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Most coronoid fractures and fracture-dislocations with no radial head involvement can be treated nonsurgically with elbow immobilization

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Hypothesis: Conservative treatment of isolated coronoid fractures and fracture-dislocations focused on soft-tissue healing can provide good clinical results in the majority of patients. Our aims were (1) to evaluate the outcome of a conservative treatment protocol designed for isolated coronoid fractures with or without associated elbow dislocations (ICFs) and (2) to characterize the fractures with a dedicated image analysis protocol.

Methods: Of 38 consecutive patients sustaining acute ICFs, 28 were treated nonsurgically after meeting specific inclusion criteria, prospectively followed up, and clinically evaluated at least 1 year after sustaining their injuries. All cases underwent elbow computed tomography scans with tri-plane and 3-dimensional reconstructions according to a specific protocol referenced to the proximal ulna.

Results: The study included 15 male and 13 female patients, with a mean follow-up period of 32 ± 14 months (range, 12-61 months). An associated dislocation was presented in 8 (29%). Mean extension and flexion were 2° ± 8° (range, –10° to 30°) and 139° ± 11° (range, 110°-155°), respectively. Mean pronation and supination were 74° ± 3° (range, 60°-75°) and 83° ± 9° (range, 40°-85°), respectively. Of the patients, 78% rated their elbow as being normal or nearly normal. The mean Mayo Elbow Performance Score was 95 ± 9 (range, 70-100). The mean Disabilities of the Arm, Shoulder and Hand score was 7 ± 13 (range, 0-57). The mean coronoid fracture height was 5.7 ± 1.2 mm (range, 3.7-7.9 mm). The mean percentage of coronoid height fractured was 33% ± 6% (range, 23%-43%). Mean fracture displacement was 2.7 ± 2 mm (range, 1-9 mm). Of the fractures, 23 (82%) were located at the anteromedial coronoid.

Conclusion: An ICF with a perfectly reduced ulnohumeral joint, a competent sublime tubercle, and a fractured coronoid height up to 50% can be treated without surgery with excellent or good results in more than 90% of cases regardless of the location of the fracture in the coronoid or the type of soft tissue–associated disruptions.

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In addition to the medial and lateral ligament complexes, the ulnohumeral joint, specifically the coronoid process of the proximal ulna, has been identified as one of the primary constraints to elbow instability.[18] Fractures of the coronoid process are part of different complex elbow instability patterns, in which ligamentous injuries are associated with bone fractures causing a loss of congruency of the ulnohumeral joint.[3,7,11,12,14,22,24,34]

Fractures of the coronoid have been associated with specific injury patterns based on the fractured part of this apophysis and the presence of associated bone and soft-tissue injuries.[5,9] Fractures occurring in the anteromedial facet of the coronoid with no radial head fracture, humeral fracture, or elbow dislocation have been associated with a specific injury pattern termed ''varus posteromedial rotatory instability'' (VPMRI), in which the coronoid fracture presents in conjunction with disruption of both the lateral collateral ligament and the posterior band of the medial collateral ligament.[17] Under varus stress, this combination of injuries may lead to anterior subluxation of the medial humeral trochlea into the coronoid fracture bed, causing progressive cartilage damage and early osteoarthritis.[17,31] Supported by findings of increased joint laxity from biomechanical studies performed in cadaveric elbows simulating such injuries[21,22] and some case reports,[30,31] surgery has been recommended for acute anteromedial coronoid fractures in the setting of posteromedial varus instability.[5,17,24] Proposed surgical procedures indicated for treatment include isolated lateral collateral ligament repair when the fractures affect less than 15% or 2.5 mm of the coronoid, with additional coronoid fixation for larger coronoid fragments.[21,33]

As mentioned earlier, the description of VPMRI injury has led to a greater interest in surgical treatment when the only bone injury found is an isolated coronoid fracture with or without an associated elbow dislocation (ICF).[16,20,24,27,28,32,34] However, unanswered questions remain as to the spectrum of injury patterns that may show as ICFs and the optimal treatment for these conditions. Biomechanical analyses describing more benign consequences of such injuries and studies showing good results without surgery in cases with isolated anteromedial coronoid fractures have been published.[6,11,12,15] In addition, in the clinical setting, ICFs involving the anteromedial coronoid rim are relatively common,[1,2,10,20] but the previous coronoid fracture classification system described by Regan and Morrey,[23] which has been used for decades, failed to recognize the location of such fractures in the coronal plane, and as a consequence, it might have underestimated the occurrence of VPMRI in the past. Despite this possible underdiagnosis, disabling early osteoarthritis as a complication following nonsurgical treatment of such injuries has been reported only anecdotally[30] and also is uncommon in our experience.

When we undertook this research, our conceptual hypothesis was that ICFs may not have deleterious consequences for the elbow joint in a significant proportion of patients when properly treated nonsurgically. Instability is the consequence of a complex interaction between several insufficient structures; therefore, if ligaments and soft tissue heal with the correct tension, as is observed after simple elbow dislocations, the remaining presence of a coronoid insufficiency would not render the elbow unstable unless there is involvement of a substantial part of this bony apophysis. The operational hypothesis of this work was that nonsurgical treatment of ICFs focused on soft-tissue healing can provide good clinical results in a majority of patients, independently of both the injury pattern (VPMRI or other mechanisms) and the location of the coronoid fracture (tip, mid transverse, or anteromedial), even in cases with a significant portion of the coronoid fractured.

This study had 2 primary aims: First, we set out to assess the clinical and radiologic outcome of a nonsurgical treatment protocol designed for ICFs focused on soft-tissue healing. Second, we sought to characterize the coronoid fractures studied using a specific protocol for computed tomography (CT) reconstruction and analysis.

Materials and methods

Cases

Between 2010 and 2015, we prospectively followed up a cohort of 38 consecutive patients who sustained elbow trauma resulting in ICFs. When present, associated dislocations were closely reduced in the emergency department. All elbows were immobilized in a long plaster cast at 90° of elbow flexion and in neutral pronation-supination. Anteroposterior (AP) and lateral elbow radiographs were taken for all cases, including before and after reduction maneuvers, when appropriate.

All cases were subsequently evaluated within the first week by a single fellowship-trained elbow surgeon (A.M.F.). A CT scan was obtained in all cases at the first evaluation if none had been taken during the emergency-department visit. The criteria for conservative treatment and study inclusion were as follows: skeletal maturity, absence of radial head fracture, acute coronoid fracture affecting less than 50% of the coronoid height, preserved

structural competency of the sublime tubercle, perfect ulnohumeral congruity on image tests, and a minimum of 1 year of follow-up. Three patients showed anterior subluxation, a positive drop sign, and/or radiohumeral joint space widening, whereas 2 patients had fractures inside the sublime tubercle. Surgery was offered to these 5 patients, but they preferred to continue with conservative treatment and were included in the study. A total of 30 cases were treated nonsurgically, 2 of which were lost to follow-up before 1 year, leaving 28 patients included in the study. Eight patients not fulfilling the inclusion criteria were treated surgically with a variety of surgical techniques. All treatments were performed by the same investigator (A.M.F.).

Conservative treatment protocol

Conservative treatment was focused on achieving soft-tissue healing, with the specific aim of collateral ligament healing by maintaining the normal distance between ligament insertion sites throughout the healing process. The elbow was immobilized for 3 weeks with a long plaster splint with the elbow at 90° of flexion and in neutral pronation-supination, as well as a commercial sling. The sling was removed every day for range-of-motion shoulder exercises with assistance from the other hand to decrease varus load on the elbow. After splint removal, the elbow was protected in the sling day and night for 3 more weeks; the immobilization system was removed only for self-care, shoulder exercises, and a home-based program of protected range-of-motion exercises for the affected elbow. These exercises consisted of elbow flexion and extension with the forearm in full pronation, as well as pronation-supination exercises at maximum elbow flexion, as tolerated by the patient; both exercises were always performed with the arm at the side of the body to avoid varus stress, in sets of 20 repetitions 3 times a day.

The sling was removed at week 6, after which the patients were allowed to resume basic daily living activities but were instructed to refrain from carrying weights or engaging in sports and to avoid painful activities. A home-based stretching program was also implemented at this time both in flexion-extension and in pronation-supination. Formal physical therapy was implemented only in the 2 cases in which the patients had difficulty recovering motion at week 6 after treatment. At 3 months, the patients were allowed to engage in all types of activity, with the only precaution being to avoid painful activities.

Clinical evaluation

A single investigator (J.C.) not involved in the treatment of the patients interviewed all patients, in person, specifically to gather the clinical data for this study. Age, sex, dominant side, affected side, injury mechanism, previous elbow pathology, and hyperlaxity were recorded. Satisfaction and pain were evaluated with visual analog scales and categorically (satisfaction rated as yes or no and pain only with unusual activities or pain with usual activities). Each patient was required to rate his or her degree of elbow functionality, with 1 indicating ''normal'' functionality; 2, ''nearly normal''; 3, ''useful for the majority of activities''; 4, ''useful only for basic daily living activities''; 5, ''with too many limitations''; or 6, ''useless.'' Elbow and forearm-rotation range of motion, elbow and grip strength, elbow stability (drawer and pivot-shift tests), neurologic symptoms (including radial, median, and ulnar nerves), and elbow and upper-extremity outcome scores (Disabilities of the Arm, Shoulder and Hand score; American Shoulder and Elbow Surgeons score; and Mayo Elbow Performance Score) were recorded. Specific maneuvers were used to overload the involved structures to search for sources of pain. The elbow was moved through a complete arc of motion; signs of anterior or posterior painful impingement were tested with forced flexion and extension, with the forearm in neutral rotation, full pronation, and full supination. Pain through the full arc of motion was also tested with the elbow under valgus stress and varus stress with the shoulder locked in external rotation and internal rotation, respectively, and the forearm in neutral rotation to look for signs of radiocapitellar overload pain and medial ulnohumeral overload pain. (These overload tests resembled the ''moving valgus stress test'' for medial collateral ligament testing[19] but through the full arc of motion, performed with valgus stress, followed by varus stress.)

Radiologic evaluation

Standard AP and lateral elbow radiographs were obtained in the emergency department in all cases, including before and after reduction in cases with associated dislocations. Radiographs were also obtained routinely, at least at weeks 3 and 6, and posteriorly after 3 months, 6 months, and 1 year and then every year during follow-up. A CT scan was performed acutely, and 3-dimensional and tri-plane image reconstructions referenced to the proximal ulna (as described later) were obtained.

Acute radiographs were evaluated in search of signs of ulnohumeral subluxation. The signs indicating this were the drop sign[8] in the lateral view; joint space narrowing on the medial side of the ulnohumeral joint in the AP view; or any irregularity, widening, or narrowing of the joint space at other locations. The same procedure was used to assess the last follow-up radiograph, and signs of osteoarthritis were recorded according to the Broberg and Morrey classification.[4]

An independent musculoskeletal radiologist (B.G.) created tri-plane and 3-dimensional CT reconstructions from raw DICOM (Digital Imaging and Communications in Medicine) files, according to a specific protocol designed for this study. Three axes referenced to the proximal ulna were defined for tri-plane reconstruction and image analysis (Fig. 1): coronoid base axis, proximal long axis of the ulna, and posterior cortical axis. A specific set of variables for image analysis was designed, and the same radiologist independently performed the image evaluation for all patients (Table I, Fig. 2). An intraobserver and interobserver validation study was being finalized at the time this article was submitted for publication.

Coronoid fractures were classified according to the classifications of both Modified Regan and Morrey[2,23] and O'Driscoll et al.[17] Anteromedial facet involvement was established when the fracture included the anteromedial rim of the coronoid process, defined as the portion of the coronoid immediately lateral to the sublime tubercle. The fracture location was considered to be at the tip when there was no involvement of the anteromedial facet of the coronoid (ie, respecting the coronoid portion in continuity with the sublime tubercle).

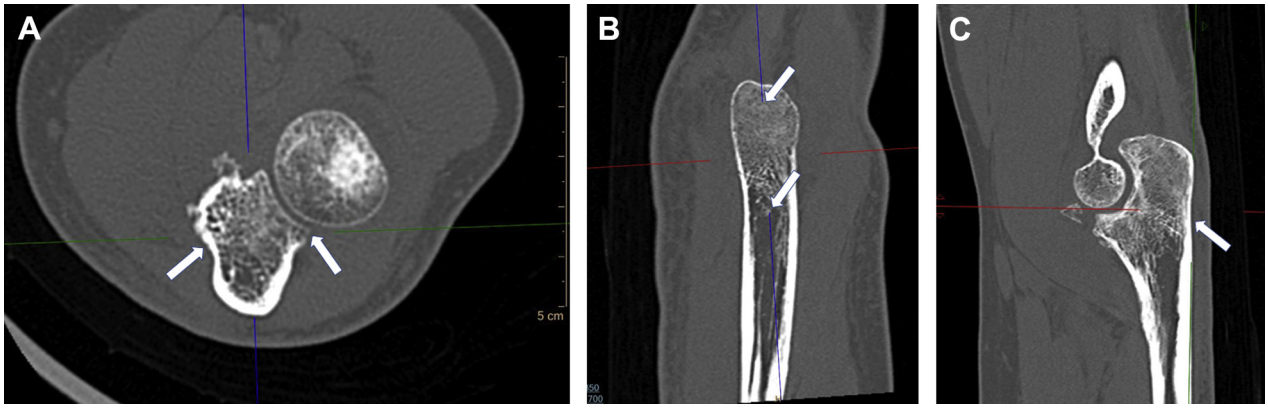

Figure 1 Three axes referenced to the ulna were defined: coronid base axis, interpreted as the line connecting the posterior margin of the ulnar lesser sigmoid nocth (*right arrow*) and the posterior margin of the sublime tubercle (*left arrow*) in a craniocaudal (axial) view, represented in *green* (**A**); proximal long axis of the ulna, considered the line in the center of the medullary canal (superior and inferior arrows) proximal to the anatomic varus angulation of the bone in the anteroposterior (coronal) ulnar view, represented in *blue* (**B**); and posterior cortical axis, defined as the line tangential to the flat posterior cortical bone of the proximal ulna (*arrow*), represented in *green*, in the lateral (sagittal) ulnar view (**C**).

Statistical analysis

Descriptive analysis of our sample was performed with IBM SPSS Statistics software (version 22; IBM, Armonk, NY, USA). As this is a descriptive study, no analytical studies were performed.

Results

A total of 15 male (54%) and 13 female (46%) patients were treated conservatively and evaluated after a mean follow-up period of 32 ± 14 months (range, 12-61 months). The mean age at the time of injury was 40 ± 15 years (range, 17-74 years). Fractures occurred in the dominant arm in 11 patients (39%). Mechanisms of injury included a fall from standing height in 16 patients (57%), a sports-related injury in 11 (39%), and a fall from a horse in 1 (4%). All fractures were closed injuries. Dislocations were documented in 8 patients (29%) (based on radiographs or a history of a reduction maneuver before radiographs were obtained). No patients had a history of problems in the injured elbow. Hyperlaxity in the contralateral elbow manifesting as joint hyperextension was noted in 6 patients (21%).

Clinical outcome

Table II summarizes clinical outcome variables at last follow-up visit. The arc of motion was nearly normal in the vast majority of patients. No signs of frank residual instability were present, and the drawer test was negative in all patients. The pivot-shift maneuver was normal in all cases, although 1 patient felt a click during the test but showed no clear signs of radial head subluxation. The push-up test was painful in 1 patient and another patient felt a click when performing the maneuver, whereas the test results were normal in the rest. When the dominant side was fractured, grip strength was 33 ± 12 kg (range, 20-54 kg), which was 118% of that of the healthy nondominant side (mean, 28 ± 10 kg; range, 18-42 kg). Elbow strength on the injured side was rated 5 of 5 in all directions in all patients, with the exception of 1 patient whose pronation was rated 4 of 5.

Regarding pain, 18 patients (65%) had no pain, 6 (22%) had pain during unusual activities, and 4 (13%) had pain when performing normal activities. Twenty-six patients (93%) were satisfied with their elbow function. Of the patients, 15 (54%) described their elbow as being normal; 8 (28%), nearly normal; and 5 (18%), useful for the majority of activities. Fourteen percent of patients had either a positive Tinel sign of the ulnar nerve (1 case) or occasional paresthesia in the region of the ulnar nerve (1 case) or had both (2 cases). No symptoms of permanent ulnar nerve sensitivity or radial or median nerve symptoms were encountered. The Mayo Elbow Performance Score showed an excellent result in 22 cases (79%), good result in 4 (14%), and fair result in 2 (7%). The injuries sustained by patients with poor outcomes did not show any specific feature compared with those of patients with good results.

In 4 patients (14%), elbow surgery was required during follow-up. One patient had post-traumatic stiffness and was treated with arthroscopic release with prophylactic ulnar nerve decompression and postoperative continuous passive motion. One patient had residual posterolateral rotatory instability and was treated with isolated lateral collateral ligament reconstruction with allograft and a docking technique, with no procedures performed on the coronoid fracture. It is interesting to note that this patient showed anterior ulnohumeral subluxation on the initial CT scan (but declined surgical treatment); in addition, during treatment of the acute injury, he discontinued adhering to

Table I Image test evaluation performed using simple radiographs and CT scans

Variable name	Definition
Elbow radiographs (initial and last follow-up visit)	
AP view	
1. Ulnohumeral joint space	Medial joint space narrowing
2. Instability	Trochlear and ulna subchondral bone parallelism
3. Osteoarthritis	Broberg and Morrey classification
Lateral view	
4. Dislocation	True ulnohumeral joint dislocation
5. Instability	Presence of drop sign; lack of perfect parallelism of articular surfaces (ulna, humerus, radius); or double-crescent sign
6. Osteoarthritis	Broberg and Morrey classification
Elbow CT scan reconstructions	
Axial reconstructions	
7. Preserved area	Area of nonfractured coronoid subchondral bone, anterior to the base of the coronoid
8. Fractured area	Area of the fractured coronoid subchondral bone
9. Fracture location	Anteromedial, tip, or anterolateral coronoid (subjective evaluation, with the assistance of 3D reconstructions)
10. Fracture inclination	Angle formed by the base of the coronoid and the line connecting the entry and exit points of the fracture
11. Fracture bed shape	Concave, convex, or neutral
Sagittal reconstructions	
12. Fragment height	Greater height of the fractured coronoid subchondral bone
13. Preserved coronoid height	Height of the intact coronoid as a perpendicular of the posterior ulnar flat cortical bone, measured from the deepest aspect of the greater sigmoid notch
14. Fracture displacement	Greater displacement between the subchondral bone fragment and that of the intact coronoid
15. Ulnohumeral instability	Joint space from the ulnar to humeral subchondral bone in 3 points: 1. Most anterior preserved coronoid margin 2. Most posterior olecranon joint surface margin 3. Middle point Lack of perfect apposition of the articular surfaces (parallelism)
Coronal reconstructions	
16. Ulnohumeral instability	Joint space from the ulnar to humeral subchondral bone in 3 points: 1. Most medial preserved coronoid margin 2. Most lateral preserved coronoid margin 3. Middle point Lack of perfect apposition of the articular surfaces (parallelism)
17. Radiohumeral instability	Joint space from the radial to humeral subchondral bone in 3 points: 1. Most medial radial head margin 2. Most lateral radial head margin 3. Middle point
3D reconstructions	
18. Overall assessment	Subluxation Sublime tubercle involvement Fracture line orientation No. of fragments

CT, computed tomography; *AP*, anteroposterior; *3D*, 3-dimensional.
Each variable number corresponds with the image numbering in Figure 2.

the immobilization period and removed his splint before the scheduled time. Both factors may have played a role in the lateral collateral ligament healing failure. Furthermore, 2 patients underwent arthroscopic débridement because of persistent pain; one had anterior pain with maximum flexion, and the other had a distal and posterior capitellar impaction fracture leaving a step that interfered with full extension. The final results of all 4 patients were satisfactory, but the outcomes before surgery were included in the overall outcomes described earlier.

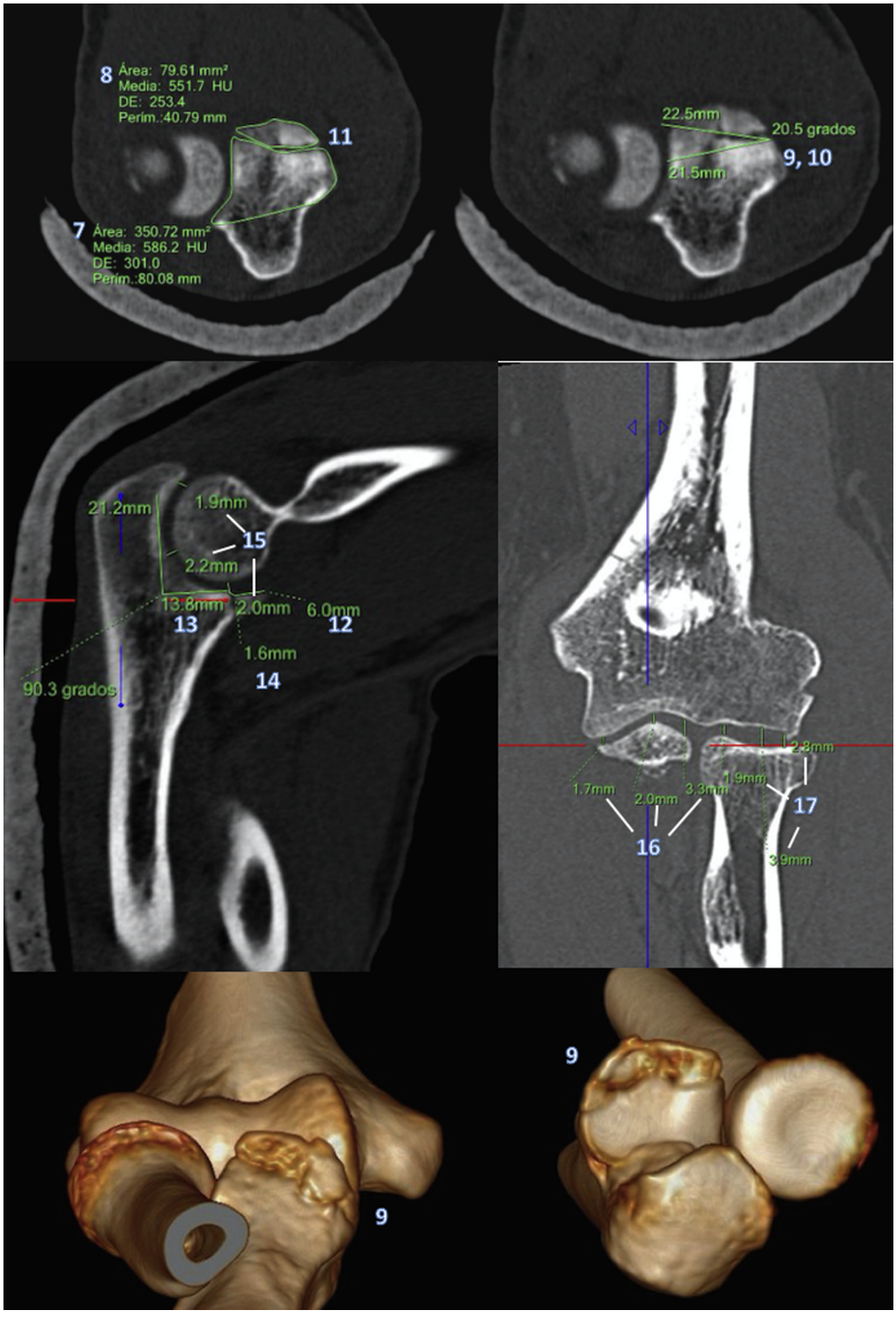

Figure 2 Examples of measurements performed in computed tomography scan reconstructions created from raw data and referenced to axes depicted in Figure 1. *White numbers* correspond to the variables described in Table I.

Radiologic evaluation

Table III shows results of the evaluations performed at initial and final follow-up, consisting of simple AP and lateral radiographs. Table IV shows measurements and evaluations performed on CT reconstructions. Three-dimensional and tri-plane reconstructions were used to classify the fractures. According to the modified Morrey classification,[2] all were considered mid transverse. According to the O'Driscoll classification,[17] 5 (18%) were considered "tip" fractures;

Table II Final clinical results (including postoperative follow-up of 4 patients requiring surgery during follow-up)

Variable	Data
Pain VAS score, mean ± SD (range)	0.9 ± 1.5 (0-5.8)
Satisfaction VAS score, mean ± SD (range)	8.6 ± 1.8 (3.2-10)
Flexion, mean ± SD (range), °	139 ± 11 (110-155)
Extension, mean ± SD (range), °	2 ± 8 (−10 to 30)
Pronation, mean ± SD (range), °	74 ± 3 (60-75)
Supination, mean ± SD (range), °	83 ± 9 (40-85)
DASH score, mean ± SD (range)	7 ± 13 (0-57)
MEPS, mean ± SD (range)	95 ± 10 (70-100)
Pain with extreme extension (posterior impingement)	
Yes	0
No	28 (100%)
Pain with extreme flexion (anterior impingement)	
Yes	0
No	28 (100%)
Pain in mid arc of motion	
Yes	0
No	28 (100%)
Valgus moving stress	
Yes	3 (11%)
No	25 (89%)
Varus moving stress	
Yes	2 (7%)
No	26 (93%)

VAS, visual analog scale; *SD*, standard deviation; *DASH*, Disabilities of the Arm, Shoulder and Hand; *MEPS*, Mayo Elbow Performance Score. The DASH score is scored from 0 to 100, with 0 being the best score. The MEPS is scored from 0 to 100, with 100 being the best score.

1 (3.5%), anteromedial subtype 1 (involvement of only the anteromedial portion); 21 (75%), anteromedial subtype 2 (involvement of anteromedial portion and tip); and 1 (3.5%), anteromedial subtype 3 (involvement of anteromedial portion, tip, and >50% of sublime tubercle).

Discussion

The results of this work demonstrate that the majority of ICFs can be treated nonsurgically. However, strict criteria should be used when selecting patients for conservative treatment because of the potential implications of treatment failure, including persistent instability and early progressive osteoarthritis. Figure 3 presents our current treatment algorithm for ICFs. The treatment approach is based on CT scan images obtained with the elbow immobilized at 90°: When there is perfect ulnohumeral articular surface apposition and the sublime tubercle is structurally competent, fractures involving up to 50% of the height of the coronoid, including those located in its anteromedial margin, can be safely treated conservatively, offering excellent or good results in more than 90% of patients. Maintaining a concentric joint reduction over time restores soft-tissue competency, so a remaining unhealed coronoid fracture as an isolated deficiency (as occurred in more than one-third of our cases) is not enough to destabilize the joint, resulting in a stable, pain-free, functional elbow independently of the initial injury pattern. During initial evaluation of these injuries, we do not use acute dynamic fluoroscope imaging because all these patients have unstable elbows and their level of instability becomes evident under image intensifier testing. Such instability is not what guides our treatment; rather, our approach is based on whether we are able to maintain a congruent joint over time for purposes of soft-tissue healing, thus restoring stability.

Following completion of our 6-week treatment protocol, the elbow should be closely examined to monitor for lateral collateral ligament competency (drawer and pivot-shift tests), and varus-overload tests of the full arc of motion should be performed to test for scratching sensations or pain due to persistent VPMRI. When there is doubt regarding the existence of persistent VPMRI, proper diagnosis should involve all means possible, including a follow-up CT scan, dynamic fluoroscopy, or even diagnostic arthroscopy, to fully understand the underlying problem and change the indication of treatment accordingly. Although none of our patients presented such signs of persistent VPMRI, we did detect lateral collateral insufficiency in 2 patients, who were then treated with isolated lateral collateral ligament reconstruction with good outcomes (1 did not complete the specific examination for this study and was thus excluded from the sample, although he was followed up by the treating author [A.M.F.]).

Follow-up radiographic images showed a 36% rate of coronoid nonunion, medial space narrowing in 32% of cases in the AP view, and a double-crescent image in 25% of cases as evidenced on lateral radiographs. None of these findings correlated with pain, range of motion, strength, satisfaction, or function, and on the basis of our study results, we believe they should not be used for treatment decision making in the acute setting (in which we use CT scans) or follow-up.

Our image test analysis suggests that ICFs can be the consequence of different injury mechanisms resulting in posterior displacement of the ulna in combination with valgus, varus, and/or rotatory torques, leading to different ligamentous injuries. Isolated anteromedial coronoid fractures have been the focus of multiple articles because of their association with VPMRI and the potential these injuries have to generate early and severe osteoarthritis.[3,5,17,21,22,24,26,30,31] However, we present evidence that anteromedial facet coronoid fractures do not necessarily lead to subluxation or disabling osteoarthritis when proper conservative treatment is performed. There are 2 possible coexisting explanations for these findings: (1) VPMRI can be successfully treated by targeting only the soft-tissue injury (either through a conservative approach or surgically), and (2) isolated fractures of the anteromedial facet of the coronoid process can be caused by mechanisms other than VPMRI. The first explanation is

Table III Simple radiographic variables characterizing injuries

Variable for elbow radiographic analysis	Data
Initial AP view, no/yes	
Medial UH space narrowing	24 (86%)/4 (14%)
Lack of continuous medial ulnar subchondral bone	24 (86%)/4 (14%)
Initial lateral view, no/yes	
Anterior UH space narrowing	27 (96%)/1 (4%)
Double-crescent sign	21 (75%)/7 (25%)
Lack of continuous anterior ulnar subchondral bone	24 (86%)/4 (14%)
Drop sign	27 (96%)/1 (4%)
Last follow-up radiographs, no/yes	
Coronoid consolidation	10 (36%)/18 (64%)
Medial UH space narrowing (AP view)	19 (68%)/9 (32%)
Lack of continuous medial ulnar subchondral bone	24 (85.7%)/4 (14%)
Anterior UH space narrowing (lateral view)	28 (100%)/0
Lack of continuous anterior ulnar subchondral bone	18 (64%)/10 (36%)
Presence of double-crescent sign (lateral view)	21 (75%)/7 (25%)
Drop sign (lateral view)	28 (100%)/0
Broberg and Morrey osteoarthritis classification at last follow-up	
No osteoarthritis	14 (50%)
Slight narrowing and/or minimal osteophytes	11 (39%)
Moderate narrowing and osteophytes	3 (11%)

AP, anteroposterior; UH, ulnohumeral.
Initial elbow radiographs are those taken in the emergency department, as well as after dislocation reduction when pertinent.

Table IV CT scan variables characterizing injuries

Variable for elbow CT scan reconstruction analysis	Mean ± SD or n	Range
Axial reconstructions		
Preserved area, mm^2	272 ± 49	191-372
Fractured area, mm^2	65 ± 28	21-109
% of fractured area	19 ± 7	7-35
Medial fracture inclination referenced to coronoid base	12° ± 8° of medial inclination	0°-27°
Medial	22	
Neutral	6	
Fracture and sublime tubercle		
Fracture exits far from sublime tubercle	9 (32%)	
Fracture exits at margin of sublime tubercle	17 (60%)	
Fracture exits inside sublime tubercle	2 (7%)	
Medial fracture bed shape		
Concave	12 (43%)	
Neutral	14 (50%)	
Convex	2 (7%)	
Sagittal reconstructions		
Fragment height, mm	5.7 ± 1.2	3.7-7.9
Preserved coronoid height (referenced to base of coronoid), mm	11.8 ± 1.3	9.1-13.8
% height fractured	33 ± 5.8	23-43
Fracture displacement, mm	2.7 ± 2	0.9-8.9
UH instability, sagittal plane		
No	26 (93%)	
Anterior subluxation	2 (7%)	
Posterior humeral impaction fracture		
No	11 (40%)	
Lateral	11 (40%)	
Medial	6 (20%)	
Coronal reconstructions		
UH instability, coronal plane		
No	25 (90%)	
Medial ulnohumeral space narrowing	3 (10%)	

CT, computed tomography; *UH*, ulnohumeral.

supported by the fact that 18 of our cases (64%) did not present with dislocations and sustained coronoid fractures located at the anteromedial facet; of these, 3 had an impaction fracture on the posteromedial trochlea, and in 2 of these 3, the medial coronoid fracture bed was concave, thus indicating a likely true VPMRI beyond any doubt. The second explanation is supported by the fact that 5 anteromedial coronoid fractures were associated with true elbow dislocation, 3 of them with a posteromedial trochlear impaction fracture, representing a posteromedial dislocation. In addition, we found 6 anteromedial facet fractures without documented dislocation but presenting with posterolateral humeral impaction fractures, pointing to a posterolateral mechanism in which the anteromedial coronoid fracture was the result of posterolateral forearm rotation after lateral collateral ligament disruption, exposing the medial coronoid to fracture against the medial trochlea instead of slipping under it, which would have resulted in a simple dislocation. The exact mechanism of injury and injury pattern for each case in this study are unclear at this point, as fluoroscopic examination or magnetic resonance imaging tests would have been necessary to respond to this question. Other authors have proposed elbow instability patterns other than the classic posterolateral rotatory (simple dislocation and terrible-triad) and posteromedial rotatory (varus posteromedial) instability,[13,25,29] supporting the theory of alternative elbow instability injury mechanisms and patterns. Figure 4 presents the distribution of radiologic findings throughout our sample according to the presence of dislocation or according to fracture location, representing the variety of mechanisms mentioned earlier.

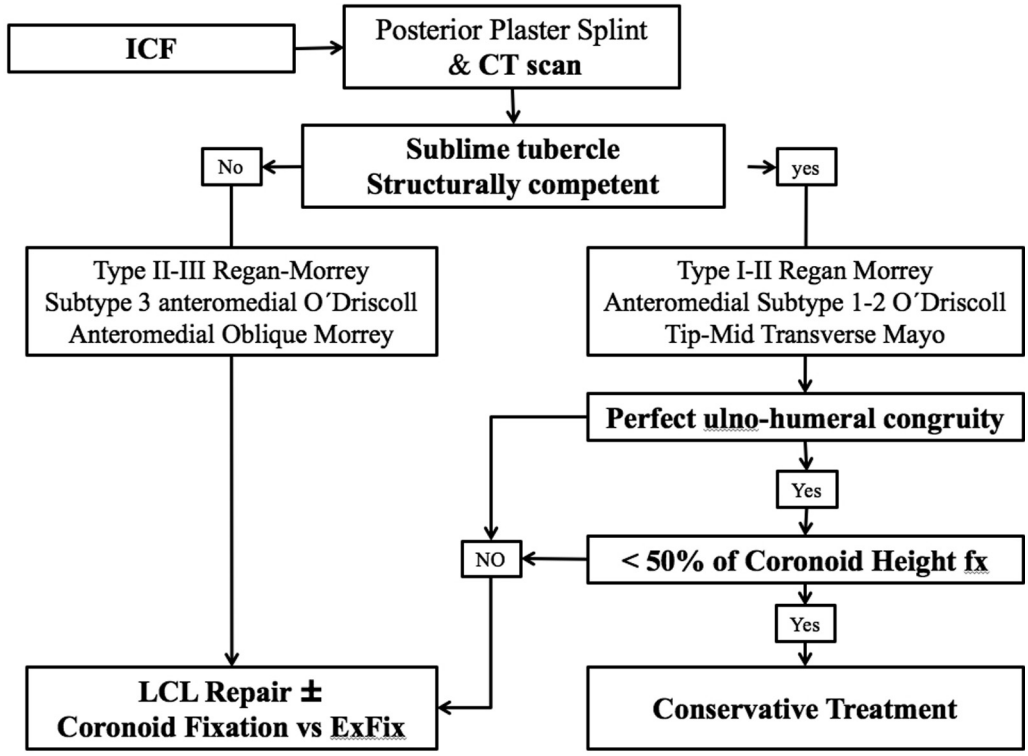

Figure 3 Treatment algorithm for ICFs. The elbow is immobilized in a cast at 90° of flexion with neutral forearm rotation. A computed tomography (*CT*) scan is obtained. If the sublime tubercle is fractured and incompetent (fully separated from the ulna or >50% fractured and displaced), surgery is indicated. If perfect ulnohumeral congruity is lost in any direction or extent, surgery is indicated. If 50% or more of the height of the coronoid process is fractured and displaced, surgery is indicated. *ICF*, isolated coronoid fracture with or without an associated elbow dislocation in the absence of a radial head or humeral fracture other than posterior humeral impaction injuries resulting from dislocations; *Fx*, fracture; *LCL*, lateral collateral ligament; *ExFix*, external fixation.

One limitation of this study concerns the relatively modest size of the patient cohort included; to our knowledge, however, this is the largest study undertaken to date involving consecutive isolated coronoid fractures and fracture-dislocations treated conservatively. Our investigation features a midterm follow-up (up to 5 years), although the good results of conservative treatment may not be maintained over time. Radiographs showed degenerative changes in a proportion of patients, and these could also increase over time. Our treatment protocol requires prolonged time off work or time away from sport activities, which may not be easily accepted by patients who require an early return to function. Finally, several injury patterns with different prognoses may be included in this sample; although this could be considered a limitation, we believe that this aspect makes the cohort more representative of current clinical practice and useful for clinical decision making.

Conclusion

This study provides empirical support for conservative treatment as a baseline for the majority of patients with isolated coronoid fractures and fracture-dislocations, regardless of the location of the fracture in the coronoid or the type of soft tissue–associated disruptions. To safely establish this treatment indication, CT scans after splint immobilization must show perfect ulnohumeral articular surface apposition, a structurally intact sublime tubercle, and a fracture involving up to 50% of the height of the coronoid. Future studies are needed to further characterize the associated spectrum of soft-tissue injuries and better understand the variety of injury patterns involved in ICF occurrence.

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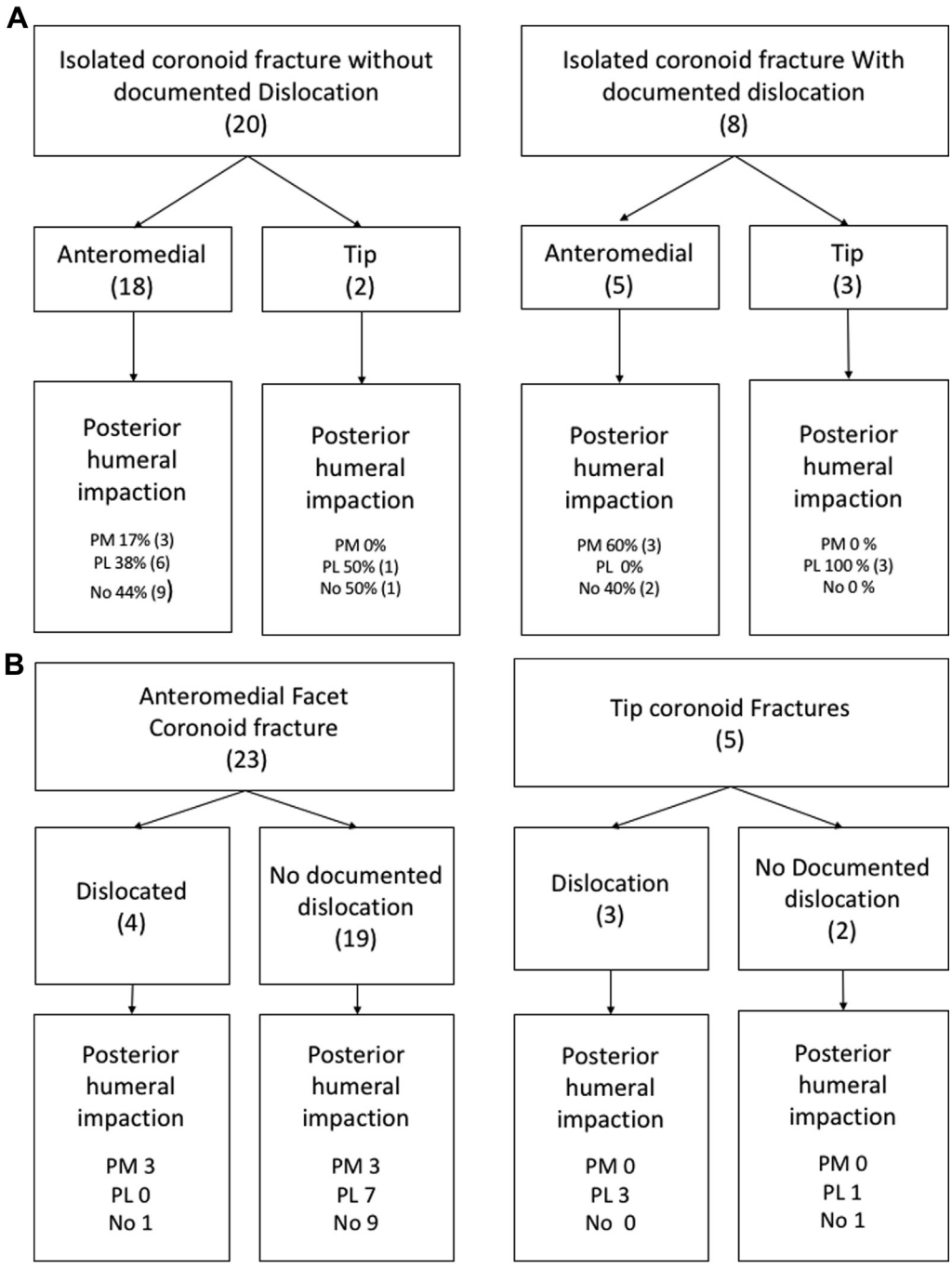

Figure 4 Representation of distribution of radiologic findings throughout our sample according to the presence of dislocation (**A**) or fracture location (**B**). *PM*, Posteromedial; *PL*, Posterolateral.

Disclaimer

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