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ORIGINAL RESEARCH

Radiomorphometric study of trochlea in humerus and its clinical correlation

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ABSTRACT
Function of the elbow joint depends heavily on the trochlea of the humerus, and its radiomorphometric characteristics have important therapeutic ramifications. The purpose of this study was to examine the trochlea's radiomorphometry and its relationship to elbow disorders in five different age groups (18–65 years). The age groups of 26–35 and 56–65 had the highest representation (22.2%), while the age group of 18–25 had the lowest (16.7%). There was little variation among participants in the average values of the trochlear parameters, which showed consistent anatomical patterns: Capitulotrochlear Angle (CTA: 151.88°), Trochlear Sulcus Angle (TSA: 141.97°), and Trochlear Angle (TA: 102.83°). Gender distribution showed 44.4% females and 55.6% males, with balanced representation across all age groups except for those aged 56–65. Males had a significantly higher CTA (152.54°) than females (151.05°, p = 0.00**), but there were no discernible gender differences in TA or TSA. According to correlation analysis, elbow disorders were more strongly predicted by TSA (r = 0.35, p = 0.01) and CTA (r = -0.28, p = 0.02) than by TA (r = 0.21, p = 0.05). The incidence of disorders was positively correlated with TSA and negatively correlated with CTA. With particular attention to gender and age-based variations, these findings highlight the clinical utility of trochlear morphometry in the diagnosis and treatment of elbow pathologies.

Keywords: Trochlea, Humerus, Trochlear Angle, Capitillo-trochlear Angle, Capitillo-trochlear Angle

INTRODUCTION
A vital component of the elbow joint, the trochlea of the humerus is essential for enabling articulation between the ulna and the humerus [1]. Its distinctive spool-shapeddesign allows for seamless flexion and extension of the forearm [2]. The morphology of the trochlea has significant clinical implications, particularly in the fields of orthopedic surgery and trauma management. Variations in trochlear morphology can influence the biomechanics of the elbow joint, affecting its stability and range of motion. For instance, a deeper trochlear groove can enhance joint stability, while a shallower groove may predispose to dislocations and other injuries. Understanding these variations is crucial for diagnosing elbow disorders, planning surgical interventions, and designing orthopedic implants [3].
In orthopedic surgery, precise knowledge of trochlear morphology is essential for successful outcomes in procedures such as elbow arthroplasty and fracture fixation. In elbow arthroplasty, the compatibility of the prosthetic components with the patient's native anatomy is critical for restoring function and achieving long-term success. Prosthetic components must be designed to match the morphometric parameters of the trochlea to ensure a proper fit and

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avoid complications such as joint instability or limited range of motion [4].

In the context of trauma management, understanding the detailed morphology of the trochlea can influence the surgical approach and fixation techniques used to treat fractures. For example, distal humerus fractures often involve the trochlea, and accurate fixation requires knowledge of its morphometric characteristics to ensure optimal alignment and stabilization of the joint. This understanding can lead to better outcomes and reduce the risk of complications such as nonunion or malalignment [5].

Despite these valuable contributions, several research gaps remain. There is a need for more comprehensive studies that include diverse populations to understand the full range of morphological variations. Additionally, standardized measurement protocols are required to improve the comparability of radiomorphometric studies. The clinical correlations of specific morphometric parameters with various elbow disorders also warrant further investigation to enhance diagnostic and therapeutic strategies.

MATERIAL AND METHODS

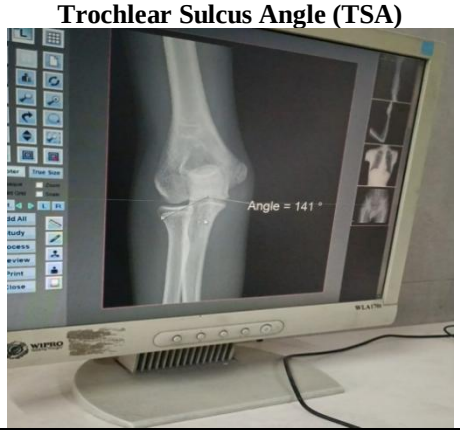
Study Design

This cross-sectional observational study included total of 90 anteroposterior (AP) view X-ray images of the lower end of the humerus, which included 50 images from male patients and 40 images from female patients. Ethical approval was obtained from the Institutional Ethics Committee (IEC/IIMSR/2024/44) of IIMSR.

Equipment

All measurements were performed using anteroposterior (AP) elbow X-ray images of patients obtained from the Radiology Department of IIMSR using a digital X-ray machine.

Radiographic Measurements Three specific angles were measured using the digital radiography system and appropriate measuring tools:

Trochlear Angle (TA) 	Definition: The angle formed by lines drawn along the distal portions of the trochlea's articular surfaces (XY) and a line (MN) along the midpoints of AB and CD. Here, AB and CD represented the transverse diameters of the upper 4/6th and upper 5/6th of the humeral length, respectively. Measurement Procedure: Points A, B, C, and D on the humeral image were identified. Lines AB and CD were drawn, and the midpoint for each was calculated. Line MN was drawn connecting these midpoints. Lines XY were drawn along the distal articular surfaces of the trochlea, and the angle between XY and MN was measured.
Trochlear Sulcus Angle (TSA) 	Definition: The angle formed by lines connecting the most distal portion of the capitulum to the apex of the trochlear sulcus and the medial slope of the trochlea's articular surface. Measurement Procedure: The apex of the trochlear sulcus, the most distal point of the capitulum, and the medial slope of the trochlea were identified. Lines connecting these points were drawn and the angle at the trochlear sulcus was measured.

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Capitillo-trochlear Angle (CTA): 	Definition: The angle formed at the junction of the most distal portion of the capitulum and the medial slope of the trochlea's articular surface. Measurement Procedure: The most distal point of the capitulum and the medial slope of the trochlea were identified. Lines from these points to the junction were drawn and the angle was measured.

Statistical Analysis

The collected data were entered into Microsoft Excel and analyzed using SPSS (Statistical Package for the Social Sciences) version 26.0. The following statistical methods were used: Continuous variables were expressed as mean ± standard deviation (SD) and Categorical variables (such as gender) were summarized using frequencies and percentages. The t-tests were performed to compare the means of the trochlear angles between male and female groups. Pearson correlation analyses were conducted to determine the relationship between different morphometric parameters. The following P-values were considered significant: $P < 0.05$ indicates significance, and $P < 0.001$ indicates high significance.

RESULTS

The age distributions of the sample population were shown in Table 1. The descriptive statistics for the trochlear measurements were shown in Table 2. The combined age and sex distribution were shown in Table 3. T-tests were conducted to compare the means of trochlear measurements between males and females (Table 4). Pearson correlation coefficients were calculated to assess the relationships between trochlear measurements and the incidence of elbow joint disorders (Table 5).

Five age groups comprise the study population (18–65 years), with the largest being 26–35 and 56–65 (22.2% each) and the smallest being 18–25 (16.7%). There is little variation in the CTA (151.88°), TSA (141.97°), and TA (102.83°), suggesting consistency amongst participants. Out of the 90 participants, 44.4% are women and 55.6% are men. All age groups have equal gender representation, with the exception of those aged 56 to 65. There are no discernible gender differences between TA and TSA. Males have a significantly higher CTA (152.54°) than females (151.05°, p = 0.00**), which may have clinical significance. TSA (r = 0.35, p = 0.01) and CTA (r = -0.28, p = 0.02) are stronger predictors of elbow disorders than TA (r = 0.21, p = 0.05), with TSA positively and CTA negatively correlated to disorder incidence.

Table 1: Age Distribution

Age Group (years)	Frequency	Percentage
18-25	15	16.7%
26-35	20	22.2%
36-45	18	20.0%
46-55	17	18.9%
56-65	20	22.2%

Table 2: Descriptive Statistics of Trochlear Measurements

Measurement	Mean ± SD	Minimum	Maximum
Trochlear Angle (degrees)	102.83 ± 1.01	101	104
Trochlear Sulcus Angle (degrees)	141.97 ± 1.53	140	145
Capitulo Trochlear Angle (degrees)	151.88 ± 1.76	149	153

Table 3: Combined Age and Sex Distribution

Age Group (years)	Male	Female	Total
18-25	9	6	15
26-35	11	9	20
36-45	10	8	18
46-55	10	7	17
56-65	10	10	20
Total	50	40	90

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Table 4: Table 1:- Showing the Trochlear Angle (TA), Trochlear Sulcus Angle (TSA) and Capitillo-trochlear Angle (CTA) in male and female subjects

Measurement	Male (Mean ± SD)	Female (Mean ± SD)	p-value
Trochlear Angle (TA) (degrees)	102.70 ± 0.97	102.80 ± 1.14	0.78
Trochlear Sulcus Angle (TSA) (degrees)	142.10 ±1.61	141.80 ± 1.44	0.36
Capitulo Trochlear Angle (CTA) (degrees)	152.54 ± 1.20	151.05 ±2.0	0.00**
*significant at the 0.05 level.			
**significant at the 0.01 level.			

Table 5: Showing the relationships between trochlear measurements and the incidence of elbow joint disorders

Measurement	Correlation with Disorder Incidence (r)	p-value
Trochlear Angle (degrees)	0.21	0.05
Trochlear Sulcus Angle (degrees)	0.35	0.01
Capitulo Trochlear Angle (degrees)	-0.28	0.02

DISCUSSION

The present study explores the radiomorphometric characteristics of the trochlea in the humerus and their clinical correlation, focusing on age, gender differences, and their association with elbow joint disorders. The results contribute to our understanding of joint biomechanics and pathologies by offering important new information about the clinical relevance and anatomical consistency of trochlear measurements.

Age and Gender Distribution: The study population was well-distributed across five age groups (18-65 years), with the largest groups being 26-35 and 56-65 years (22.2% each) and the smallest being 18-25 years (16.7%). Gender representation was balanced, with 44.4% females and 55.6% males, except for the 56-65 groups, where the gender ratio was equal. This balanced distribution supports the reliability and generalizability of the findings across different age groups and sexes.

Trochlear Measurements and Variability: The trochlear angle (TA), trochlear sulcus angle (TSA), and capitulo-trochlear angle (CTA) showed minimal variability, with mean values of 102.83°, 141.97°, and 151.88°, respectively. These narrow ranges reflect anatomical consistency among participants, emphasizing the uniformity of these radiomorphometric parameters. Such consistency highlights their potential as reliable reference points in clinical and surgical applications.

Gender Differences in Trochlear Measurements: While no significant gender differences were observed in TA and TSA, CTA was significantly higher in males (152.54°) compared to females (151.05°, p = 0.00**). This gender disparity in CTA suggests possible biomechanical or anatomical differences that may influence elbow joint function or susceptibility to disorders. This finding warrants further investigation into gender-specific joint mechanics and their clinical implications, particularly in orthopedic or rehabilitation contexts. This finding aligns with previous studies indicating sex-related anatomical variations in the elbow joint [6]

Clinical Correlation with Elbow Joint Disorders: Among the trochlear measurements, TSA and CTA were stronger predictors of elbow joint disorders than TA. TSA demonstrated a moderate positive correlation with disorder incidence (r = 0.35, p = 0.01), indicating that larger TSA values may increase the likelihood of elbow joint pathology. Conversely, CTA exhibited a moderate negative correlation (r = -0.28, p = 0.02), suggesting that higher CTA values may have a protective effect. TA showed only a weak positive correlation (r = 0.21, p = 0.05), indicating limited clinical relevance.

Clinical Implications: The findings underline the importance of TSA and CTA as key parameters in assessing elbow joint health. The positive correlation of TSA with disorder incidence may relate to changes in the trochlear groove's structural integrity, leading to altered joint biomechanics.

The negative correlation with the Capitulo Trochlear Angle suggests that certain morphological traits may confer a protective effect, potentially by optimizing the distribution of mechanical loads during movement [7].

CONCLUSIONS

This study highlights the anatomical consistency of trochlear measurements and their clinical correlation with elbow joint disorders. The significant gender difference in CTA and its association with disorder incidence underscore the need for further research into sex-specific anatomical and biomechanical factors.

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