ORIGINAL ARTICLE

Clinical outcomes and radiographic correlations with fracture complexity in isolated capitellum fractures: A retrospective cohort study

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ABSTRACT

BACKGROUND: Isolated capitellum fractures, though rare, significantly impact elbow function and are often associated with falls on an outstretched hand (FOOSH). This study aims to evaluate the relationship between forearm radiological parameters and fracture complexity, as well as to assess clinical outcomes in patients with isolated capitellum fractures.

METHODS: A retrospective cohort analysis was conducted on 28 fractures in 27 patients treated surgically at a tertiary center. Fractures were classified using the Bryan-Morrey system, and forearm parameters (maximum radial bow, location of maximum radial bow, proximal ulna dorsal angulation [PUDA], and proximal ulna varus angulation [PUVA]) were measured. Clinical outcomes were assessed using the Mayo Elbow Performance Score (MEPS) and QuickDASH (Quick Disabilities of the Arm, Shoulder, and Hand) scores.

RESULTS: Complex fractures (Bryan-Morrey Types III and IV) were associated with worse functional outcomes ($p<0.05$). A significant correlation was found between the distal location of the maximum radial bow and fracture complexity ($p=0.0468$). Union was achieved in 86.9% of osteosynthesis cases, with avascular necrosis (AVN) and heterotopic ossification observed in some patients.

CONCLUSION: Fracture complexity correlates with poorer functional outcomes. The distal location of the maximum radial bow may influence fracture patterns, suggesting a biomechanical role in energy transfer during FOOSH injuries. Surgical fixation yields favorable outcomes, particularly in Bryan-Morrey Type I-II fractures.

Keywords: Capitellum fractures; fall on outstretched hand; intraarticular fractures.

INTRODUCTION

Isolated capitellum fractures of the humerus, although rare among intra-articular elbow fractures, are serious injuries that affect the articular surface and directly influence functional outcomes. These fractures are often the result of low-energy trauma, such as a fall on an outstretched hand (FOOSH), in which energy is directly transmitted to the capitellum through axial loading of the radius.[1-3] In addition, anatomical variations of the forearm, such as valgus or radial bowing, may enhance energy transfer from the forearm to the capitellum, predisposing to fracture.

Capitellum fractures of the humeri are commonly associated with concomitant injuries, such as radial head fractures and lateral ligament instability, with such injuries noted in up to approximately 60% of patients.[4] However, isolated capitellar fractures are usually reported only in limited case series and are commonly classified using the Bryan-Morrey system. Because of their rarity, studies with small cohorts or case series have investigated fracture patterns and treatment outcomes.[5,6]

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Although previous literature has primarily focused on classification systems and treatment options for capitellar fractures, the influence of anatomical differences in forearm anatomy is underexplored.[7,8] Recent studies suggest that variations in forearm anatomy significantly influence load transmission during axial loading. Kim et al.[5] demonstrated that radial bow asymmetry alters rotational mechanics, while Shi et al.[6] linked ulnar varus angulation to proximal forearm fracture patterns, underscoring the potential role of morphological differences in capitellum fracture complexity.

Given the complex nature of these injuries and their frequent association with other injuries, open reduction and internal fixation (ORIF) is the favored treatment for displaced capitellar fractures, aiming to achieve anatomical reduction and stable fixation to allow for early range of motion and to prevent elbow stiffness.[1,4,9]

The main aim of this study is to evaluate whether there is a relationship between clinical outcomes and forearm radiological parameters with the fracture complexity of isolated capitellum fractures due to FOOSH injury.

MATERIALS AND METHODS

The study was conducted in a tertiary, high-volume trauma center. Data were collected retrospectively. Ethical approval was obtained from the ethics committee (Date: 17.09.2020; No: 06). This study was carried out in accordance with the Declaration of Helsinki.

Between January 2013 and January 2020, a total of 718 surgically treated humeral fractures at our institution were reviewed retrospectively. Of these, 158 involved distal humeral fractures. Among the 158 distal humeral fractures, 33 patients had isolated capitellum fractures. Five were excluded: three due to motorcycle accidents, one due to penetrating trauma, and one due to loss to follow-up. A total of 28 fractures in 27 patients who sustained a FOOSH injury and were followed up regularly were retrospectively analyzed (Fig. 1).

Fractures were classified according to the Bryan-Morrey system with the McKee modification.[10,11] Radiographic assessment included anteroposterior and lateral views of the elbow and forearm. The following forearm parameters were measured: maximum radial bow (mm), location of maximum radial bow (%), proximal ulna dorsal angulation (PUDA°), and proximal ulna varus angulation (PUVA°) (Fig. 2).[7,8,12] Measurements were performed in a double-blind manner by an orthopedic specialist.

Postoperative radiological outcomes were assessed in terms of union, avascular necrosis (AVN), heterotopic ossification (HO, Brooker classification), and degenerative arthritis (Broberg-Morrey classification). Clinical outcomes were evaluated using the Mayo Elbow Performance Score (MEPS) and the Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) score.

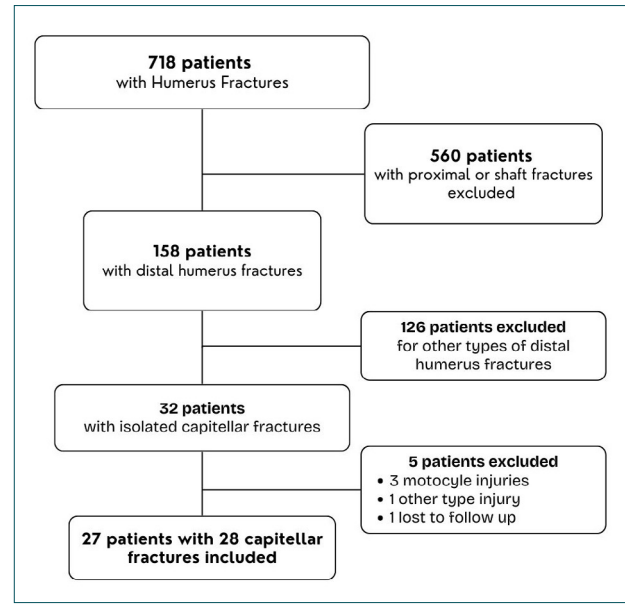

Figure 1. Flow diagram of the patient cohort.

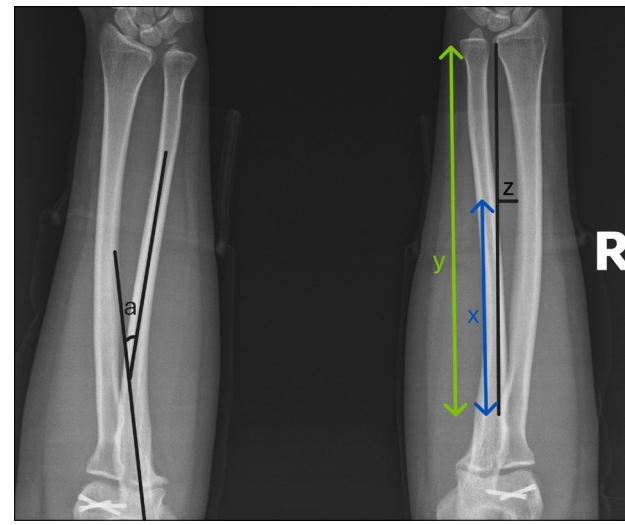

Figure 2. Anteroposterior (AP) view of a patient with assessment of radiological parameters (a: proximal ulna varus angulation [PUVA]; % (x/y)100 = Location of Maximum Radial Bow; z: Maximum Radial Bow [mm]).

Statistical Analysis

Statistical analysis was performed using IBM SPSS v25.0 (SPSS Inc., Chicago, IL, USA). Continuous variables were presented as mean±standard deviation. The normality of data distribution was assessed using distribution plots, normality tests (Shapiro-Wilk), and sample sizes; variables were found not to follow a normal distribution. Therefore, non-parametric tests were used for group comparisons. The Kruskal-Wallis test was applied to compare continuous variables among more than two groups. For post-hoc analysis following significant Kruskal-Wallis results, Dunn's test with Bonferroni correction was used to determine pairwise differences. A p-value <0.05 was considered statistically significant.

Table 1. Descriptive statistics of the patients

Demographic Information	N=28
Sex	
Female	22 (23 fractures)
Male	5
	Mean±SD (Min-Max)
Age (years)	47.8±18.4 (15-79)
BMI (kg/m²)	29.5±4.1 (21-37)

RESULTS

A total of 28 capitellum fractures in 27 patients (22 females and five males) were included in the analysis. The mean follow-up duration was 26.2 months (range, 12–79 months). Descriptive statistics for the cohort are detailed in Table 1. Fractures were classified according to the Bryan-Morrey system, and patients were grouped accordingly. At the final follow-up, the mean QuickDASH score was 25.6 (range, 4.5–75), and the mean MEPS was 83.2 (range, 50–100).

Statistical analysis revealed significant differences in patient-reported outcome measures (PROMs) among fracture types (Table 2). Results of the Kruskal-Wallis test showed that both QuickDASH and MEPS scores differed significantly among Bryan-Morrey types (p=0.015 and p=0.009, respectively). Post-hoc comparisons showed that QuickDASH scores were significantly higher (worse) in Type 4 vs. Type 1 (p=0.012), Type 3 vs. Type 2 (p=0.016), and Type 4 vs. Type 2 (p=0.014). MEPS scores were significantly lower (worse) in Type 3 vs. Type 1 (p=0.007), Type 4 vs. Type 1 (p=0.009), and Type 3 vs. Type 2 (p=0.048).

Radiological parameters of the forearm, which included maximum radial bow (mm), location of maximum radial bow (%), PUVA, and PUDA, were analyzed to evaluate their relationship with forearm anatomy and isolated capitellar fracture complexity (Table 3). Results of the Kruskal-Wallis test showed that only the location of maximum radial bow (%) was associated with Bryan-Morrey types (p=0.0468). Post-hoc analysis demonstrated that the maximum radial bow was located more distally in Bryan-Morrey Type 3 vs. Type 1 and Type 2 (p=0.0189 and p=0.0211, respectively), and in Type 4 vs. Type 1 and Type 2 (p=0.039 and p=0.0475, respectively). No significant difference was found between Type 3 and Type 4 (p=0.0709).

Surgically, 26 patients underwent a lateral Kocher approach, while two required a posterior approach with olecranon osteotomy. Headless compression screws were used in 23 cases (82.1%), and fragment excision was performed in five cases (17.9%). Union was achieved in 20 (86.9%) osteosynthesis cases. AVN was observed in five patients without the need for additional intervention. Heterotopic ossification (Brooker stage 1) was seen in 14 elbows, and degenerative changes (Broberg-Morrey stages 1-2) were found in eight elbows.

DISCUSSION

Our findings demonstrate a clear correlation between fracture type and PROMs in capitellum fractures, with more complex fractures (especially Type 3) associated with worse functional outcomes. Additionally, as our secondary aim, we

Table 2. Cohort distribution of Bryan-Morrey fracture types and associated patient-reported outcome measures (PROMs)

Bryan-Morrey Type	Number of Cases	QuickDASH Score (Mean±SD)	MEPS (Mean±SD)
Type 1	8	16.9±11.39	91.88±7.53
Type 2	3	10.2±9.93	90±7.07
Type 3	8	39.76±26.48	74.38±14.74
Type 4	9	32.03±12.38	79±11.97

Table 3. Cohort distribution of Bryan-Morrey fracture types and associated patient-reported outcome measures (PROMs)

Bryan-Morrey Type	Number of Cases	Maximum Radial Bow (mm)	Location of Max. Radial Bow (%)	PUDA (°)	PUVA (°)
Type 1	8	9.91±2.21	56.5±4.1	4.2±2.61	8.7±2.15
Type 2	3	9.88±2.39	56.9±3.8	4.1±2.52	8.6±2.41
Type 3	8	10.01±2.53	60.1±9.5	4.5±1.9	8.9±3.45
Type 4	9	9.93±2.97	61.2±3.9	4.3±2.11	8.5±3.01

investigated whether patients' forearm radiological parameters were related to fracture complexity. Except for the location of the maximum radial bow (%), there was no significant relationship between forearm morphological variations and fracture complexity.

A study by Widhalm et al.[13] reported an inverse relationship between fracture complexity and PROMs over a five-year follow-up period. Notably, the frequency of osteoarthritis and heterotopic ossification increased in Type 3 and Type 4 fractures. Similarly, Gao et al.[14] reported a higher incidence of functional impairment in more complex fracture types. Their findings showed a significant decline in functional scores (MEPS and QuickDASH) as fracture complexity increased in the Dubberley classification, which is consistent with the long-term data reported by Widhalm et al.[13] Our results align with the literature, as we observed that MEPS and QuickDASH scores were significantly lower in Bryan-Morrey Type 3 and 4 fractures compared to Types 1 and 2.

From a biomechanical perspective, studies by Markolf et al.[15] demonstrated that under valgus stress, approximately 93% of the axial load is transmitted through the radial head to the capitellum via the interosseous membrane. In another study, variations in elbow flexion angle were shown to alter stress distribution on the coronoid and radial head, potentially influencing fracture patterns.[16] Furthermore, Chou et al.[17] highlighted the impact of forearm rotation on valgus and varus stresses, suggesting that these rotational dynamics may modify load transfer mechanisms.

One important finding in our study is the association between the distal location of the maximum radial bow (%) and increased fracture complexity. This could be explained by biomechanical studies demonstrating that a more distally positioned radial apex may shift force distribution toward the distal humerus during a fall, increasing the energy absorbed by the capitellum. Firl and Wünsch previously established that variability in radial bow affects rotational mechanics of the forearm, which in turn could influence stress patterns during axial loading events such as FOOSH injuries.[12] Moreover, Rouleau et al.[8] emphasized that PUDA also plays a critical role in altering elbow joint mechanics under load. Garner et al.[18] previously noted that such morphological variations may influence fracture localization and load transmission, particularly in elderly individuals. Our study also observed a marked predominance of female patients, which is consistent with previous studies. This may be attributed to gender-specific biomechanical predispositions, including increased cubitus valgus angle, osteoporosis, and elbow hyperextension in women.[1-3,19]

Most authorities recommend surgical intervention for displaced capitellar fractures, given the risk of long-term instability, arthritis, and restricted motion if anatomical reduction is not achieved.[3,20,21] In our series, osteosynthesis using headless compression screws provided high union rates and satisfactory functional outcomes. Elkowitz et al.[22] demonstrated in a biomechanical study that headless compression screws placed postero-anteriorly offer superior stability compared to conventional screw systems. As an alternative procedure, fragment excision carries the potential risk of instability, pain, and limited range of motion in the long term. Nonetheless, Garner et al.[18] reported that excision can be acceptable in elderly patients with low functional demand. In our cohort, the lateral surgical approach combined with headless screw fixation yielded favorable outcomes. In five patients with highly comminuted Type 3 fractures where fixation was not feasible, fragment excision was performed. However, this subgroup exhibited poorer PROM scores compared to others.

The strengths of our study include its rare focus on the relationship between forearm morphology and capitellum fractures, the inclusion of comparative radiographic measurements, and the presentation of long-term functional outcomes.

The primary limitation of the study is the relatively small patient population, which is inherent to the rarity of capitellum fractures. Additionally, heterogeneity in surgical techniques (fragment excision vs. screw fixation) may have confounded outcome comparisons. Lastly, due to the low incidence of these injuries, the study was designed retrospectively, which constitutes another limitation.

CONCLUSION

This study demonstrated a relationship between isolated capitellum fracture complexity and clinical outcomes, with more complex fractures associated with worse functional scores. In addition, a distal location of the maximum radial bow was linked to increased fracture complexity, suggesting that forearm morphology may play a role in energy transmission during FOOSH injuries. Surgical intervention, particularly osteosynthesis with headless compression screws, provided satisfactory results, although fragment excision was necessary in highly comminuted cases.

Ethics Committee Approval: This study was approved by the SBÜ İzmir Bozyaka Research and Training Hospital Clinical Research Ethics Committee (Date: 17.09.2020, Decision No: 06).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: O.C., S.S., K.Y.; Design: O.C., S.S., K.Y.; Supervision: O.C., S.S., K.Y.; Resource: O.C., K.Y.; Materials: K.Y.; Data collection and/or processing: K.Y.; Analysis and/or interpretation: O.C., K.Y.; Literature review: S.S., O.C.; Writing: O.C., S.S., K.Y.; Critical review: O.C.

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

İzole kapitellum kırıklarında kırık kompleksitesinin klinik sonuçlar ve radyografik değerler ile korelasyonu: Retrospektif bir kohort çalışması

AMAÇ: Nadir de olsa izole kapitellum kırıkları dirsek fonksiyonunu önemli ölçüde etkiler ve sıklıkla açık el üzerine düşme (FOOSH) ile ilişkilidir. Bu çalışma, önkol radyolojik parametreleri ile kırık sınıflandırması arasındaki ilişkiyi değerlendirmeyi ve izole kapitellum kırıklı hastalarda klinik sonuçları değerlendirmeyi amaçlamaktadır.

GEREÇ VE YÖNTEM: Üçüncü basamak bir merkezde cerrahi olarak tedavi edilen 27 hastada 28 kırık retrospektif olarak değerlendirilmiştir. Kırıklar Bryan-Morrey sistemi kullanılarak sınıflandırılmış ve önkol parametreleri (maksimum radial eğim, maksimum radial eğim konumu, Proksimal Ulna Dorsal Angulasyonu "PUDA" ve Proksimal Ulna Varus Angulasyonu "PUVA") ölçülmüştür. Klinik sonuçlar Mayo Dirsek Performans Skoru (MEPS) ve Quick-DASH skorları kullanılarak değerlendirilmiştir.

BULGULAR: İleri evre kırıkların (Bryan-Morrey Tip 3 ve 4) daha kötü fonksiyonel sonuçlarla ilişkili olduğu gözlendi ($p<0.05$). Distalde konumlanmış olan maksimum radial eğim ile kırık ileri evresi arasında anlamlı bir korelasyon bulunmuştur ($p=0.0468$). Osteosentez vakalarının %86.9'unda kaynama sağlanmış, bazı hastalarda AVN ve heterotopik ossifikasyon gözlenmiştir.

SONUÇ: İleri evre kırıklar daha kötü fonksiyonel sonuçlarla ilişkilidir. Distalde konumlanmış olan maksimum radyal eğim kırık ciddiyetini etkileyebilir ve bu da FOOSH yaralanmaları sırasında enerji transferinde biyomekanik bir rolün varlığını düşündürmektedir. Özellikle Bryan-Morrey 1-2 grubu hastalarda cerrahi tespit olumlu sonuçlar vermektedir.

Anahtar sözcükler: Kapitellum kırığı; eklem içi kırık; el üzeri düşme.

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