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ORIGINAL PAPER

Avulsion fracture of the supinator crest of the proximal ulna in the context of elbow joint injuries

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Abstract
Purpose While performing CT examinations of the elbow, we frequently observed a previously undescribed fracture fragment of the supinator crest of the ulna. According to the anatomy of the lateral collateral ligament complex, this fracture might be an avulsion fracture of the annular ligament and/or the lateral ulnar collateral ligament. The aim of this study was to further characterize these fragments and document their associated injuries.
Methods Retrospective evaluation of CT scans of the elbow was performed. Conventional X-ray and CT diagnoses were used to systematically document any associated injuries.
Results A total of 152 CT scans were evaluated. The fragment in question was discovered in 17 patients (11.2 %). The average age of the patients was 40 years (±14.9; 9–71 years). The fragment size varied between a few millimetres and 2.4 cm. Multifragmented fractures were observed. In 82.3 % of the cases, associated radial head fractures were diagnosed. In 29.4 %, a coronoid process fracture was present. Distal humerus fractures were found in 23.5 %. Instability in the medial collateral ligament and an Osborne-Cotterill lesion were found in 11.8 % of the patients, respectively.
Conclusions In a significant percentage of the population, a previously undescribed fracture fragment of the supinator crest of the ulna could be detected. The most frequently occurring associated injuries were fractures of the radial head, the coronoid process, and the distal humerus. The aetiology of these lesions is unknown; however, bony avulsion of the annular or the lateral ulnar collateral ligament seems to be the most likely cause. If this fragment is to be diagnosed by CT, the possibility of lateral or posterolateral instability should be considered.

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Introduction

In recent years, computed tomography (CT) has become a valuable tool for diagnosing complex fractures around the elbow. Because conventional X-ray diagnostics are often hindered by the projection-dependent overlying of bones, small fracture fragments might not be detectable. Thus, X-rays are often supplemented with CT scans to allow the more precise specification of the fracture's nature. Multiplanar and 3D surface reconstructions permit a detailed analysis of fracture pathology and improve the spatial sense.

While performing CT examinations, we frequently observed a fracture fragment dorsal to the radial head within our own patient population (Figs. 1, 2 and 5).

Literature research (search PubMed: supinator crest, avulsion lateral collateral ligament) revealed that this fragment was previously undescribed. Anatomically, this fragment involves the supinator crest and tubercle of the proximal ulna (Fig. 3).

Functionally, the supinator crest serves as the attachment of the supinator muscle and the insertion of the annular and lateral ulnar collateral ligament. In addition, in conjunction with the annular ligament, it plays a role as the dorsolateral osseous margin of the fibro-osseous ring around the radial head, maintaining the integrity of the proximal radioulnar joint. It is a dorsal buttress for the radial head.

According to the anatomy of the lateral collateral ligament complex, we believe that this fracture of the supinator crest is

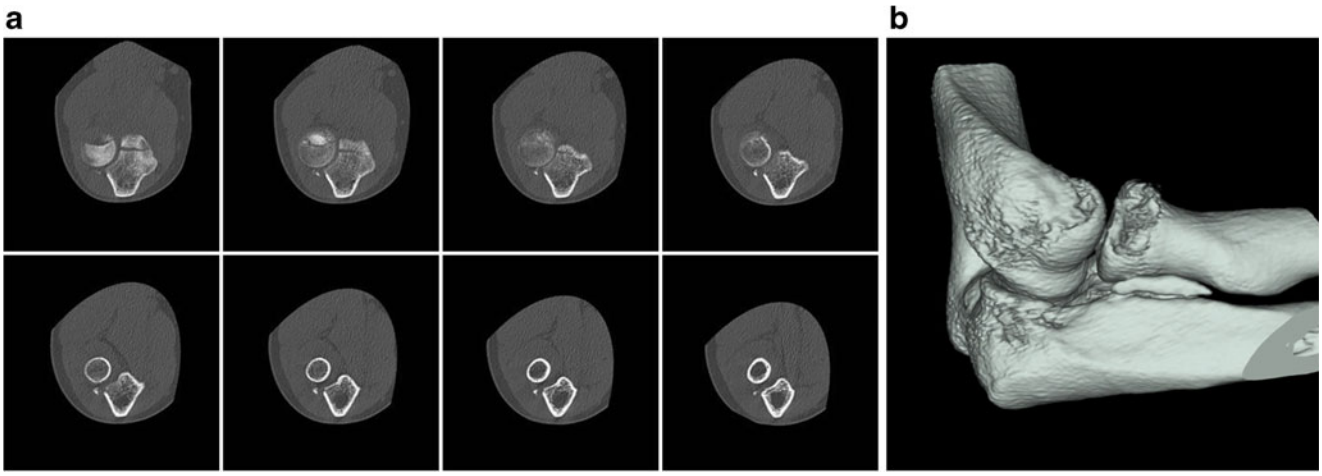

Fig. 1 Fracture of the supinator crest of the ulna in a complex elbow trauma. Accompanying radial head (Mason type II) and coronoid process (O'Driscoll type I) fracture (male, 38 years). **a** Axial reconstruction. **b** 3D surface reconstruction

an avulsion of the annular ligament and/or the lateral ulnar collateral ligament of the proximal ulna.

In our opinion, the fragment described might be the equivalent to avulsion fractures of the collateral ligaments of the

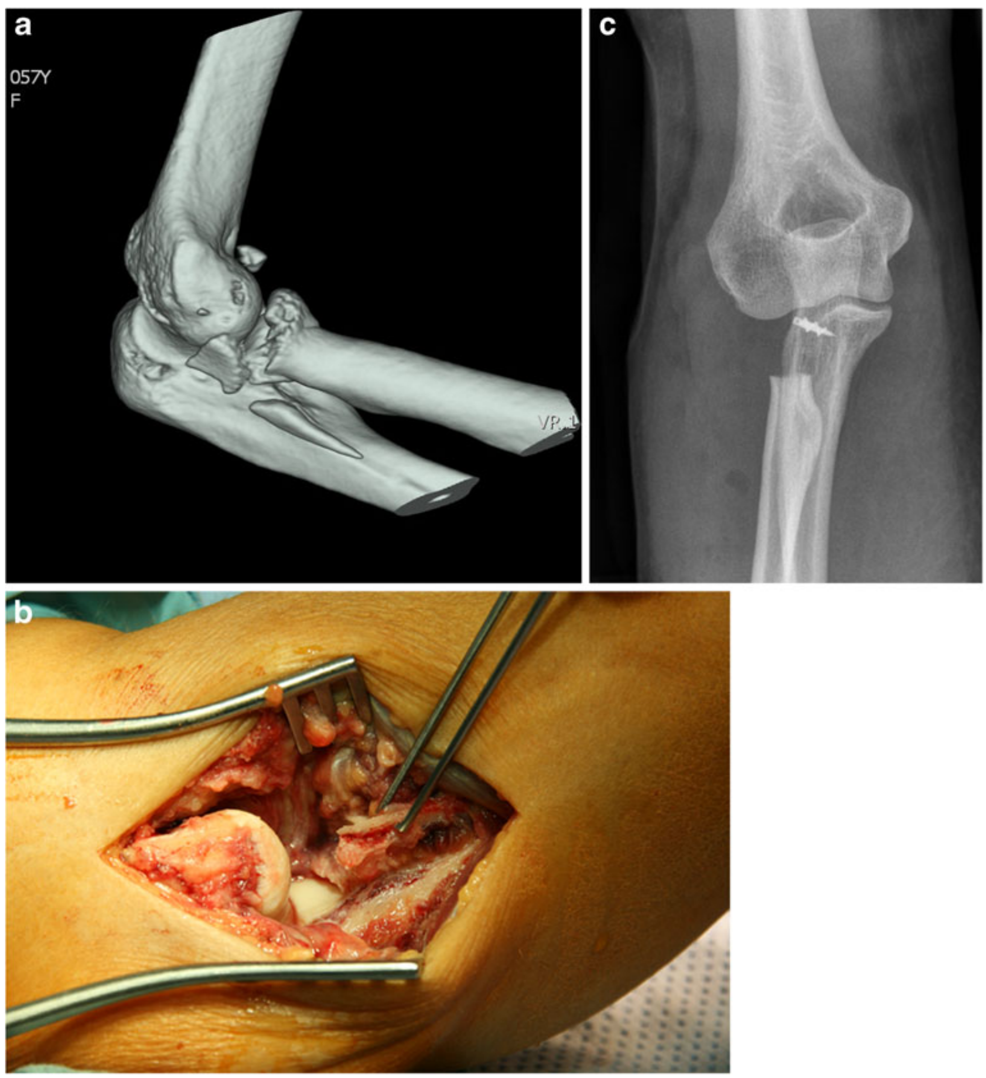

Fig. 2 Fracture of the supinator crest of the ulna with accompanying Mason type III fracture. **a** 3D surface reconstruction. **b** Intraoperative finding. **c** While too small for screw fixation, the ligament was repaired using a 3.5-mm screw anchor

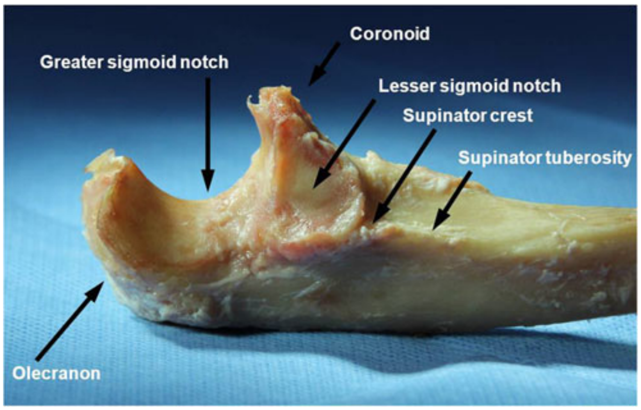

Fig. 3 Lateral view of a right proximal ulna after soft tissue dissection (female, 78 years)

epicondyles; osteocapsular disruption of the dorsoradial humerus, as in Osborne-Cotterill lesions; or avulsion fractures of the sublime tubercle of the ulna [1–3].

The purpose of our retrospective study was to determine the frequency and characteristics of the fracture fragment of the supinator crest using CT analysis and to identify the accompanying injuries.

Materials and methods

This study is a retrospective analysis of all computer tomography (CT) scans of the elbow performed between June 1, 2010, and December 12, 2010, in a Level 1 trauma centre. The study protocol was reviewed and approved by the Institutional Review Board of the department involved. The CTs were detected by defining the following search criteria in the Picture Archiving and Communication System (PACS): period, June 1, 2010, to December 12, 2010; modality, CT; and region of study, elbow. Four orthopedic and trauma surgery investigators evaluated all CT scans independently, and the fragment of the supinator crest was only affirmed when all investigators confirmed a concordant consensus. The raw data for the CT scan and coronal, sagittal and frontal reconstructions and 3D surface views were analysed. In addition, conventional X-rays in orthogonal planes were interpreted in terms of their detectability of the supinator crest fragment.

The length of the fragment was measured in the coronal reconstructions by counting the slices in which the fragment was present and multiplying them by the slice thickness. Accompanying injuries were diagnosed in CT scans only. Fractures of the radial head were classified using the Mason classification modified by Johnston [4] and judged as simple or complex depending on coexisting injuries. For olecranon fractures, the Schatzker classification was used [5]. Fractures of the coronoid process were classified according to O'Driscoll [6]. Fractures of the distal humerus were categorized according to the OTA classification [7]. Bony ligamentocapsular avulsions at the dorsoradial aspect of the distal humerus were designated as Osborne-Cotterill lesions [2]. Medial ligament pathology was assumed when a humeral or ulnar bony avulsion was detectable. Monteggia fractures were subclassified according to Bado [8]. Patient charts were evaluated to determine the type of trauma and history of elbow dislocation in all cases for which the supinator crest fragment was found.

The statistical analysis of the patient data and results was performed using SPSS 18 software (SPSS 18, IBM, Germany). Metric data are represented as the means and standard deviation, minimum and maximum.

Results

Using the search criteria mentioned, a total of 152 CT scans were found. The fragment in question was concordantly discovered in 17 patients (11.2 %). The average age of the seven female and ten male patients was 40 years (±14.9; 9–71 years).

The mechanism of injury was a ground-level fall in eight patients (47 %) and a fall from a height of more than three metres in three (18 %) patients. A bicycle accident was the cause for two patients (12 %) and a fall downstairs was the mechanism for one (6 %). In three cases (17 %), the mechanism was unknown. Dislocation of the elbow joint at the moment of trauma was documented in two patients (12 %).

The mean size of the supinator crest fragment was 8 mm (±5.2, 4–24 mm). Multifragmented fractures were observed in three patients. None of the fractures involved the lesser sigmoid notch.

The CT scans revealed accompanying injuries in all patients (Table 1).

In 82.3 % (n=14), associated radial head fractures were diagnosed. Those were isolated in half of the patients (n=7). In the remaining patients, the radial head fractures were accompanied by fractures of the coronoid process (n=5), the distal humerus and the olecranon (n=1).

Using the Mason classification, one type I, four type II, seven type III and two type IV fractures were found. All five fractures of the coronoid process were Type I fractures, according to O'Driscoll.

The fractures of the distal humerus included one 13 B1.1, two 13 B3.1 and one 13 C3.2. A bony pathology of the medial collateral ligament and an Osborne-Cotterill lesion were detected in 11.8 % of the patients (n=2), respectively. There was one Monteggia fracture (Bado IIc) and one Essex–Lopresti injury.

The fragment of the supinator crest could be delineated in only one patient using conventional X-ray diagnostics.

Table 1 List of accompanying injuries, in descending order of frequency, in the 17 identified patients with fracture of the supinator crest. The injuries might be coincidental

Accompanying injuries (potentially coincidental)			
Type of injury		Quantity (*n*)	Percentage
Radial head fractures	Simple	7	41.1
	Complex	7	41.1
Coronoid process fractures		5	29.4
Distal humerus fracture		4	23.5
Osborne-Cotterill lesion		2	11.7
Medial ligament pathology		2	11.7
Essex-Lopresti injury		1	5.8
Monteggia injury		1	5.8

Discussion

This study analysed 152 CT scans of elbow fractures identifying a fracture of the supinator crest in 17 individuals (11 %). In most cases (82.3 %, $n=14$), associated radial head fractures were diagnosed. Those were simple ones in half of the patients ($n=7$) and accompanied by coronoid process fractures in five and distal humerus and olecranon fractures in one patient, respectively.

To our knowledge no other study focused on this particular fracture fragment indicating that this study describes something new.

The understanding of the lateral collateral ligamentous complex as the primary constraint to posterolateral rotational instability, limiting the external rotation of the radius and ulna relative to the humerus, has been advanced in recent years [9–11]. Basic biomechanical and joint kinematic data were acquired by serial sectioning of the ligamentous and bony stabilizers of the elbow [11–15]. Such studies support the pathoanatomic process postulated by O'Driscoll, which suggests that insufficiency of the lateral ligament complex, particularly the lateral ulnar collateral ligament, plays an outstanding role in the genesis of posterolateral rotational instability (PLRI) of the elbow [9].

The lateral collateral ligament complex (LCL) is believed to consist of four parts, which are less distinct than the medial collateral ligament (MCL) of the elbow. The annular ligament (AL) passes from the anterior margin of the lesser sigmoid notch to the supinator crest, keeping the radial head in contact with the proximal radioulnar joint. The radial collateral ligament (LCR) originates from the lateral epicondyle and blends with the AL. The accessory lateral collateral ligament originates from the inferior margin of the AL and inserts with discrete fibres at the tubercle of the supinator crest. The lateral ulnar collateral ligament (LUCL) also originates from the lateral epicondyle and inserts at the supinator crest [16, 17]. Based on anatomic studies, the insertion was found to be bilobed (type I) or broad (type II) [12].

It is well known that in elbow trauma, particularly radial head fractures and elbow dislocations, injuries of the collateral ligaments are frequent [18, 19]. Using arthrography or MRI in Mason type II and III fractures, Johannsson and Itamura found consistent disruption of the LCL in up to 80 % of their subjects [20, 21]. Interestingly, LUCL lesions were only found in one of these two patterns: proximal avulsion in 15/18 (83 %) and midsubstance disruption in three of 18 (17 %) [20]. Those findings were confirmed by McKee et al., who found that 88.6 % of patients who required ligament repair due to acute instability had proximal avulsion or midsubstance disruption of the lateral ligament complex. Ulnar avulsions were reported in three patients (4.8 %), and bony avulsion at the ulnar only in one patient (1.6 %) [22].

After analysing our patients and their most frequently observed injury accompanying supinator crest fractures (i.e., radial head fractures) we believe such fractures are the result of a posterolateral subluxation mechanism, which is usually the cause of radial head fractures [23]. This results in increased tension of the lateral collateral ligaments and a force that pushes the radial head dorsally against the rim of the supinator crest (Fig. 4). Depending on the fracture size, the avulsion of the supinator crest might alternate the lateral collateral ligament complex and contribute to elbow instability, particularly posterolateral rotational instability.

Several biomechanical cadaveric studies have examined the impact of the LCL complex on elbow stability. The loss of the AL's stabilizing effect significantly increased the mediolateral and anteroposterior travel of the radial head, while the pronation-supination axis of the forearm remained unaffected [24]. Cutting the LUCL resulted in a 4.4° rotational instability and a 3.5-mm posterior radial head translation. Additional severance of the AL resulted in 37° rotational instability and a 16-mm posterior radial head translation [25]. Upon LUCL dissection, Dunning found insignificant alterations in joint kinematics; however, dissection of both the LUCL and LCR resulted in significant posterolateral instability [14].

Similar results were presented by Seki, who found gross instability with subluxation after cutting the origin of the LCR and the insertion of the LUCL [13]. Those findings are supported by the studies of Jensen and Beingessner [11, 26, 27]. Those biomechanical findings are exactly what we found in those cases we treated operatively. Patients presented with posterior translation of the radial head and widening of the humeroradial joint space (Fig. 5).

Based on the existing biomechanical and clinical reports, we feel comfortable recommending ligament repair in terms of the instability present, because a residual laxity of the LCL may cause recurrent PLRI [9–12, 28–30]. Certainly, the extent of instability resulting from an avulsion fracture of the

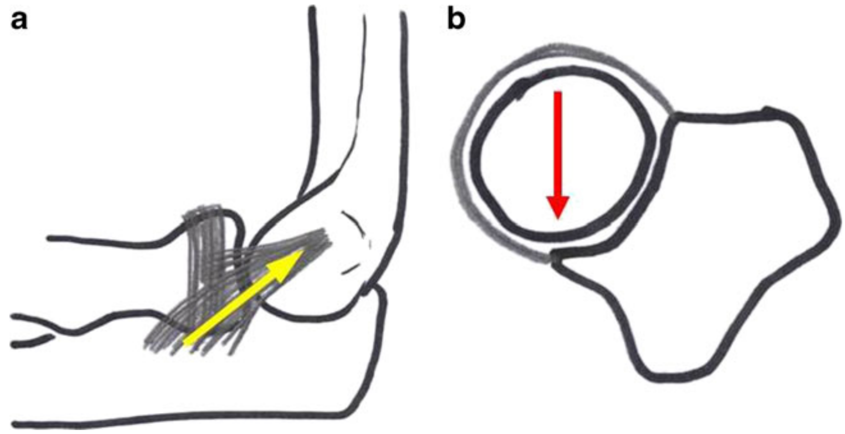

Fig. 4 **a** Lateral view of a left elbow. The yellow arrow indicates the tensioning force vector. **b** Coronal slice of the proximal radioulnar joint. The red arrow indicates the vector resulting from a force from anterior to posterior, as generated in the dorsal subluxation mechanism of the radial head under the capitellum

supinator crest is unknown. Subsequently, intraoperative examinations are indispensable and need to be included in the treatment algorithm. In biomechanical testing, the O'Driscoll test for PLRI was found to be pathologic only when distinct instability was present and the AL was severed [14]. Additionally, the original O'Driscoll posterolateral pivot shift test cannot be performed when the radial head is fractured or resected [9].

Resection arthroplasty was used for many years when a radial head fracture was not amendable to fixation. However, in cases with concurrent collateral ligament insufficiency, this procedure may result in significant alterations of elbow kinematics [11, 31]. Concordantly, Beingessner and Jensen found complete restoration of joint stability after both radial head replacement and lateral collateral ligament repair. Jensen found that joint kinematics were restored when the LCL was repaired

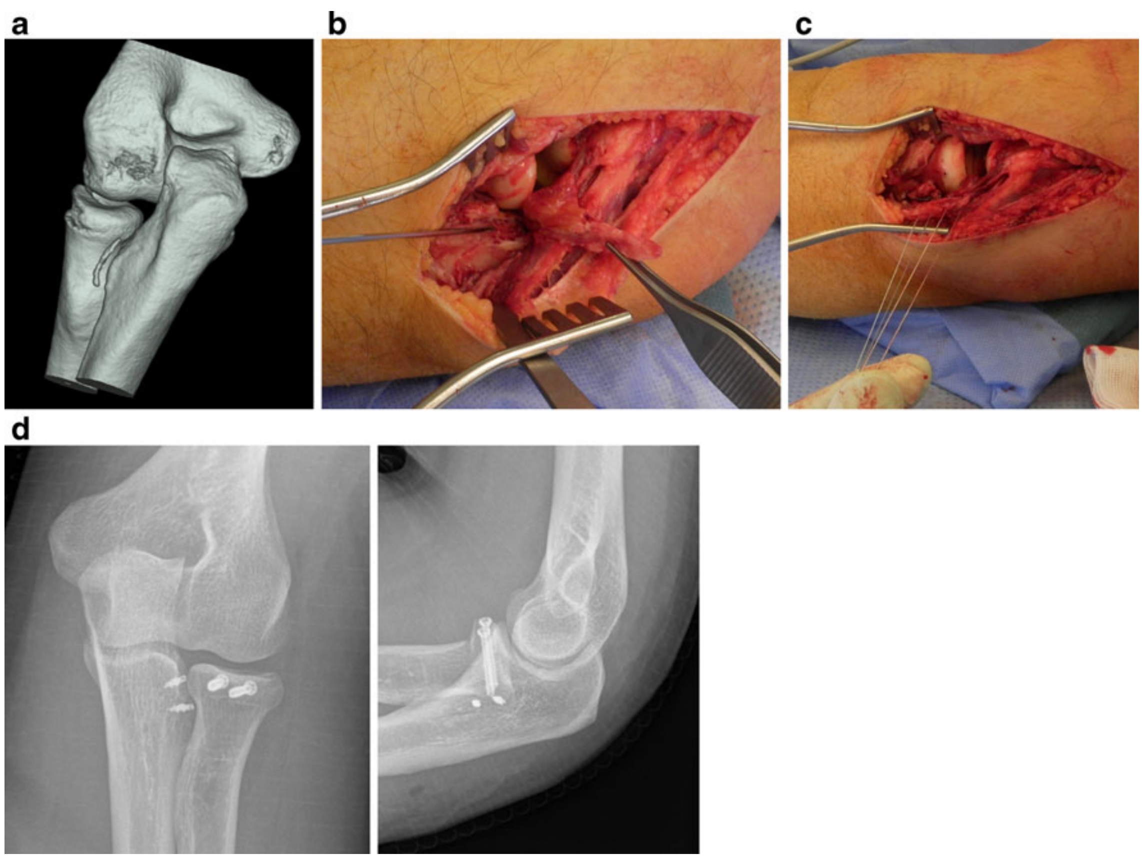

Fig. 5 **a** A 40-year-old male. Fracture of the radial head and supinator crest of the ulna. 3D surface reconstruction. **b** Forceps: fracture fragment of the supinator crest with attaching LUCL. Posterior translation of the radial head and widening of the humeroradial articulation demonstrating the instability. **c** Fixation with screw anchors and fibre wire. **d** Postoperative X-rays display congruent articulation. Radial head fixed with cannulated screws

without radial head replacement, while Beingessner detected lasting posterolateral instability under these conditions [11, 26]. The integrity of the LCL might play a crucial role in bipolar radial head arthroplasty because peak subluxation forces were significantly reduced in ligament-deficient elbows [32]. In our opinion radial head resection is not a valuable option in acute trauma. Radial head excision causes altered elbow kinematics and increased laxity [27]. Concordantly, Leppilahti and Jalovaara found high rates of osteoarthritis at the elbow and wrist five years after radial head resection. In addition, they found proximal radius migration of 1.4-mm mean in 65 % of their patients [33]. Nevertheless we performed radial head resection in one patient (Fig. 2 in this article). Certainly, this patient had low demands and the compliance was of concern (alcohol abuse). There was no evidence for an Essex-Lopresti type injury, and after lateral ulnar collateral ligament repair with a 3.5-mm screw anchor at the supinator crest the humeroulnar articulation was stable in the full arc of motion. To date the patient is doing well with a free active range of motion and without signs of instability.

One limitation of our study is its retrospective nature and the associated cohort heterogeneity. Furthermore, the suspected instability of the elbow can only be verified clinically, not with CT scans. As a consequence we are not able to estimate the association between instability and fragment size or displacement. However, based on pathoanatomic and joint kinematic assumptions, an LCL insufficiency must be expected when the insertion is fractured [9–14, 24–27, 32]. Finally, the distribution of accompanying fractures can only be regarded as a hint because the accompanying injuries, rather than the fracture of the supinator crest, were indications for the CT evaluation. It may be that supinator crest avulsion is also present in simple elbow dislocations; however, in our practice, CT and MRI investigations are not used routinely for these injuries.

The importance of the supinator crest for elbow and proximal radius instability needs to be examined. In our opinion, there is a need for further biomechanical studies, although in-vitro testing of elbow instability does not account for tissue healing and adaptation over time. Therefore, both biomechanical and clinical observations are required to assist with improved characterization of this undescribed fracture fragment and its impact on elbow instability.

Conclusion

To our knowledge, this is the first detailed description of an avulsion fracture of the annular ligament and/or lateral ulnar collateral ligament of the supinator crest of the proximal ulna. Because this fracture was most often present in combination with radial head fractures, we believe that it is the result of a posterolateral subluxation mechanism. CT scans should be evaluated with specific regard to this fragment. If this fragment is diagnosed and clinical examination presents elbow instability, we recommend ligament repair or reconstruction at the ulna if instability persists following treatment of the accompanying injuries.

Conflict of interest The authors declare that they have no conflict of interest.

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