The types and prevalence of soft tissue constraint injuries associated with complex elbow instability have been rarely investigated. The purpose of this study was to analyze the intraoperative findings of soft tissue constraint injuries in complex elbow instability and provide a comprehensive classification of these lesions. Forty-seven patients undergoing surgery for complex elbow instability were prospectively analyzed. Ligament injuries were classified as simple or complex lesions, depending on whether the ligament was damaged at a single zone or 2 to 3 zones, including its proximal, middle, and distal portions. Posterolateral capsule injuries were classified as small or large in the presence of capsular avulsions smaller than or larger than 1 cm, respectively. The presence of lesions of the common extensor and flexor–pronator muscles were also recorded. Ligament injuries were found in 96% of patients. The lateral collateral ligament showed a simple lesion, including a proximal and distal avulsion, in 19% and 2% of patients, respectively, and a middle-zone tear in 13%. Complex lesions, including the association of a middle-zone tear with a proximal or distal avulsion, were found in 47% and 6% of patients, respectively, and a combination of proximal, distal, and middle-zone injuries in 4%. Small and large posterolateral capsule lesions were found in 49% and 17% of patients, respectively. A medial collateral ligament injury was present in 45% of patients. A high prevalence of soft tissue constraint lesions was found to be associated with complex elbow instability. Soft tissue constraint status should be carefully evaluated pre- and intraoperatively in patients with complex elbow instability. The classification reported herein may be helpful in planning the proper treatment of these complex injuries.
Complex elbow instability consists of 1 or more osteoarticular fractures associated with capsular, ligamentous, and muscle-tendinous injuries leading to a loss of elbow stability.\textsuperscript{1-4} They include severe injuries of the upper limb requiring challenging reconstructive surgeries, the results of which may be unpredictable.\textsuperscript{5-8}

The stability of the elbow joint is provided by primary stabilizer structures, including soft tissue constraints (ie, lateral and medial collateral ligaments) and bony constraints (ie, coronoid process, olecranon, and humeral trochlea), which equally contribute to elbow stability.\textsuperscript{9,13} Secondary stabilizers of the elbow are the radiohumeral joint, anterior and posterior joint capsule, and epitrochlear and epicondyle muscle-tendinous units.\textsuperscript{9,10,14,15} Elbow instability occurs when 2 or more primary stabilizers of the joint are injured; it may further worsen when lesions of secondary stabilizers are associated.\textsuperscript{2,3,9,11}

Although soft tissue constraint injuries are a consistent finding in complex elbow instability,\textsuperscript{1,4} little is known about the pathoanatomic changes of soft tissue constraint structures associated with complex elbow instability. In the only retrospective study on lateral ligamentous damage in elbow dislocations, the authors did not distinguish between ligaments damage found in simple and complex elbow instabilities.\textsuperscript{16} Two other studies documented medial collateral ligament injuries in simple elbow dislocations, but the series analyzed did not include patients with complex elbow instability.\textsuperscript{17,18}

The purposes of the current prospective study were to analyze the prevalence and pathoanatomic features of soft tissue constraint lesions found intraoperatively in patients with complex elbow instability and to design a comprehensive classification of these injuries.

**Materials and Methods**

According to Italian law, the authors were not required to ask for institutional review board or ethical committee approval for this type of study. However, each author certifies that his or her institution approved the human protocol for this study and that the study was conducted in conformity with ethical principles of research.

Between January 2005 and December 2008, forty-seven patients underwent surgery for complex elbow instability. Patients with previous injuries or elbow surgeries were excluded. The patients included 24 men and 23 women with a mean age of 54.6 years (range, 22-75 years). Twenty-seven injuries were the result of a fall from a standing height, 11 the result of a motor vehicle accident, 5 the result of a fall from a greater height, and 4 the result of sports activities. The left arm was involved in 24 patients and the right in 23. Preoperative diagnosis included a Monteggia-like lesion in 17 patients, a terrible triad in 13, a comminuted radial head fracture associated with posterior elbow dislocation in 6, a capitulum humeri and trochlea fracture with posterior dislocation in 6, a coronoid fracture associated with posterior dislocation in 3, and a transolecranon fracture–dislocation in 2.

Patients with elbow dislocation underwent closed reduction and spica cast immobilization in the emergency department. No patient had an irreducible dislocation. High-quality radiographs and computed tomography (CT) scans, including 2- and 3-dimensional reconstructions, were obtained in all cases. Surgical treatment was performed a mean of 3 days (range, 1-7 days) after trauma. All surgeries were performed by a single surgeon (G.G.) in a 1-step procedure. No patient had multiple injuries or open fractures requiring further surgical procedures or temporary stabilization with external fixation. A posterior or extended posterolateral skin incision was used in all patients. The Kocher interval was used to expose the lateral compartment while an over-the-top approach or, alternatively, the elevation of flexor–pronator muscles from the subcutaneous and medial border of the ulna was accomplished to expose the medial compartment. In all patients, the lateral compartment was exposed, and the presence of any injury involving the common extensor origin, lateral collateral ligament complex, and posterolateral joint capsule was identified. Medial collateral ligament status was assessed in all patients with intraoperative valgus–pronation stress testing at 30\(^\text{\circ}\) of flexion under fluoroscopy; a medial collateral ligament tear was diagnosed when the medial joint space increased more than 2 mm during the test.\textsuperscript{19} In patients with persistent elbow instability after open reduction and internal fixation and lateral compartment reconstruction, the medial compartment was exposed and the status of flexor–pronator origin and medial collateral ligament directly visualized. The medial compartment was also exposed for internal fixation of anteromedial coronoid fractures.

Soft tissue injuries observed intraoperatively were jointly assessed by 2 operating surgeons (G.G., G.C.) and recorded with a digital camera. The collected images were then reassessed by 3 orthopedic surgeons (F.M.S., S.G., A.G.) who were not present at the surgery.

Intraoperative findings showed that lateral collateral ligaments and medial collateral ligaments were injured in different zones of the ligament, including their proximal, middle, and distal portions. Because such injuries occurred as either isolated or joint lesions, they were classified as simple (ie, a single zone was damaged) or complex lesions (ie, injury involved 2 or 3 portions of the same ligament). Simple lesions were subclassified into 3 types: type P (proximal), a lesion located within 1 cm from its humeral insertion; type M (middle-zone), a lesion located 1 cm or more distal to its humeral origin or proximal to its ulnar insertion; and type D (distal), a lesion located within 1 cm from its ulnar insertion. In some patients, a bony avulsion was found to be associated with the ligament injury. It usually involved, on
the lateral side, the lateral epicondyle or the supinator crest and, on the medial side, the inferior part of medial epicondyle and sublime tubercle. When the avulsed bone fragment was larger than 5 mm, it was recorded as BF (bone fragment). As a result, types P and D were further classified as type P-BF and D-BF when associated with a detached bone fragment.

Complex lesions included a combination of simple lesions: type PM (type P+type M), a proximal avulsion associated with a middle-zone lesion; type DM (type D+type M), a distal avulsion associated with a middle-zone lesion; and type PMD (type P+type M+type D), an entirely torn ligament. Type PM and DM were further classified as PM-BF and DM-BF when associated with a bone fragment.

Posterolateral capsule injuries were classified as small or large, depending on whether the capsular detachment from the posterolateral aspect of the distal humerus adjacent to the lateral collateral ligament origin was smaller than or larger than 1 cm, respectively. Posterolateral capsule lesions were further classified as type small-BF and large-BF when associated with an avulsed bone fragment smaller or larger than 5 mm. To describe injuries of common extensor and flexor–pronator muscle origin, the criteria of McKee et al were used; these injuries were diagnosed in the presence of a lack of tendon continuity greater than 50%. Because the medial compartment was exposed only in patients in whom the medial collateral ligament or anteromedial coronoid fracture was reconstructed, the type of injury of flexor–pronator origin was assessed in only these patients. The types of injuries included in the soft tissue constraint classification are shown in Figures 1 through 3.

Statistical Analysis

Inter- and intraobserver reliability of classification was assessed in 25 randomly selected patients by 3 surgeons who were asked to classify each soft tissue constraint injury based on intraoperative images. Three weeks later, a second evaluation was performed; the order of initial images was randomly changed to generate a new sequence. Data were collected on spreadsheets and the κ coefficient was used to assess agreement.20

RESULTS

Ligament lesions were found in 45 (96%) patients. In the remaining 2 (4%) patients, both of whom had a transolecranon fracture–dislocation, no ligament injury occurred. Two patients with a Bado I Monteggia-like lesion had an isolated annular ligament injury. In one of these patients, the annular ligament torn was interposed in the proximal radioulnar joint, preventing the reduction of the radial head. In the other patient, a middle-zone lesion in the anterior portion of the annular ligament was observed.

Lateral Collateral Ligament Injuries

Lateral collateral ligament tears were found in 43 (91%) patients. Proximal avulsions were found in 31 (66%) patients (Figures 4, 5); 7 (15%) were type P, 22 (47%) were type PM, and 2 (4%) were type P-BF. In all cases, the proximal avulsion was associated with a posterolateral capsule lesion.

Lateral collateral ligament type M lesions were found in 6 (13%) patients and type D in 1 (2%). The latter was associated with a bony avulsion of the supinator crest and thus classified as type D-BF (Figure 6). A type DM lesion was observed in 3 (6%) patients. A type PMD disruption of the lateral collateral ligament was observed in 2 (4%) patients (Figure 7). The prevalence of lateral collateral ligament lesions found in different complex elbow instability patterns is shown in Table 1.

Medial Collateral Ligament Injuries

Medial collateral ligament tears were noted under fluoroscopy in 21 (45%) patients. In 6 (29%) of these patients, the medial collateral ligament was exposed intraoperatively, showing an avulsion from its humeral origin in 4 (19%) cases. The remaining 2 (10%) patients exhibited a ligament avulsion from its ulnar insertion, associated in 1 (5%) case with a sublime tubercle fragment. In all 6 patients, the lesion was classified as complex because a concomitant middle-zone tear was found. As a result, 4 (19%) cases were classified as type PM (Figure 8), 1 (5%) as type DM, and 1 (5%) as type DM-BF. Medial collateral ligament tears were observed more frequently in terrible triads (61%), distal humerus shear fracture–dislocations (67%), and coronoid fracture–dislocations (66%) than in other complex elbow instability patterns (Table 2).

Posterolateral Capsule, Common Extensor, and Flexor–Pronator Muscle Origin Injuries

Posterolateral capsule lesions were observed in 31 (66%) patients. They were classified as small in 23 (74%) cases, large in 7 (23%), and large-BF in 1 (3%) (Figure 9). Large posterolateral capsule lesions were always associated with anconeus detachment from the humeral insertion. Posterolateral capsule lesions were observed more frequently in terrible triads (69%) and Monteggia-like lesions (70%) than in other complex elbow instability patterns. Injuries of the common extensor muscle origin were present in 10 (21%) patients and were always associated with complex lateral collateral ligament lesions (Figure 7). This lesion was observed more frequently in terrible triads (54%) than in other complex elbow instability patterns. The flexor–pronator muscle origin was damaged in 2 (33%) of the 6 cases assessed intraoperatively. The frequency of medial collateral ligament, posterolateral capsule, common extensor, and flexor–pronator muscle origin injuries found in different complex elbow instability patterns is shown in Table 2.

The interobserver reliability of classification was good, with a κ value of 0.72.
(range, 0.56-0.82), whereas the intraobserver reliability was excellent, with a $\kappa$ value of 0.85 (range, 0.78-0.94).

**DISCUSSION**

Although the presence of soft tissue constraint lesions may increase the complexity of reconstructive surgery and compromise the surgical outcomes in patients with complex elbow instability, little is
known about their prevalence and pathoanatomic features. McKee et al16 retrospectively analyzed the operative records of 62 elbow injuries, including simple and complex elbow instabilities, and reported 6 patterns of pathoanatomical lesions. The most frequent type of lateral collateral ligament injury observed was a proximal avulsion (52%), followed by a midsubstance rupture (29%) and a humeral condylar avulsion fracture (8%). Common extensor origin disruptions and medial collateral ligament tears were observed in more than half of cases, and distal soft tissue avulsions, proximal ulnar avulsions, and a combined pattern of the previous types were found in 12% of cases. However, the authors did not distinguish between the results of patients with simple and complex elbow instabilities or report what type of complex elbow instability was present. In addition, the intraoperative findings may have been biased by the long time interval between trauma.

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**Figure 3:** Classification of posterolateral capsule (PLC) and muscle-tendinous origin injuries. Abbreviations: BF, bone fragment; CEO, common extensor origin; FPO, flexor–pronator origin.

**Figure 4:** Intraoperative photograph of lateral compartment exposed through the Kocher interval showing a lateral collateral ligament type P lesion. The detached origin of the lateral collateral ligament is raised by the clamp. The middle zone of the lateral collateral ligament is intact (arrowhead). The extensor carpi ulnaris muscle (asterisk) and anconeus muscle (double asterisk) are shown.

**Figure 5:** Intraoperative photograph of lateral compartment exposed through the Kocher interval showing a lateral collateral ligament proximal avulsion associated with a middle-zone tear, classified as type PM. The clamp raises the detached origin of the lateral collateral ligament. The middle-zone tear (arrowheads), radial head (arrow), and lateral epicondyle (asterisk) are shown.

**Figure 6:** Intraoperative photograph of lateral compartment exposed through the Kocher interval showing a lateral collateral ligament distal avulsion, classified as type D-BF. The clamp raises the detached insertion of the lateral collateral ligament. The radial head (arrow), bony avulsion of the supinator crest (arrowhead), and lateral epicondyle (asterisk) are shown.

**Figure 7:** Intraoperative photograph of lateral compartment exposed through the Kocher interval showing a complete disruption of the lateral collateral ligament (type PMD) with a concomitant rupture of the common extensor tendon. The radial head (arrow), common extensor tendon injury (arrowheads), and lateral epicondyle with proximal lateral collateral ligament avulsion (asterisk) are shown.
and surgery (average, 15 days; range, 1-76 days). Nevertheless, to the authors’ knowledge, no other studies have reported intraoperative findings or pathologic changes involving soft tissue constraint structures in patients with complex elbow instability. The current study reports elbow soft tissue constraint injuries observed in a large series of patients with complex elbow instability. Each lesion was evaluated intraoperatively by 2 orthopedic surgeons and thereafter reassessed on digitalized images by 3 independent examiners.

The results showed that the lateral collateral ligament complex was the soft tissue structure most frequently injured; it was found to be damaged in all but 2 patients. Conversely, medial collateral ligament tears were observed in approximately half of the cases. Only 2 patients in this series, both of whom had transolecranon fracture-dislocations, had no soft tissue constraint lesions present, confirming that, in these injuries, ligament damage is

| Table 1 | LCL Complex Lesions for Each Pattern of Complex Elbow Instability |
| Complex Elbow Instability Pattern | Type P | Type M | Type D | Type PM | Type DM | Type PMD | Total |
| Terrible triad (n=13) | 1 | 1 | 1BF | 8 | 0 | 2 | 13 |
| Radial head fracture-dislocation (n=6) | 1 | 2 | 0 | 3 | 0 | 0 | 6 |
| Monteggia-like lesion (n=17) | 5 (1BF) | 1 | 0 | 7 | 2 | 0 | 15 |
| Distal humerus shear fracture-dislocation (n=6) | 1 | 2 | 0 | 2 | 1 | 0 | 6 |
| Transolecranon fracture-dislocation (n=2) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Coronoid fracture-dislocation (n=3) | 1BF | 0 | 0 | 2 | 0 | 0 | 3 |
| Total | 9 | 6 | 1 | 22 | 3 | 2 | 43 |

Abbreviations: BF, bone fragment; D, distal; DM, distal-middle zone; LCL, lateral collateral ligament; M, middle zone; P, proximal; PM, proximal-middle zone; PMD, proximal-middle zone-distal.

| Table 2 | CEO, MCL, and PLC Lesions for Each Pattern of Complex Elbow Instability |
| Complex Elbow Instability Pattern | CEO | MCL | PLC±Small | PLC±Large | Total |
| Terrible triad (n=13) | 7 | 8 | 4 | 5 | 24 |
| Radial head fracture-dislocation (n=6) | 2 | 2 | 3 | 1BF | 8 |
| Monteggia-like lesion (n=17) | 0 | 5 | 11 | 1 | 17 |
| Distal humerus shear fracture-dislocation (n=6) | 0 | 4 | 3 | 0 | 7 |
| Transolecranon fracture-dislocation (n=2) | 0 | 0 | 0 | 0 | 0 |
| Coronoid fracture-dislocation (n=3) | 1 | 2 | 2 | 1 | 6 |
| Total | 10 | 21 | 23 | 8 | 62 |

Abbreviations: BF, bone fragment; CEO, common extensor origin; MCL, medial collateral ligament; PLC, posterolateral capsule.

**Figure 8:** Intraoperative photograph of medial compartment exposed through the Hotchkiss approach showing a medial collateral ligament proximal avulsion associated with a midsubstance tear, classified as type PM. The clamp raises the detached origin of the medial collateral ligament. The medial collateral ligament reversed (arrowhead), medial epicondyle (asterisk), and flexor carpi ulnaris (double asterisk) are shown.

**Figure 9:** Intraoperative photograph taken after posterior exposure of the elbow and after ulnar osteosynthesis in a Monteggia-like lesion. The posterolateral capsule is detached from the posterolateral aspect of the humerus with a bone fragment. This lesion was classified as posterolateral capsule-large-BF lesion. The posterolateral aspect of the humerus (asterisk) and posterolateral capsule with bone avulsion (arrowhead) are shown.
rare and osteosynthesis of an ulnar fracture is usually sufficient to restore elbow joint stability.\(^1\)\(^2\)\(^4\)\(^11\)\(^22\)

In contrast with a previous investigation,\(^16\) the current authors found that complex ligament lesions (ie, 2 or 3 portions of the same ligament damaged) were present in a relevant percentage (57%) of patients with complex elbow instability. For example, in lateral collateral ligament injuries, a proximal or distal avulsion was associated with a tear of the middle zone of the ligament in 73% of cases. Complex ligament lesions should be distinguished from simple ligament injuries, in which an isolated portion of the ligament is disrupted, because they usually require a more complex reparative surgery.\(^23\)

Based on this assumption, the authors designed a comprehensive classification of the different types of soft tissue constraint injuries. In particular, in addition to simple lesions of the collateral ligaments (types P, M, and D),\(^16\) complex ligament lesions (types PM, DM, and PMD) are also classified because they are likely to require different reconstructive procedures. For example, when the lesion is located more than 1 cm from ligament insertions (ie, in the middle zone of the ligament), a side-to-side suture is usually indicated, whereas in the presence of a ligament tear occurring within 1 cm from its insertion, a bony reinsertion technique should be used. The classification also includes the presence of bony avulsions greater than 5 mm because, in that case, a different ligamentous repair technique may be needed.\(^23\)

Lateral collateral ligament injuries were distinguished from posterolateral capsule lesions, and the latter were further classified into small and large lesions because they usually require different treatments. Small posterolateral capsule lesions are easily repairable during lateral collateral ligament reinsertion at the epicondyle and further treatments are rarely necessary, whereas large posterolateral capsule lesions often require specific surgical procedures, including the positioning of suture anchors on the posterior aspect of the capitellum or on the lateral border of olecranon.\(^23\) Large posterolateral capsule lesions were also found to be associated, in all cases, with anconeus detachment. Because the anconeus muscle is a secondary stabilizer of the elbow,\(^14\)\(^24\)\(^25\) it should be repaired when the lateral collateral ligament is severely damaged, a condition that was frequently observed in the current series.

Several studies have reported the clinical and biomechanical relevance of secondary stabilizers of the elbow, including capsule and common extensor and flexor origin muscles.\(^9\)\(^10\)\(^14\)\(^15\)\(^2\) The entity of muscular damage has been correlated with the tendency to redislocate under anesthesia,\(^18\) and flexor–pronator muscle mass plays a role in elbow valgus stability.\(^14\) In the current series, a common extensor origin tear was observed in 21% of cases. It was always accompanied by a posteromedial lesion of the lateral collateral ligament and by a posterolateral capsule injury, suggesting that lateral soft tissue constraints are likely to be detached sequentially from the lateral condyle during a posterolateral dislocation.\(^16\)

In the current series, soft tissue constraint injuries showed a different prevalence in each pattern of complex elbow instability. Medial collateral ligament tears were observed more frequently in terrible triads, humeral shear fracture–dislocations, and coronoid fracture–dislocations. Posterolateral capsule lesions were observed more frequently in terrible triads and Monteggia-like lesions, whereas common extensor origin injuries were more frequent in terrible triads than in other complex elbow instability patterns. However, such differences were not statistically significant, likely due to the limited sample size, which did not allow definitive conclusions to be drawn.

This study had some limitations. A relatively small number of patients was reported for each complex elbow instability pattern. Furthermore, because the medial collateral ligament was explored intraop-

eratively only when necessary (eg, when elbow instability persisted after reconstruction of the lateral collateral ligament complex), data on the types and severities of medial collateral ligament injuries are incomplete and need to be further investigated. However, this is the first study prospectively analyzing the pathoanatomy of acute soft tissue constraint lesions in patients with complex elbow instability. In addition, because a short time interval occurred between trauma and surgery, it was possible to identify several pathologic changes involving elbow soft tissue constraint not previously described.

**CONCLUSION**

Complex elbow instability is considered a challenging condition, even for expert elbow surgeons. The diagnosis of a lesion involving primary and secondary elbow constraints, which may be encountered in complex elbow instability, is crucial to performing an accurate joint reconstruction and planning an adequate rehabilitation program.\(^1\)\(^4\) A comprehensive and reproducible classification of these injuries may be useful to guide surgeons in the reconstruction of soft tissue constraints of the elbow joint and to compare the results of different surgical techniques. Further studies with larger series of patients are needed to evaluate whether the reported classification may achieve these goals.

**REFERENCES**


