kumar et al. in their MRI based study where males of North Indian population were found to have larger patellae than their female counterparts.<sup>[19]</sup>

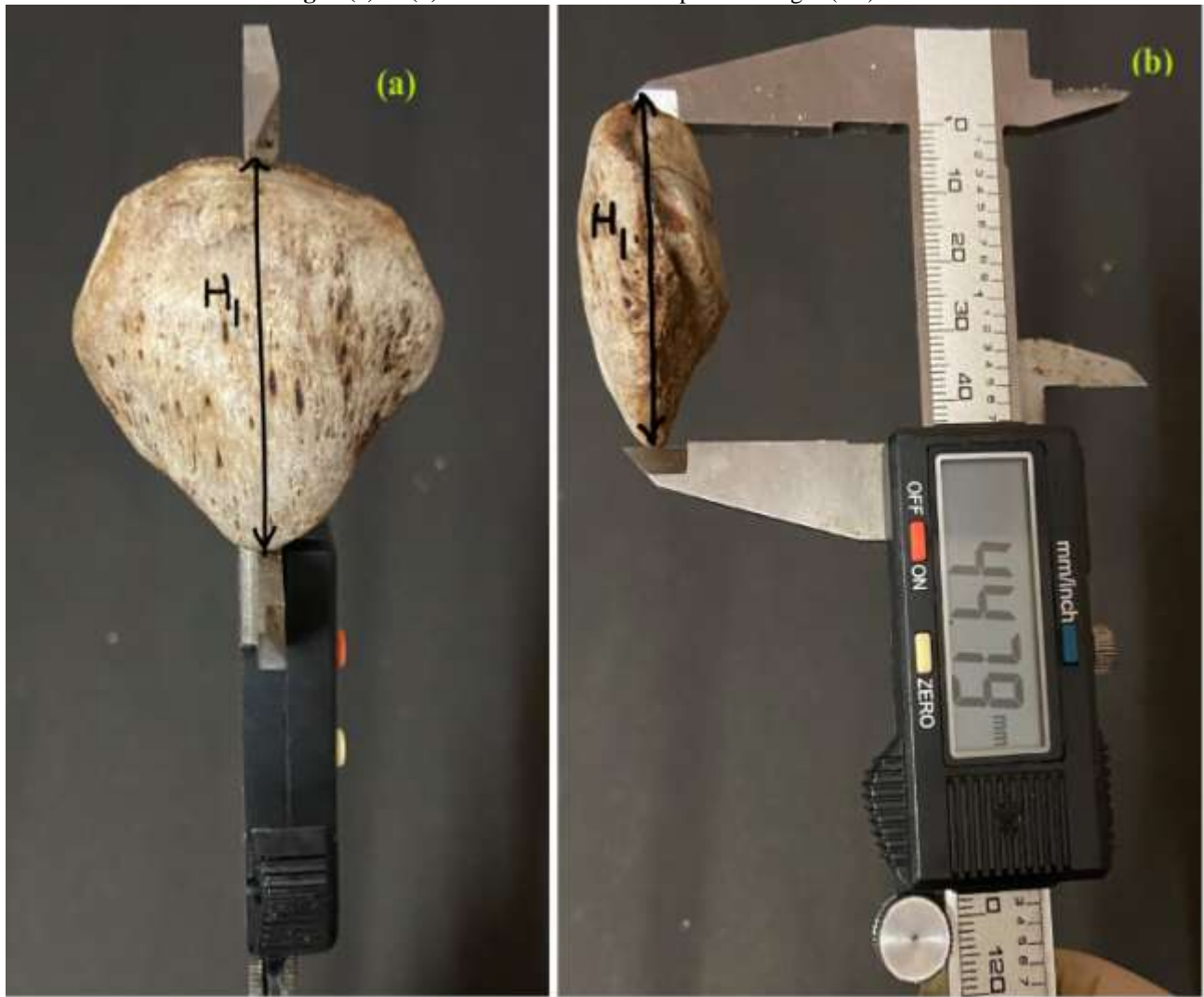
On comparing the various parameters of left & right sided patellae in our study, no statistically significant difference was seen except for patellar width which was found to be slightly greater on right side (mean= 42.83± 3.02) than on left side (mean= 41.65± 2.78) ( $p=0.044$ ). This might be due to predominant use of one limb leading to better muscle tone on that side which can apparently alter the dimensions of patella. Other factors like postural & ethnic habits could also be responsible for the same.<sup>[4]</sup> Further studies could be helpful in this regard for deriving any conclusion.

### Conclusion: -

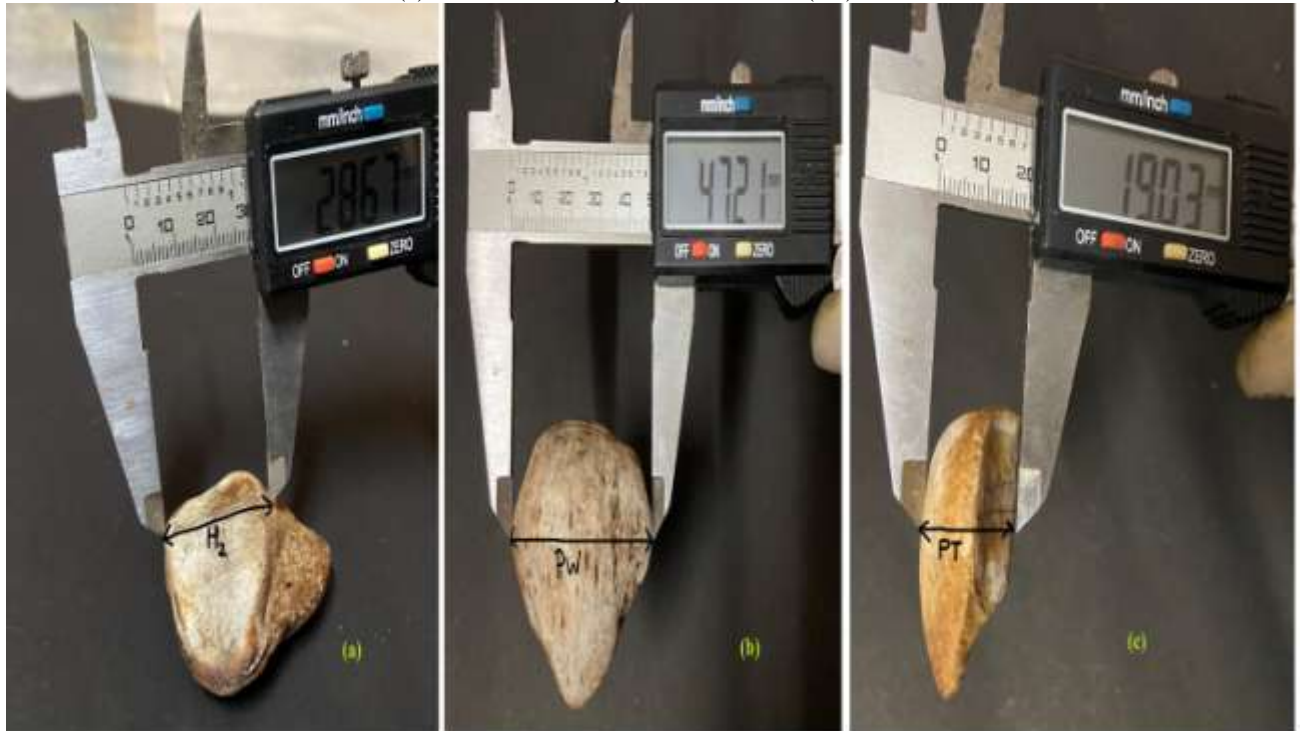
Anthropology, Comparative anatomy, Forensic Medicine and Orthopaedic surgery are among the disciplines of Medicine which can be benefitted from our findings related to patella. Indian population exhibit smaller dimensions of patella as compared to that of Western population. Due to this disparity, most of the available prosthesis, which are based on the anthropometric measurements of Western population, may not be suitable for Indian population and could rather lead to inconvenience like pain in knee with restricted movements. Thus, measuring anthropometric patellar dimensions from different regions of India can enable us to design patellar prosthesis with better accuracy and hence result in better surgical outcome for the patients who are operated for chronic knee pain or disorders of patellofemoral joint. It can also prove to be useful for estimation of sex in forensic science when no other osteological evidence is available.

### Figure Legends:

Fig. 1 (a) & (b):- Measurement of total patellar height (H1).



**Fig. 2:-** (a) Measurement of maximum height of articular surface (H2)  
(b) Measurement of patellar width (PW)  
(c) Measurement of patellar thickness (PT)



**Fig. 3:-** (a) Measurement of width of medial articular facet (WMAF).  
(b) Measurement of width of lateral articular facet (WLAF).



Fig. 4:- Distribution of left sided patella.

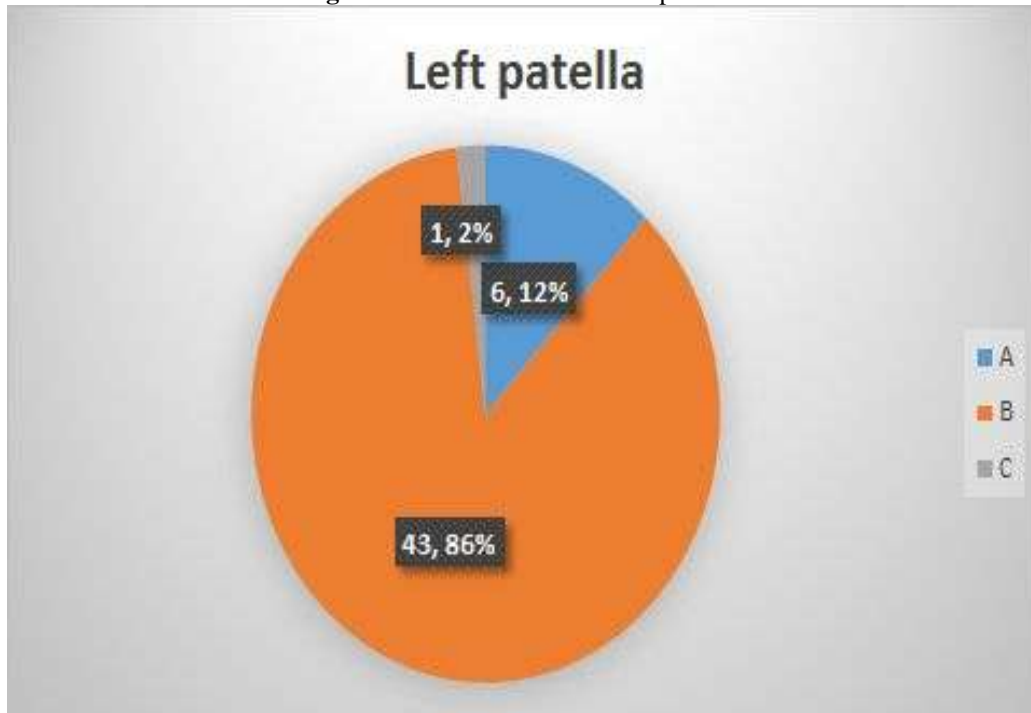
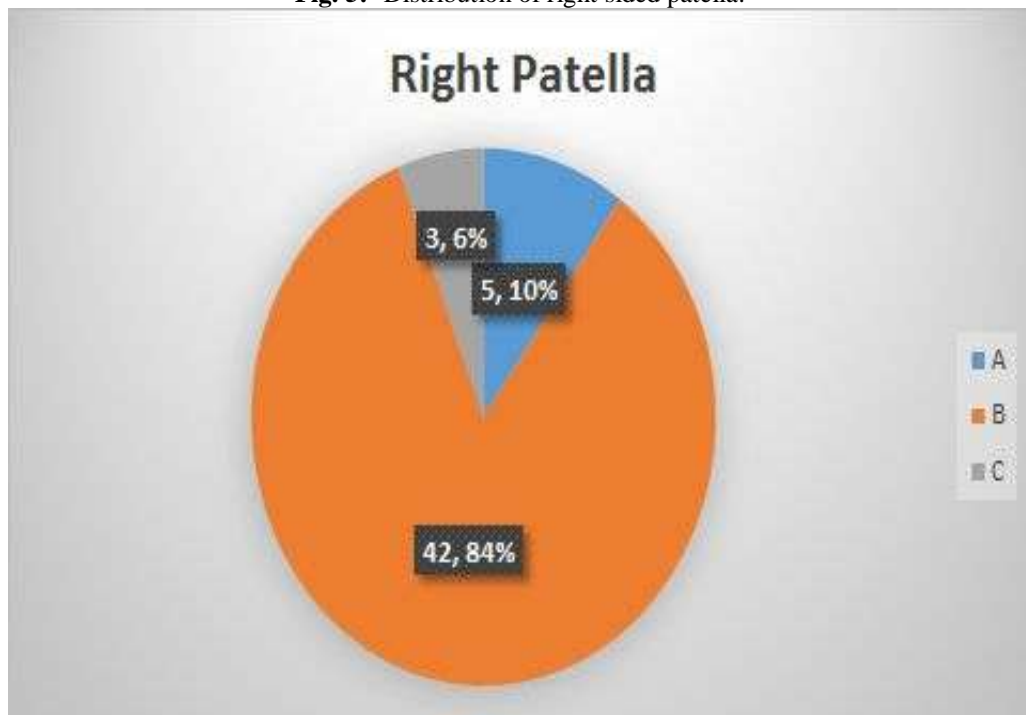
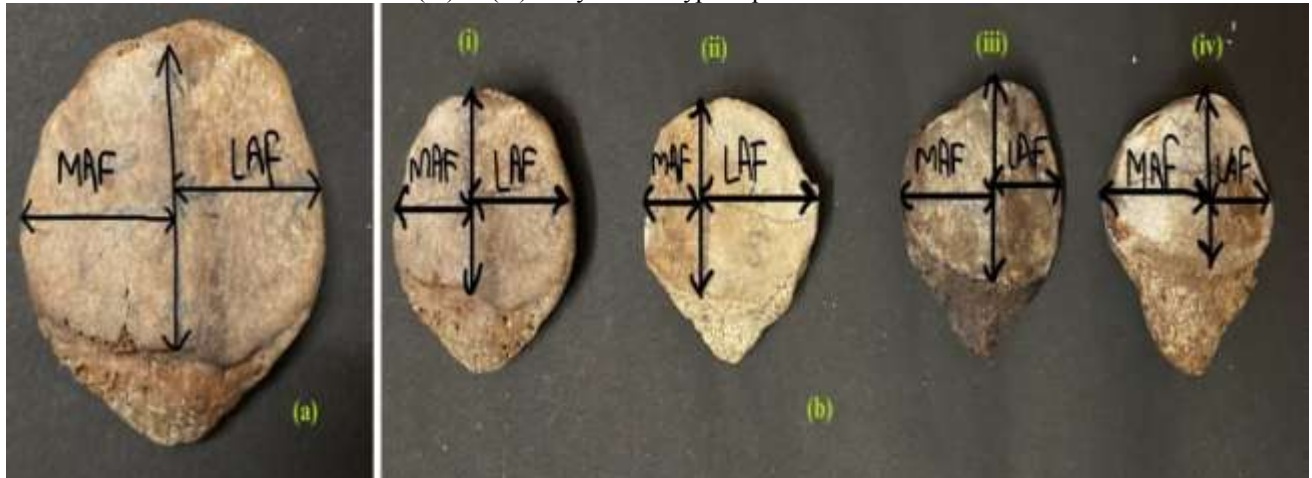


Fig. 5:- Distribution of right sided patella.



**Fig. 6:** (a) Koyuncu's Type A patella  
 (b) (i) & (ii): Koyuncu's Type B patellae  
 (iii) & (iv): Koyuncu's Type C patellae



**Fig. 7:-** Classification according to shape of patella.



**Table 1:-** Description of parameters of patella.

PARAMETER	ABBREVIATION	DESCRIPTION
Total patellar height	H1	Linear distance between superior border and apex.
Max. height of articular surface of patella	H2	Maximum height of articular surface on the posterior surface of patella.
Patellar width	PW	Linear distance between medial & lateral borders.
Patellar thickness	PT	Linear distance between anterior surface & median ridge.
Width of medial articular facet	WMAF	Max. width from medial border to median

		ridge.
Width of lateral articular facet	WLAFF	Max. width from lateral border to median ridge.

**Table 2:-** Anthropometric measurements of right & left patellae.

Measurement	Side	Min.	Max.	Mean	S.D.	Significance of difference (t-test)
Total patellar height (H1)	<b>Left</b>	34.18	46.25	40.02	2.68	't'=0.336; p=0.738
	<b>Right</b>	34.31	47.17	40.21	2.93	
Max. height of articular surface (H2)	<b>Left</b>	27.33	34.14	30.69	1.65	't'=1.119; p=0.266
	<b>Right</b>	22.85	43.20	31.26	3.17	
Patellar width (PW)	<b>Left</b>	37.49	51.56	41.65	2.78	't'=2.036; p=0.044
	<b>Right</b>	35.71	48.67	42.83	3.02	
Patellar thickness(PT)	<b>Left</b>	16.69	23.81	20.14	1.51	't'=0.547; p=0.585
	<b>Right</b>	16.48	24.01	20.31	1.49	
WMAF	<b>Left</b>	18.91	25.01	21.88	1.52	't'=1.490; p=0.140
	<b>Right</b>	18.16	26.15	22.38	1.77	
WLAFF	<b>Left</b>	21.72	30.89	25.78	1.94	't'=0.210; p=0.834
	<b>Right</b>	20.95	31.44	25.87	2.32	

**Table 3:-** Koyuncu's classification of patella.

Class	Left Patella		Right Patella	
	No.	%	No.	%
<b>A</b>	<b>6</b>	<b>12.0</b>	<b>5</b>	<b>10.0</b>
<b>B</b>	<b>43</b>	<b>86.0</b>	<b>42</b>	<b>84.0</b>
<b>C</b>	<b>1</b>	<b>2.0</b>	<b>3</b>	<b>6.0</b>

$$\chi^2=1.103 \text{ (df=2); } p=0.576$$

**Table 4:-** Classification according to shape of patella.

Shape	Left Patella		Right Patella	
	No.	%	No.	%
<b>Triangular</b>	<b>37</b>	<b>74.0</b>	<b>30</b>	<b>60.0</b>
<b>Rounded</b>	<b>10</b>	<b>20.0</b>	<b>15</b>	<b>30.0</b>
<b>Irregular</b>	<b>3</b>	<b>6.0</b>	<b>5</b>	<b>10.0</b>

$$\chi^2=2.231 \text{ (df=2); } p=0.328$$

**Table 5:-** Comparative analysis with similar studies on different populations.

STUDY	SAMPLE & SUBJECTS	POPULATION	PATELLAR HEIGHT		PATELLAR THICKNESS		PATELLAR WIDTH	
			Mean	SD	Mean	SD	Mean	SD
Baldwin et al. <sup>[12]</sup> (2005)	35 Adult patellae (Total Knee Arthroplasty)	American	38.60	2.47	23.90	2.30	50.30	5.65
Yoo et al. <sup>[16]</sup> (2007)	MRI of 163 adults	Japanese	44.6	3.7	22.3	1.9	45.8	1.9
Iranpour et al. <sup>[17]</sup> (2008)	3-D CT scan from 37 adults	British	34.3	4.8	22.4	2.3	44.8	4.8
Agnihotri G et al. <sup>[8]</sup> (2013)	Dry bones	North Indian	35.8	-	16.95	-	37	-
Olateju et al. <sup>[4]</sup>	46 Adult	South African	43.7	3.6	23.9	2.1	45.1	3.9

(2013)	Cadaveric patellae							
Shang Peng et al. (2014) <sup>[11]</sup>	CT scan from 40 Chinese volunteers	Southern Chinese	39.94	3.68	22.72	1.81	44.13	3.96
Kayalvizhi I et al <sup>[9]</sup> (2015)	62 Dry bones	North Indian	42.9	4.8	19.7	1.1	42.1	3.1
Muruganet al. <sup>[1]</sup> (2017)	65 adult dry patella	Indian (Pondicherry)	38.07	3.7	18.29	1.73	38.58	3.81
Jain R et al. <sup>[10]</sup> (2019)	200 Normal X ray	North Indian	41.67	4.01	19.22	2.19	43.35	4.10
Parameshet al. <sup>[7]</sup> (2020)	66 Dry bones	Indian (Maharashtra&Tamilnadu)	40.00	-	21.3	-	40.2	-
Katchyhet al. <sup>[18]</sup> (2020)	60 cadaveric patellae	Nigeria	46.1	0.47	26.6	0.15	46.9	0.29
Baisakhhet al. <sup>[20]</sup> (2021)	60 dry bones	Indian (Odisha)	36.75	-	18.39	-	36.58	-
Present study (2021)	100 dry bones	Indian (Lucknow)	40.11	2.81	20.23	1.5	42.24	2.9
Taj et al. <sup>[21]</sup> (2022)	50 dry bones	Indian (Chennai)	40.7	-	20.3	-	41.2	-

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