SCIENTIFIC ARTICLE

An Online Video Investigation Into the Mechanism of Elbow Dislocation

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Purpose Acute elbow instability leading to dislocation is thought to be a spectrum initiated by an injury to the lateral stabilizing structures of the elbow. Previous cadaveric studies have shown elbow dislocations to occur in flexion. The purpose of this study was to analyze videographic evidence of the deforming forces and upper extremity position during elbow dislocations. We sought to corroborate previous biomechanics studies with *in vivo* observations.

Methods We included 62 YouTube.com videos with a clear videographic view of an elbow dislocation. Three senior elbow surgeons independently evaluated arm position at the time of dislocation, along with the suspected deforming forces at the elbow based on these positions.

Results Of the 62 visualized elbow dislocation events, the vast majority (92%) dislocated at or near full extension. The most common arm positions were forearm pronation (68%) with shoulder abduction (97%) and forward flexion (63%). The typical elbow deforming forces were a valgus moment (89%), an axial load (90%), and progressive supination (94%). We identified 4 discrete patterns of arm position and deforming forces.

Conclusions Acute elbow dislocations *in vivo* occur in relative extension irrespective of forearm position, a finding distinct from previous cadaveric studies. The most common mechanism appears to involve a valgus moment to an extended elbow, which suggests a requisite disruption of the medial collateral ligament, the known primary constraint to valgus force. These videographic findings suggest that some acute elbow dislocations may result from acute valgus instability and therefore are distinct in nature and mechanism from posterolateral rotatory instability. This information could lead to improved understanding of the sequence of structural failure, modification of rehabilitation protocols, and overall treatment. *(J Hand Surg 2013;38A:488–494. Copyright © 2013 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Diagnostic IV.

Key words Elbow dislocation, injury mechanism, posterolateral rotatory instability, video.

Much of what we currently know about the mechanism of elbow dislocation is based on either reported patient history or theoretical, cadaveric, or radiographic models.[1–4] Asking patients to reliably recall the position of the arm and hand during a fall is difficult, and video and film records of elbow dislocation are sporadic and few. However, with the expansion and increasingly pervasive nature of the Internet and digital media, it is progressively easier to record and share videographic evidence of musculosk-

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eletal injuries. The Web site YouTube.com is the third most visited Web site on the Internet globally, with over 100 billion page views.[5] It provides an ever-increasing library of publicly shared videos that can be useful for obtaining information on *in vivo* positioning and physiologic loading at the time of injury. This was recently used in the orthopedic literature in an ankle fracture analysis to bridge the divide between extrapolations made from controlled cadaveric studies and real-life injuries.[6]

The classic teaching of a hyperextension mechanism of elbow dislocations lacks convincing literature support.[2] A more recent contribution by O'Driscoll et al[3,4] describes the spectrum of posterolateral rotatory instability (PLRI) leading to eventual elbow dislocation. In this hypothesized mechanism, the patient falls on an outstretched hand, producing axial compression and flexion at the elbow joint. The body then rotates internally on the elbow (external rotation of the forearm on the humerus), resulting in progressive elbow external rotation. As flexion and external rotation progress, the elbow typically experiences a valgus moment produced by the hand being lateral to the body's center of gravity (shoulder abduction). This combination of axial compression, external rotation, flexion, and valgus moment produces a progressive disruption of the stabilizing ligaments of the elbow from lateral to medial, thereby facilitating dislocation. The pathoanatomy is referred to as the Horii circle. The lateral ulnar collateral ligament (LUCL) is first disrupted, followed by other lateral ligamentous structures. The circle progresses to sequentially disrupt the anterior and posterior capsule, followed by posterior and finally anterior fibers of the medial collateral ligament (MCL). The result is a proposed spectrum of clinical pathology from elbow instability (PLRI) to frank dislocation.

Although PLRI remains a well-accepted model of elbow instability, other findings suggest that the sequence of soft tissue disruption may begin medially.[7–10] Given the controversy in the literature regarding the mechanism of acute elbow dislocations, we proposed an *in vivo* observational study evaluating upper extremity positions in patients with videographically documented elbow dislocations on YouTube.com. We also sought to identify the deforming forces acting upon the elbow in an attempt to evaluate the proposed mechanisms and patterns predicted by different dislocations models.

MATERIALS AND METHODS

We obtained an institutional review board exemption before commencing the study. We accessed the Web site YouTube.com on September 2, 2011, and searched combinations of the term "elbow" with "dislocate," "dislocating," or "dislocated." We reviewed all videos for depiction of a clearly nonphysiologic elbow motion sustained during a sporting event. We chose for review only videos showing an apparent elbow dislocation with clear videographic views of shoulder, elbow, and forearm positions.

We recorded demographic data including sport, sex, laterality, and level of competition. Three senior elbow surgeons reviewed the videos and recorded the positions of the arm at the time of injury. Because of the measurement error inherent in this type of data acquisition, joint position was categorized broadly. We defined shoulder position as being abducted or adducted and assessed flexion relative to the coronal plane of the body (extension, neutral, flexion, or hyperflexion). Forearm position was graded as supinated or pronated, and elbow position as extended, flexed up to 45°, 45° to 90°, or greater than 90°. We also recorded the deforming forces at the elbow joint (axial, varus, or valgus).

We defined the deforming force at the elbow as the presence or absence of axial load, making a distinction between a valgus moment (elbow lateral to the body's center of gravity) and varus moment (elbow medial to the body's center of gravity). We defined an external event to include an extrinsic force to the elbow (eg, opponent's body falling onto a planted arm, such as tackling in football or an arm-bar in the martial arts); we defined a self-induced event as a simple fall onto an outstretched arm.

After video review, we used the elbow dislocation events with universal consensus among reviewer evaluation. If a consensus was not obtained among all 3 reviewers, the video was eliminated from the final data analysis. We used chi-square test to analyze categorical proportions.

RESULTS

The search query produced a total of 873 unique videos. The reviewers initially chose for analysis 77 high-quality videos with clearly visualized elbow dislocation events. Of the 77 videos, 15 did not receive universal consensus evaluation or were deemed inadequate by 1 or more of the reviewers and were eliminated, which resulted in 62 videos included in the final data set. Table 1 shows demographic results of analyzed videos. All but 1 captured dislocation event occurred in male athletes.

Of the 62 visualized elbow dislocation events, the most common position was shoulder abduction (97%; n = 60; $P < .001$) and forward flexion (63%; n = 39;

TABLE 1. Demographics of Dislocation Events

Sport	Events	Laterality	Events	Competition Level	Events
Wrestling	29	Right	33	Professional	12
Skateboarding	9	Left	29	Collegiate	4
Martial arts	7	Total	62	Amateur	46
Football	6			Total	62
Basketball	4				
Weightlifting	3				
Rugby	2				
Gymnastics	1				
Rollerblading	1				
Total	62				

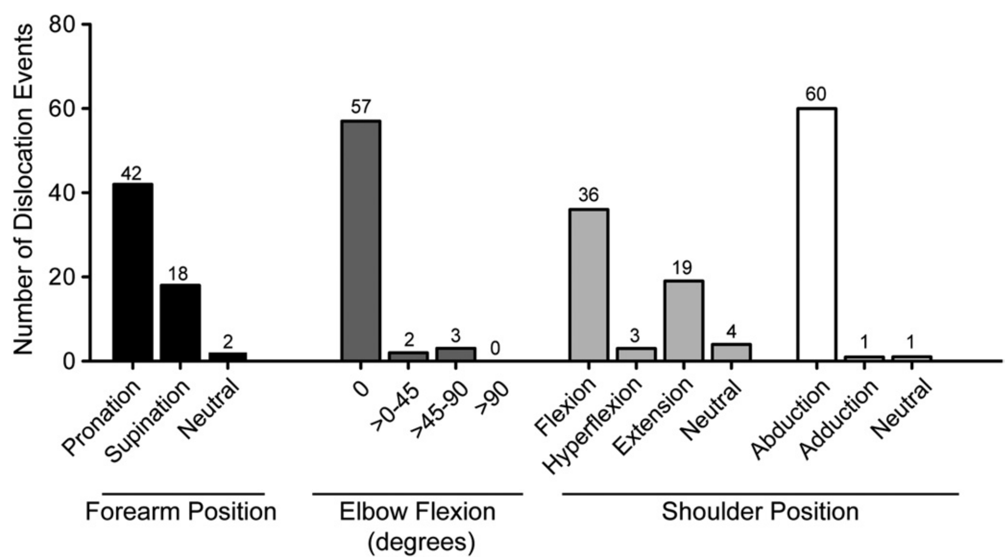

FIGURE 1: Position of forearm, elbow, and shoulder at the time of dislocation.

$P < .008$) with the elbow in full extension (92%; $n = 57$; $P < .001$) and the forearm in pronation (68%; $n = 42$; $P < .002$) (Fig. 1). The mechanism involved a valgus moment (89%; $n = 55$; $P < .001$) combined with axial compression (90%; $n = 56$; $P < .001$) at the elbow (Fig. 2). Most commonly, the body was internally rotating (94%; $n = 58$; $P < .001$) on a planted forearm, resulting in progressive external rotation of the entire forearm (independent of the relation of the radius on the ulna) relative to the humerus. After viewing the video records, we observed 4 distinct patterns of injury (Table 2).

We also identified sport-specific injury patterns. Pattern I (Fig. 3A) accounted for the elbow dislocation mechanism in 86% of wrestlers and 67% of football players. By contrast, 90% of inline skating dislocations occurred via pattern II (Fig. 3B). Pattern III was visible in all dislocations incurred by weightlifters (Fig. 3C).

DISCUSSION

Most elbow dislocations in our series resulted from an axial load, external rotation, and valgus moment acting upon an extended elbow (Fig. 4). These forces are consistent with the mechanism of PLRI. However, although external rotation was generally subtle, we commonly noted a gross valgus deformity immediately after loading regardless of forearm position. The anterior bundle of the MCL (AMCL) has been shown biomechanically to be the most important soft tissue constraint to valgus instability.[2,11–15] This suggests that failure of the AMCL may be necessary before joint dislocation occurs in at least some dislocations. In these

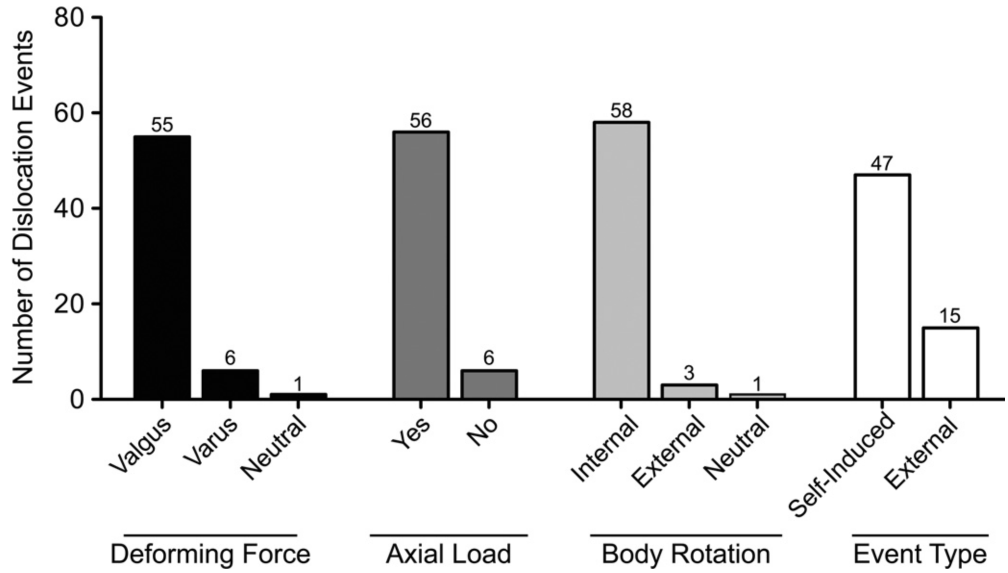

FIGURE 2: Forces acting upon the elbow joint at the time of dislocation. Body rotation is expressed as the rotation of the trunk and humerus relative to the forearm. Self-induced events were defined as a fall onto an outstretched arm; external events included an extrinsic force assisting in deformation of the elbow joint.

TABLE 2. Patterns of Elbow Dislocation Mechanism

Pattern	Shoulder Position	Elbow Position	Deforming Force	No. (%)
I	Flexion-abduction	Pronation-extension	Axial/valgus	33 (53)
II	Extension-abduction	Supination-extension	Axial/valgus	16 (25)
III	Hyperflexion-abduction	Pronation-extension	Axial/valgus	3 (5)
IV	Flexion-abduction	Flexion	Varus (extrinsic)	4 (6)

cases, the progressive soft tissue disruption may be in contradistinction to the Horii model.

O'Driscoll et al[4] showed that posterior dislocations could be produced in cadaveric specimens with an intact AMCL and inferred that soft tissue disruption begins laterally. However, there is literature support that soft tissue disruption may begin medially. Another cadaveric dislocation study showed that AMCL rupture (80%) was significantly more common than LUCL rupture (20%).[7] Josefsson et al[8] evaluated 31 patients under anesthesia after acute elbow dislocations and found all patients unstable to valgus stress in extension and only 26% unstable to varus stress, with no direct PLRI evaluation. Epidemiologic studies have shown most elbow dislocations to be in a posterolateral direction, which further implies a requisite medial disruption resulting from a valgus moment.[9] Finally, a recent magnetic resonance imaging study evaluated ligamentous injury and bony contusion patterns after acute elbow dislocations. Both suggest a medial-sided origin of instability.[10]

Another discrepancy highlighted by these videographic observations is the degree of elbow flexion during dislocation, which was found to be 69° (range, 50° to 86°) in a cadaveric study,[4] an elbow position seen in only 5% of video-captured events. We propose that the discrepancy can be because the AMCL was left intact in the cadaveric study. Although that study demonstrated that it is possible to dislocate the elbow while preserving the functional integrity of the AMCL, the extreme valgus deformity observed *in vivo* would likely produce disruption of the AMCL.

Chronic PLRI from LUCL disruption has been extensively described and is well accepted.[3,4,16] It can be posttraumatic or may result from isolated lateral deficits such as iatrogenic injury after steroid injections or inadvertent damage during radial head resection. Insufficiency of the LUCL allows for a rotatory subluxation of the elbow joint because of external rotation of the entire forearm relative to the humerus. Patients with chronic instability have evidence of an injured LUCL on magnetic resonance imaging and on direct inspection during

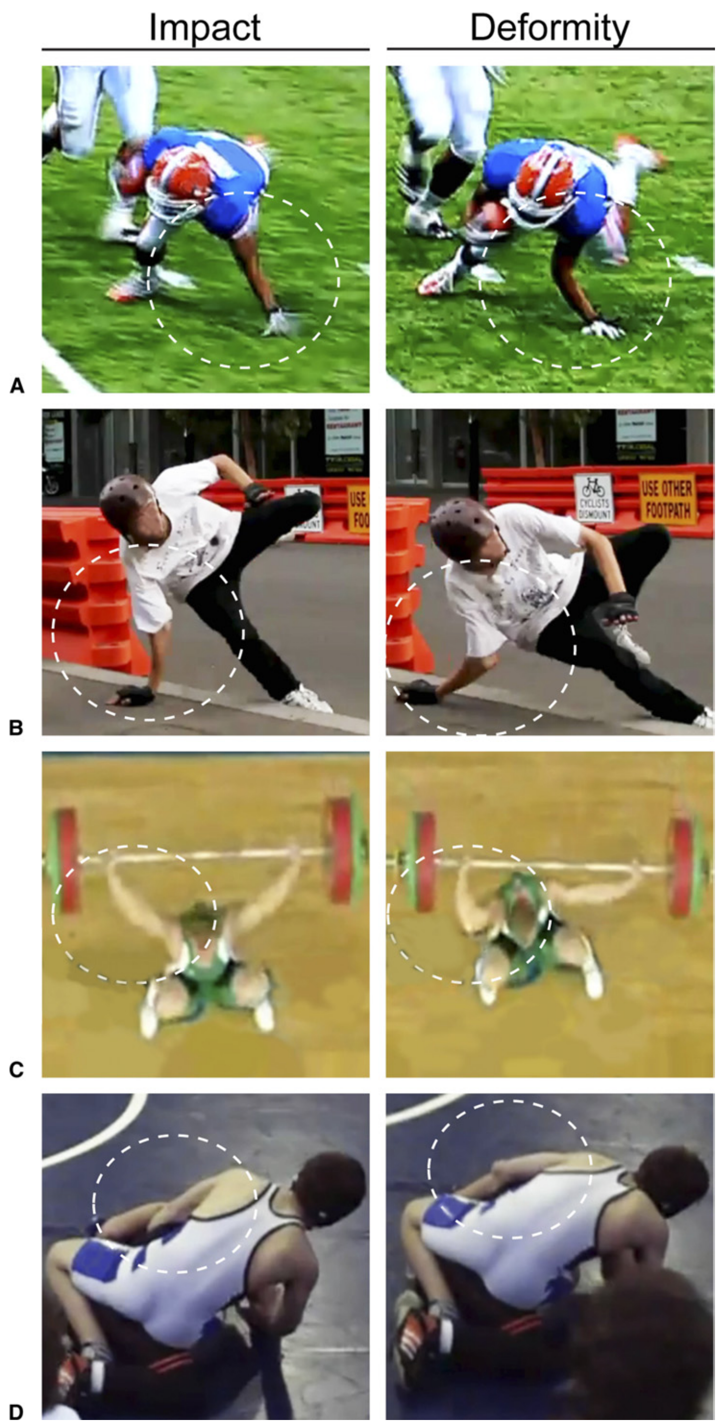

FIGURE 3: Dislocation patterns identified. **A** Pattern I: pronated forearm with axial and valgus moment to extended elbow, shoulder flexion, and abduction, body internally rotating on forearm (n = 33). **B** Pattern II: deforming forces as in **A** externally rotated forearm, and extended shoulder (n = 16). **C** Pattern III: as in **A** with shoulder hyperflexion (n = 3). **D** Pattern IV: (extrinsic) varus moment to flexed elbow (n = 4).

surgical exploration.[17] More important, surgical repair eliminates the instability.[3,17]

The presence of PLRI after acute elbow dislocations may not be the result of isolated lateral ligamentous injury. The PLRI may occur regardless of the sequence of ligamentous injury because of differences in healing between the LUCL and the MCL. Physical therapy after elbow dislocation often begins with the patient seated upright, the shoulder slightly abducted, and the forearm in a variety of positions.[18] Shoulder abduction

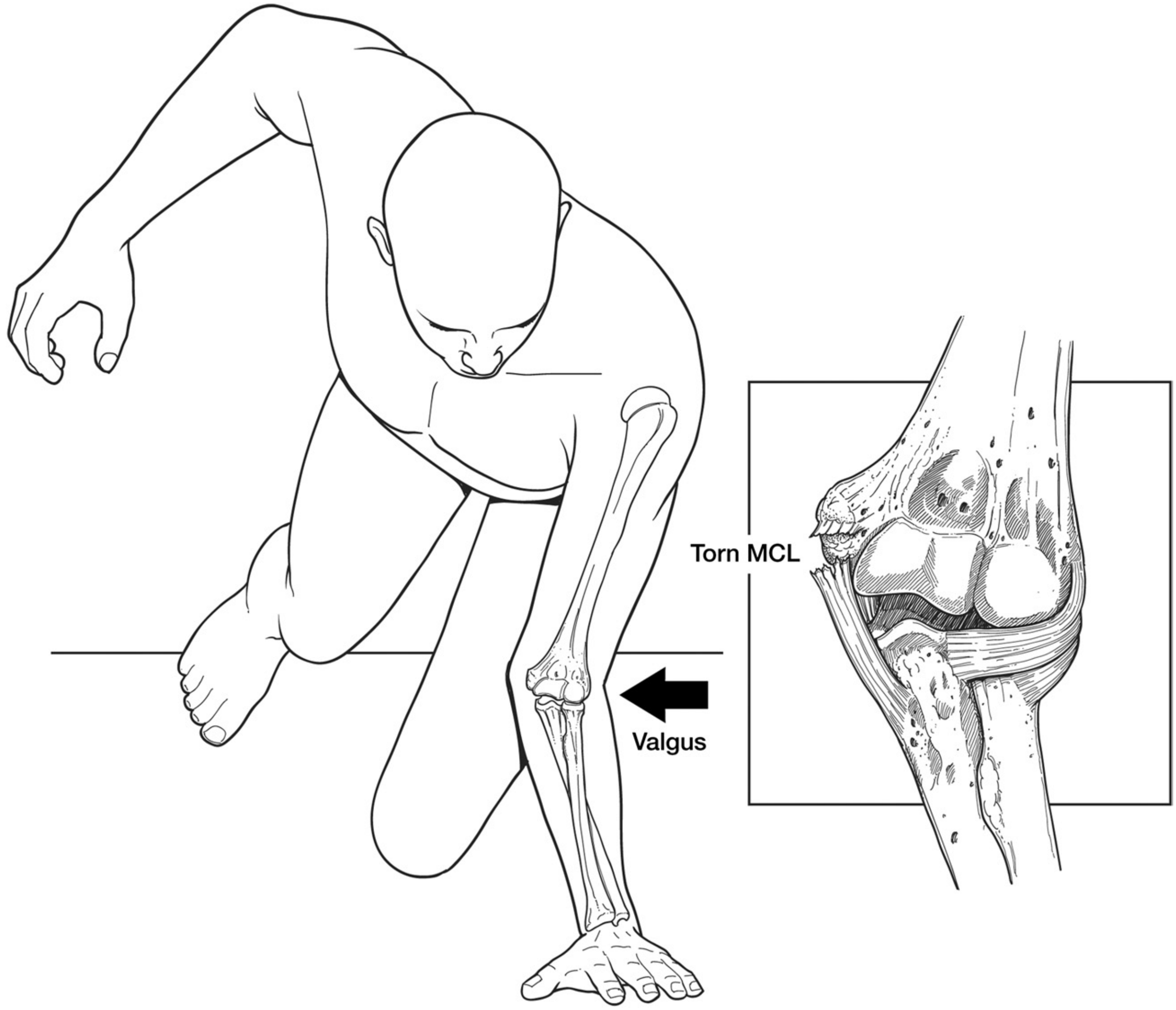

FIGURE 4: Arm position and deforming force of typical elbow dislocation mechanism. Valgus and axial forces are apparent at the elbow joint with the elbow extended and forearm pronated. Resultant damage to the medial collateral ligament is visible.

creates a varus moment at the elbow, producing strain at the LUCL. This may lead the LUCL to heal in a relatively lengthened position or simply not fully reattached at the humeral origin, thereby potentially resulting in PLRI. By contrast, MCL injuries do not typically require surgical repair and may go clinically unnoticed. The same varus and supination force creating laxity on the lateral side closes down the medial side, allowing the MCL to heal in an isometric fashion. Furthermore, human elbows infrequently experience valgus load during normal daily functions, which makes the medial side an uncommon initiator of chronic instability.

Our results highlight the difference between intrinsic and extrinsic forces at the elbow. Pattern IV dislocation events deviate from the norm as a result of extrinsic forces (eg, intra-athlete contact in football) overcoming the innate stability of the elbow and producing a unique dislocation mechanism.

There are several limitations of this study. Although we included only videos with strong videographic evidence of elbow dislocations, we lack radiographic proof of dislocation or knowledge of associated fractures. The difficulty of formally recruiting patients for inclusion in a YouTube.com study was previously documented in an ankle fracture mechanism study.[6] Their successful recruitment rate for obtaining radiographs was only 6% (15 of 240) because of difficulty locating patients and patient skepticism. Our attempt to contact individuals posting videos also proved difficult. Although all videos were self-described as dislocations, our clinical knowledge was limited to media reports documenting pure dislocations in high-profile athletes, along with occasional patient documentation of radiographs and reduction. Given our methods and criteria, we did not require radiographic correlations for inclusion.

There was also variability in video quality and inherent subjectivity in video analysis, which resulted in elimination of 8 videos because of insufficient resolution and 7 videos because of a lack of consensus evaluation. Previous studies have used video analysis to objectively evaluate mechanisms of ankle injuries,[19] head injuries,[20] and shoulder dislocations.[21] Others have shown that video analysis is both reliable and reproducible for studying injuries.[22]

Despite limitations, this study explores a unique modality for evaluation of the *in vivo* mechanism of elbow dislocations. YouTube.com provides a repository of videos that can be used to objectively confirm our knowledge of injury mechanics that were previously largely based on patient histories, surgical findings, or cadaveric models. We showed that the typical elbow dislocation occurs through an extended elbow that sustains a combined axial load, external rotation, and deforming valgus moment. Based on the elbow deformity and degree of flexion involved, we suggest that the anterior bundle of the MCL may occasionally be the initial site of soft tissue disruption. This implies that some acute elbow dislocations may result from acute valgus instability and therefore are distinct in nature and mechanism from PLRI. Future investigations exploring the progression of soft tissue disruption are required to definitively distinguish between these 2 models. Nonetheless, these *in vivo* data contribute to our knowledge of elbow dislocation mechanisms, which may prove useful in implementing preventive measures. Improved understanding of the sequence of structural failure may also lead to modification of rehabilitation protocols and affect overall treatment.

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