Innovations

Morphological and Morphometric Evaluation of Distal end of Dry Human Ulna – A Cross-sectional Study

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Abstract

Introduction: *The distal end of the ulna plays an essential role in wrist articulation and the attachment of key ligaments, including the triangular fibrocartilage complex (TFCC) and extensor carpi ulnaris tendon. Its morphology and morphometry are critical in orthopaedic, reconstructive, and prosthetic applications, particularly in fracture management and joint replacement surgeries. Variations in anatomical features influence the surgical approach and implant design. A detailed evaluation of both morphological and morphometric characteristics aids in refining clinical interventions and improving functional outcomes. The present study investigated these features in adult dry ulnae, comparing the right and left sides and correlating the findings with their potential clinical implications.* ***Materials and Methods****: A cross-sectional study was conducted on 100 adult dry ulnae (50 right and 50 left) from the Department of Anatomy, KIMS, Amalapuram. The morphological features of the pole, seat, fovea, and styloid process were recorded. Morphometric parameters were measured using digital Vernier calipers. The data were statistically analyzed to compare the right and left sides.* ***Results:*** *Morphologically, semicircular poles were the most common. The styloid process was present in over 95% of specimens, with blunt tips being more common than sharp tips. Vascular foramina were frequently observed, and grooves for the extensor carpi ulnaris were nearly universal in all specimens. Morphometric analysis revealed no significant differences between the right and left sides for most parameters, except for the width of the fovea, which was significantly greater on the right side ($p = 0.031$). These findings indicate a general bilateral symmetry with minor variations.* ***Conclusion:*** *The distal ulna exhibits consistent morphology and morphometry across sides, with only the fovea width differing significantly. These insights enhance anatomical knowledge and support orthopedic and prosthetic applications, aiding precise surgical planning and reconstructive procedures.*

Key words: *Distal radio-ulnar joint, Fovea, Lower end of ulna, Morphometric, pole, seat, Styloid process.*

Introduction

Understanding the anatomy of the distal end of the ulna is essential for wrist joint reconstructive procedures. This part of the ulna includes the head, styloid process, and fovea. The head is divided into two sections: the 'pole' and the 'seat.' The pole articulates with the triangular fibrocartilaginous complex, separated from the triquetral. The apex of the triangular fibrocartilaginous complex set in the fovea is the chief stabilizer. The seat articulates with the ulnar notch of the radius, forming the distal radioulnar joint, and the seat has more than two-thirds of the perimeter of the head of the ulna, which is covered by articular cartilage (1). The distal radioulnar joint plays a crucial role in forearm pronation and supination, and provides additional stability to the wrist joint and gripping. It transfers the force from the radius to the ulna.

The Styloid process is a bony projection located at the posteromedial aspect of the distal part of the ulna, and its end attaches to the ulnar collateral ligament of the carpus, which stabilizes the ulnar side of the wrist joint (2). Ulnar Styloid Triquetral impaction is a medical condition characterized by pain on the ulnar side, along with specific radiographic and clinical characteristics.Morphometric values of the styloid process of the ulna are helpful in several clinical anatomical contexts. Wrist with elongated ulnar styloid processes is susceptible to ulnar styloid impaction syndrome, a condition in which the excessively long ulnar styloid process collides with the triquetrum, leading to chondromalacia, synovitis, and discomfort (3).

A vertical groove is located on the posterior side of the ulna, situated between the head and styloid process, through which the tendon of the extensor carpi ulnaris muscle passes. A vascular foramen was present at the lower end of the ulna. This study of the lower end of the ulna helps in planning surgical approaches, fixation techniques, and prosthetic designs.

The lower end of the ulna is generally disturbed in traumatic injuries of the distal radioulnar joint, such as Galeazzi, Monteggia, and Colle's fractures. While playing sports, a forceful impact on the thenar side of the hand causes the wrist to hyperextend with ulnar deviation and intercarpal supination (4). Major injuries to the ulna can lead to the development of arthrosis of the distal radioulnar joint if left untreated or delayed (5). The distal end of the ulna forms a part of the distal radioulnar joint. It is essential for forearm rotation (pronation and supination), wrist stability, and load transmission. It affects grip strength, wrist motion, and load sharing with the radius.

Morphometric analysis of the distal ulna is crucial for orthopedic surgeons and prosthetists when addressing fractures at the lower end of the ulna, particularly in cases involving triquetral rheumatoid arthritis, traumatic arthritis, arthrosis, tenosynovitis of the extensor carpi ulnaris, injuries to the triangular fibrocartilaginous complex, and Colle's fracture. Additionally, this analysis aids in the early treatment of wrist pain, impingement syndrome, and ulnar styloid-triquetral impaction syndrome.

Aim and Objectives:

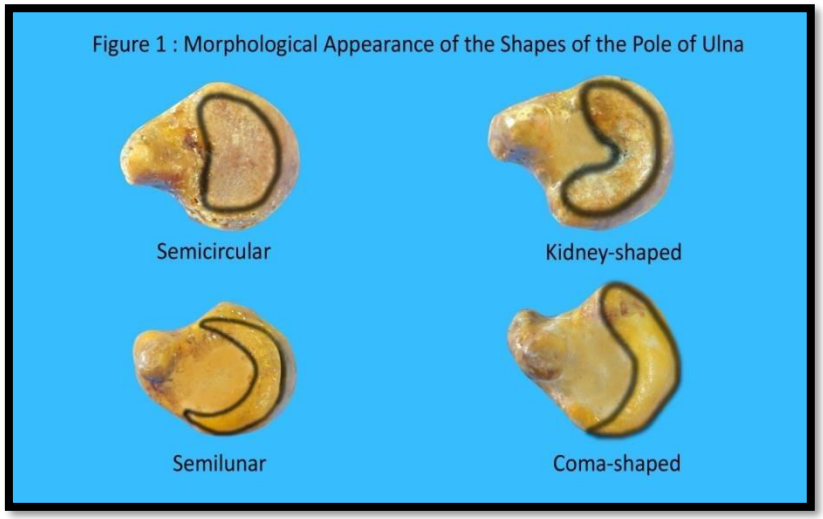
1. To investigate the morphology and morphometry of the distal end of the dry human ulna, which is crucial for reconstructive surgeries.
2. To assist prosthetists in managing fractures at the lower end of the ulna.

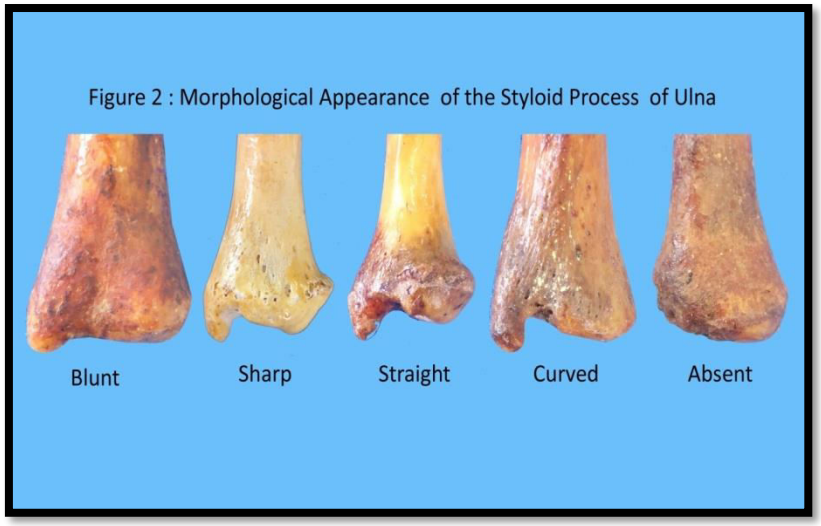
Materials and Methods:

A descriptive cross-sectional study was conducted to analyze the morphological and morphometric characteristics of the lower end of ulna. This study focused on both qualitative (morphological) and quantitative (morphometric) parameters.

A total of 100 adult human dry ulnae (50 right-sided and 50 left-sided) of unknown sex were included in this study. Bones with visible damage or pathological deformities were excluded from the study.

The study was conducted at the Department of Anatomy, Konaseema Institute of Medical Sciences and Research Foundation, Amalapuram, India, using dry human ulnar bones available in the bone bank of the Anatomy Department. All measurements were taken using digital Vernier calipers with an accuracy of up to 0.01 mm. The following morphological and morphometric parameters of the distal end of the ulna were observed and recorded.





A. Morphological Parameters

Poleshape: The pole shape was observed as semicircular, kidney-shaped, comma-shaped, and semilunar.

Direction of the seat: The seat was observed to be sloping or nonsloping.

Styloid process: This was recorded as present or absent. The shape of the styloid process was observed to be either curved or straight. The tip of the styloid process was observed to be blunt or sharp.

Vascular Foramen: It is observed as present or absent.

Groove for Extensor Carpi Ulnaris: It is observed as present or absent.

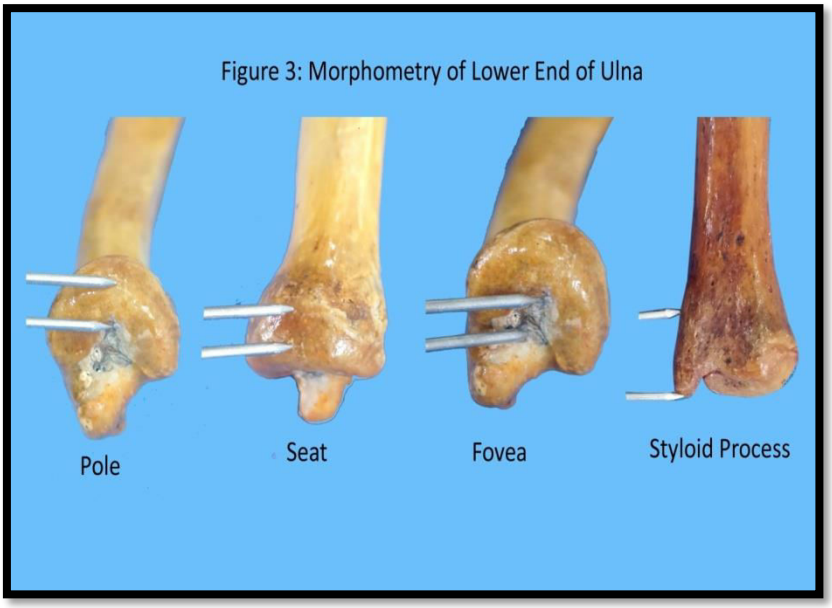


Figure 3: Morphometry of Lower End of Ulna

B. Morphometric Parameters

1. Transverse width of the pole: This was measured along the horizontal (transverse) axis at the distal end of the ulna. The measurement was taken between the two points where the diameter of the ulnar head was at its maximum.

2. Anteroposterior width of the pole: This was measured from the anterior (palmar) aspect to the posterior (dorsal) aspect of the ulnar head at its widest point along the sagittal plane.

3. Height of the seat: The vertical distance between the upper margin of the lateralmost point and the lower margin of the seat of the ulna represents the height of the seat at the lower end.

4. Length of the styloid process: Measured from the point where the styloid process emerged from the head of the ulna to its tip.

5. Width of the styloid process: The horizontal distance between the farthest lateral and medial points at the base of the styloid process was measured.

6. Width of the fovea: The maximum transverse width of the fovea was measured between the point where the transverse axis intersected the lateral margin of the fovea and the lateral end of the base of the styloid process.

Statistical analysis of the data obtained was performed using an unpaired t-test ($p < 0.05$ was considered significant). IBM SPSS Version 21 was used for the analysis.

Results:

The results obtained from the examination of the lower end of 100 dry human ulnae (50 right-sided and 50 left-sided) are listed in Tables 1 and 2.

Table 1: Morphological features observed on the lower end of ulna on the right and left sides.

PARAMETER	RIGHT SIDE	LEFT SIDE
Shape of the pole		
Semicircular	21 (42%)	25 (50%)
Kidney shape	13 (26%)	11 (22%)
Coma shape	6 (12%)	9 (18%)
Semilunar	10 (20%)	5 (10%)
Direction of the seat		
Sloping	31 (62%)	33 (66%)
Nonsloping	19 (38%)	17 (34%)
Styloid process		
Present	48 (96%)	49 (98%)
Absent	2 (4%)	1 (2%)
Shape of styloid process		
Curved	14 (28%)	22 (44%)
Straight	34 (68%)	27 (34%)
Tip of the styloid process		
Blunt	36 (72%)	36 (72%)
Sharp	12 (24%)	13 (26%)
Vascular foramen		
Present	49 (98%)	43 (86%)
Absent	1 (1%)	7 (14%)
Groove for Extensor carpi ulnaris		
Present	50 (100%)	47 (94%)
Absent	0	3 (6%)

1. Pole Shape: A semicircular shape was the most common morphology, with 42% on the right side and 50% on the left side. Kidney-shaped poles were noted in 26% of the right-sided and 18% of the left-sided specimens. Coma-shaped poles were observed in 12% of right-sided and 18% of left-sided ulna. A semilunar shape was observed in 20% of right-sided and 10% of left-sided specimens.

2. Direction of the Seat: A sloping seat was more prevalent, found in 62% of the right and 66% of the left-sided specimens. Non-sloping seats were observed in 38% and 34% of the specimens on the right and left sides, respectively.

3. Styloid Process: This was present in most specimens, 96% on the right side and 94% on the left side. It was absent in 4% and 6% of specimens on the right and left sides, respectively.

4. Shape of the Styloid Process: Curved styloid processes were observed in 32% and 44% of the cases on the right and left sides, respectively, while straight

styloid processes were more common (68 %) on the right side and less common (56 %) on the left side.

5. Tip of the Styloid Process: The blunt tip was dominant and was found in 72% of the specimens on both sides. A sharp tip was observed in 24% and 26% of the specimens on the right and left sides, respectively.

6. Vascular Foramen: Present in 98% of the right and 86% of the left ulnas. It was absent in 2% of the right and 14% of the left specimens.

7. Groove for Extensor Carpi Ulnaris: Present in all right-sided specimens (100%). On the left, it was present in 94% of the specimens and absent in 6% of the specimens.

The mean values and standard deviations for all parameters examined were calculated, and statistical analysis was performed using IBM SPSS Version 21. The observations are listed in Table 2.

Table 2: Measurement of various parameters observed on the lower end of ulna on the right and left sides.

PARAMETER	RIGHT SIDE	LEFT SIDE	P-VALUE
Antero-posterior width of the pole	5.04±1.01	5.10±0.84	0.746
Transverse width of the pole	15.40±1.76	15.04±1.49	0.274
Height of the seat	4.68±0.88	4.81±0.87	0.439
Length of the styloid process	4.78±1.16	4.94±1.09	0.101
Width of the styloid process	3.93±1.10	4.12±0.96	0.093
Width of the fovea	3.09±0.56	2.88±0.36	0.031

1. Anteroposterior Width of the Pole: The average anteroposterior width of the ulnar pole on the right side was 5.04 ± 1.01 mm, whereas on the left side, it was 5.10 ± 0.84 mm. The difference between the two sides was not statistically significant (p = 0.746), indicating symmetry.

2. Transverse Width of the Pole: The transverse width of the pole measured 15.40 ± 1.76 mm on the right and 15.04 ± 1.49 mm on the left. The difference was minor and statistically insignificant (p = 0.274), indicating no significant lateral variation.

3. Height of the Seat: On right side, the height of the seat was 4.68 ± 0.88 mm, whereas on the left, it was 4.81 ± 0.87 mm. The difference was not significant (p = 0.439), indicating relative morphological symmetry between the two sides.

4. Length of the Styloid Process: The mean length of the styloid process on the right side was 4.78 ± 1.16 mm, whereas on the left side, it was 4.94 ± 1.09 mm.

Although the left side showed a slightly greater length, the variation was not statistically significant (p = 0.101).
5. Width of the Styloid Process: The width on the right side was 3.93 ± 1.10 mm, compared with 4.12 ± 0.96 mm on the left side. This difference approached significance but remained statistically insignificant (p = 0.093).
6. Width of the Fovea: The width of the fovea showed a clear asymmetry, with the right side measuring 3.09 ± 0.56 mm and the left side measuring 2.88 ± 0.36 mm. This difference was statistically significant (p = 0.031), suggesting notable lateral variation in this parameter.
The parameters observed in the right and left ulnae were compared. All parameters showed no significant difference between the right and left ulnae, except for the width of the fovea, which was found to be significantly larger on the right side (p = 0.031).

Discussion

The distal end of the ulna plays an important role in wrist articulation and the attachment of ligaments, particularly the triangular fibrocartilage complex (TFCC) and extensor carpi ulnaris (ECU) tendon. In this study, both morphological and morphometric features of the distal ulna were examined and statistically analyzed on both the right and left sides. The findings were also compared with those of previously published studies.
Shape of the Pole: The semicircular shape was the most prevalent, appearing in 42% of cases on the right side and 50% on the left side. Kidney-shaped poles followed, with 26% on the right and 22% on the left. Coma and semilunar shapes were less common on both the right and left sides. These shape variations are clinically significant because they can influence the stability and contact area of the ulnar-carpal joint. This observation is consistent with the findings of Gupta et al. (6), where kidney shapes (48%) were more prevalent than coma and semicircular shapes (20%), with semilunar shapes being the least common (12%). Joshi et al. (7) reported that the semilunar shape was the most common for the pole (60% and 63.76% on the right and left side respectively), followed by coma-shaped (10% and 23.18% on the right and left side respectively), semicircular (20% and 13.04% on the right and left side respectively), and kidney-shaped (10% and 0% on the right and left side respectively) on the right and left sides. Variations in pole shape can affect articular congruency and are crucial for prosthesis design.
Direction of the Seat: In 62% and 66% of the cases on the right and left, respectively, the seat was found to be sloping, highlighting its prevalence. The remaining were flat, with 38% on the right and 34% on the left side. This slant may be vital for the stability of the distal ulna and its connection to the radius and carpal bones. Joshi et al. (7) noted that sloping seats were more common in males, likely due to mechanical stress. Our findings confirmed the predominance of sloping patterns in both the limbs. The direction of the seat influences the

angle of the articular disc and the range of motion, as explained by Giachino et al. (8), who discussed its role in distal ulnar arthroplasty.

Styloid Process: The styloid process was present in 96% of the right bones and 98% of the left bones. The left side more frequently exhibited a curved shape (44%), whereas the right side predominantly exhibited a straight shape (68%). On both sides, the tip was generally blunt (72% of specimens). The configuration of the styloid process, including its shape and tip, is crucial for surgical planning and prosthesis design, particularly in cases of ulnar-sided wrist pain or fracture. Studies by Sharma et al. (5) and Ashiyani et al. (9) confirmed the high prevalence of the styloid process, establishing it as a consistent anatomical feature. Joshi et al. (7) observed that straight styloid processes were more common, which is associated with load-bearing and the stability of ligament attachments.Styloid curvature may vary owing to genetic or occupational factors. Giachino et al. (8) stressed that curved styloid processes might lead to ulnar impaction syndromes in athletes and manual laborers owing to repetitive stress.

Tip of the styloid Process: The common type of tip was blunt, appearing in 72% of cases on both right and left sides. In contrast, sharp tips were found in 24% and 26% of the samples on the right and left sides, respectively. These results are consistent with the findings of Ashiyani et al. (9), who noted a higher prevalence of blunt tips in females and sharp tips in males. Sharma et al. (5) emphasized the clinical importance of a sharp styloid process in trauma situations, as it can cause impingement.

Table 3: Comparison of results of the present study with the results obtained in the previous studies by various authors.

Author	Right / Left	Width of the pole	Height of the seat	Width of the fovea	Length of styloid process
Present study	Right Left	5.04 5.10	4.68 4.81	3.09 2.88	4.78 4.94
Vijaykishan B et al 2016	Right Left	4.92 4.93	6.06 5.75	5.42 5.17	4.89 4.50
Oommen S S 2015	Right Left	5.04 5.00	6.51 6.42	4.14 4.50	5.80 5.50
Zarana AA et al 2014	Right Left	5.67 5.72	6.01 6.43	4.76 4.10	4.25 5.28
Sharma A et al 2011	Right Left	5.40 6.10	5.90 6.90	4.50 4.90	5.20 5.00
Joshi S D et al 2009	Right Left	5.26 4.76	6.39 5.26	5.26 5.18	- -

The present study aimed to conduct a comprehensive morphometric analysis of the lower end of the ulna on both the right and left sides, including measurements

of the anteroposterior (AP) width of the pole, transverse width of the pole, height of the seat, length and width of the styloid process, and width of the fovea (Table 3). These anatomical parameters were statistically analyzed and compared with those of previous similar studies to understand variations and provide clinically relevant data for orthopaedic, prosthetic, and anthropological applications.

Anteroposterior Width of the Pole: In the present study, the AP width of the pole was found to be 5.04 ± 1.01 mm on the right side and 5.10 ± 0.84 mm on the left side, with a p-value of 0.746, indicating no significant side difference. This is consistent with Oommen SS (10), who also reported 5.04 mm on the right side and 5.00 mm on the left side, supporting the notion of bilateral symmetry in this dimension. Vijaykishan et al. (11) noted slightly smaller values (4.92 mm on the right side and 4.93 mm on the left side, while Sharma et al. (5) and Zarana et al. (12) found much higher measurements (up to 6.10 mm in Sharma's study), indicating considerable population variability. Joshi et al. (7) reported 5.26 mm on the right side and 4.76 mm on the left side, which are fairly close to the present findings. These variations may be due to regional, genetic, ethnic, or sample size differences. The present study's values fall within the lower range, possibly indicating that the study population had a smaller skeletal build than the populations in the studies by Sharma (5) and Zarana (12).

Transverse Width of the Pole: The transverse width was observed as 15.40 ± 1.76 mm on the right side and 15.04 ± 1.49 mm on the left side in the present study. Although not compared in all previous studies, these values contribute new information to the literature. The non-significant p-value (0.274) suggests no significant side differences were observed. The inclusion of transverse width adds value, especially for prosthetic and implant sizing, where such lateral dimensions are crucial. Future studies should validate and expand upon this lesser-reported parameter.

Height of the Seat: In present study, the height of the seat was 4.68 ± 0.88 mm on the right side and 4.81 ± 0.87 mm on the left side. This is lower than that of all the other studies. For instance, Vijaykishan et al. (11) reported 6.06 mm on the right side and 5.75 mm on the left side, and Oommen SS (10) reported even greater values of 6.51 mm on the right side and 6.42 mm on the left side. Zarana AA (12) documented 6.01 mm on the right side and 6.43 mm on the left side, and Sharma A et al. (5) observed the highest values 5.90 mm on the right side and 6.90 mm on the left side. The markedly smaller values in the present study may reflect population differences, particularly in stature or sex distribution. This deviation is significant for anthropological classification and suggests that Indian subpopulations exhibit considerable morphometric diversity even within a single country. From a clinical perspective, a lower seat height may have implications for joint articulation and prosthetic seating.

Length of the Styloid Process: In this study, the styloid process was 4.78 ± 1.16 mm on the right side and 4.94 ± 1.09 mm on the left side. These findings are similar to those of Vijaykishan et al. (11), who found lengths of 4.89 mm on the

right side and 4.50 mm on the left side. Conversely, Oommen SS (10) recorded longer measurements of 5.80 mm on the right side and 5.50 mm on the left side, as did Sharma A (5) with 5.28 mm on the right side and 5.20 mm on the left side, and Joshi SD (7) with 5.28 mm on the right side and 5.18 mm on the left side. Zarana AA (12) reported shorter lengths of 4.25 mm on the right side and 4.50 mm on the left side, which are close to the current study's results. The slight predominance of the left side is consistent with most previous studies, suggesting a possible link between handedness and functional adaptation. However, this side dominance was not statistically significant (P = 0.101) in the present study.

Width of the Styloid Process: This parameter was measured as 3.93 ± 1.10 mm on the right side and 4.12 ± 0.96 mm on the left side. Although this metric was not consistently evaluated across the cited studies, the trend of larger left-side values continues here. Although the p-value was 0.093, it approached significance and may suggest slight asymmetry. This could be functionally relevant for surgical fixation or fracture repair of the ulnar styloid, especially if dominance or load-bearing use influences the growth patterns.

Width of the Fovea: One of the most significant findings in the present study was the width of the fovea, which measured 3.09 ± 0.56 mm on the right side and 2.88 ± 0.36 mm on the left side, with a statistically significant p-value of 0.031. Compared with previous studies, these values were notably lower. Vijaykishan et al. (11) reported 5.42 mm on the right side and 5.17 mm on the left side. Oommen SS (10) observed 4.14 mm on the right side and 4.04 mm on the left side. Zarana AA (12) and Sharma A (5) also reported higher values (above 4.5 mm on both sides). The significantly smaller foveal width in the present study may imply anatomical variation based on genetic, ethnic, or environmental influences.

Clinically, the fovea is essential for distal radioulnar joint stability, and significant differences can affect ligament attachment and joint motion. Hence, these findings have orthopaedic and reconstructive relevance.

In all parameters, the left side consistently showed slightly higher values than the right side, a pattern echoed in earlier studies by Sharma (5), Joshi (7), and Zarana (12). Although most differences were not statistically significant, the trend might suggest handedness or developmental dominance that subtly influences the morphometry. The only statistically significant difference between the sides in the present study was observed in the foveal width.

Conclusion:

The ulnar styloid process and distal ulna are critical for wrist stability through their attachment to the triangular fibrocartilage complex (TFCC) and ulnar collateral ligaments. Morphological variations can influence susceptibility to fractures, TFCC tears, and ulnocarpal impaction syndromes. Recognizing morphological variations can help prevent changes in load distribution across the wrist during reconstructive surgeries, such as ulnar shortening osteotomy or Darrach's procedure, thereby minimizing postoperative complications. Precise

morphometric knowledge is essential for managing distal ulna fractures, DRUJ instability, and arthroplasty. This study highlights the importance of population-based morphometric data by connecting anatomical research with applications in orthopaedics, radiology, and forensic sciences. These findings provide a reference for clinical decisions, surgical planning, and anthropological analyses. Future multicenter studies with larger populations and 3D imaging are recommended to refine these anatomical benchmarks.

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