Stability of severely stiff elbows after complete open release: treatment by ligament repair with suture anchors and hinged external fixator

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Background: Instability is a crucial issue in severe post-traumatic elbow stiffness during complete-release surgery. This study aimed to evaluate the efficacy of ligament repair using a suture anchor in the operative treatment of severely stiff elbows for which a hinged external fixator was indicated.

Methods: We retrospectively reviewed 46 cases of severely stiff elbows (flexion arc <60°) undergoing open release. During the operation, all 46 elbows were noted to have instability. Suture anchors were applied to restore the ligament if it was impossible to repair the ligament directly, and a hinged external fixator was simultaneously applied to protect the vulnerable ligament and facilitate rehabilitation. No allograft or autograft was used in any of our cases. The stability, arc of motion, Mayo Elbow Performance Score, ulnar nerve symptoms, and radiographs were evaluated.

Results: At a mean follow-up of 24.3 months, the postoperative Mayo Elbow Performance Score was 91 points, as compared with 63 points preoperatively. The mean flexion arc improved from 25° to 126°. Three patients presented with moderate elbow instability when the hinged external fixator was removed; however, all of them regained stability by the last follow-up. Furthermore, 7 cases of new-onset nerve palsy were noted; however, all of them resolved with conservative management. None of the patients required secondary surgery for any reason.

Conclusions: Repair of an avulsed collateral ligament with suture anchors and hinged external fixation was effective in restoring functional mobility in patients with severe post-traumatic elbow stiffness after complete release. This could be an option for treating ankylosed, severely or very severely stiff elbows.

Level of evidence: Level IV, Case Series, Treatment Study.

Keywords: Elbow stiffness; severe; release; instability; ligament; anchor; hinged external fixator

Wei Wang and Shi-chao Jiang are co-first authors. This is a retrospective study. The authors contacted the Ethics Committee of Shanghai Jiao Tong University Affiliated Sixth People’s Hospital, and it was concluded that no approval of the committee was necessary because of the retrospective design of the study. We planned to analyze the data anonymously, so there was no need for informed consent of the patients using routine data for scientific purposes. However, all patients approved the publication of the results of this study by oral consent, and oral-consent approval was documented in the patients’ files. The retrospective review of the medial records and follow-up were approved and supported by the Ethics Committee of Shanghai Jiao Tong University Affiliated Sixth People’s Hospital and our institutional review board. All clinical investigations were conducted in accordance with the guidelines of the 2008 Declaration of Helsinki.

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Clinically, the severity of elbow stiffness can be classified according to the arc of motion as "severe" when the flexion-extension arc ranges from 30° to 60° or "very severe" when the flexion-extension arc is less than 30°; furthermore, an ankylosed elbow is defined as a very severely stiff elbow with a range of motion (ROM) of 0°. Instability is a crucial issue that surgeons have to overcome while performing complete elbow release for severely stiff elbows. Perioperative instability may be caused by various intraoperative findings and procedures, including osseous congruity disruption, impaired ligaments, global joint release, removal of collateral ligament ossification, procedures for humeroulnar joint exposure, and aggressive stretching during the operation. After an ideal arc of motion is achieved during the operation, obvious laxity indicates instability of the elbow when a lateral stress test is performed, as well as the "dimple sign" of the humeroradial joint during the pivot-shift test. In this situation, the affected collateral ligament needs to be repaired to the maximum possible extent. Otherwise, tendon graft reconstruction is indicated for the collateral ligament defect with bone tunnels on both the ulna and humerus, and use of a suture anchor to restore the origin on the humerus can further repair the ligament, as we showed in our previous work. Furthermore, a hinged external fixator is usually adopted in severely stiff elbows because of the urgent need for early rehabilitation and for adjustment of the tensile stress of the elbow after arthrolysis, as well as ligament repair and reconstruction.

However, few reports have focused on the influence of ligament repair with suture anchors on the outcome of open elbow release in stiff elbows. Therefore, this study aimed to evaluate the outcomes and stability of severe post-traumatic elbow stiffness after complete open elbow release and to test the hypothesis that repair of the collateral ligaments using a suture anchor combined with a hinged external fixator for assisting rehabilitation could help in restoring the functional mobility in severely stiff elbows after complete release.

Materials and methods

Patients

Over a 1.5-year period between January 2011 and June 2012, we retrospectively reviewed 46 adult patients who underwent open elbow arthrolysis and fulfilled the following inclusion criteria: (1) the patient was skeletally mature, (2) post-traumatic elbow stiffness with ROM no greater than 60° was present, (3) a suture anchor or suture anchors were applied to reconstruct the collateral ligament, and (4) a hinged external fixator was indicated. The exclusion criteria were as follows: (1) associated injury to the central nervous system; (2) loss of joint integrity such as radial head luxation/subluxation, prior untreated fractures, and osseous defects; (3) cubitus varus/valgus; and (4) associated nonunion, malunion, or advanced articular injury requiring interposition arthroplasty or total joint arthroplasty. All operations were carried out by the same senior surgeon (C.-y.F.).

The patients comprised 25 men and 21 women with a median age of 37 years (range, 21-64 years). The median interval from primary injury to our operative intervention was 11 months (range, 3 months to 20 years). The initial trauma was low-energy damage (falling from a standing height) in 31 cases, high-energy damage (falling from a height >2 m or a vehicular accident) in 14 cases, and a cutting injury in 1 case (detailed in Table I).

The initial treatment was open reduction and internal fixation of the fracture in 30 patients, cast or splint immobilization in 13, and ligament repair in 1, whereas 2 patients received no initial treatment. The mean immobilization duration of the 46 patients after primary treatment was 4.6 weeks (range, 1-20 weeks). Seven patients had undergone a secondary operation before admission for our surgical procedure (detailed in Table I). Furthermore, 17 patients presented with ulnar nerve symptoms preoperatively and were classified according to the McGowan scale as follows: grade 1 in 15 patients and grade 2 in 2 patients (Table II and Fig. 1, A).

Surgical techniques

All patients underwent the operation in the standard supine position with abduction of the affected upper limb after a brachial plexus block. A sterile tourniquet was routinely applied. The choice of incision depended on several elements, including the prior operative intervention, location of heterotopic ossification (HO), and symptoms of ulnar neuropathy.

The procedures were generally started with the lateral approach—a column procedure. The hypertrophic capsule was excised. If needed, we exposed the fossa coronoida for joint clearing. Further release of the contracture of the annular ligament and humeroradial joint was required in 8 patients who presented with forearm rotation defects. A medial approach was used to address the medial and posterior targets. The ulnar nerve was routinely identified, released from its tunnel, and protected. Blunt dissection of the triceps, clearance of the olecranon fossa, excision of HO, and resection of the posterior and transverse bundles of the medial collateral ligament were performed to further improve the arc of motion. The anterior bundle of the medial collateral ligament (AMCL) was preserved as long as the motion of the elbow was not affected significantly even if ossification was embedded in this bundle. However, injury to parts of this crucial medial stabilizer was inevitable in some of the patients during surgical resection of the scar and the osseous tissue surrounding these soft-tissue structures.

No further attempt at release was required if a passive 0° to 135° arc of elbow motion was achieved with the force of 2 fingers applied by the surgeon. In 19 patients (40%), additional manipulation under anesthesia and release of the lateral collateral ligament were performed to reach the required functional arc. A partial resection of the radial collateral ligament fulfilled the required release in all cases. In principle, the lateral unlar collateral ligament should be left intact to prevent instability.

In the patients operated on through a posterior incision, a global approach was performed, based on the same pattern of the previously mentioned operative techniques, with the exclusion of the additional lateral incision for anterior contracture release in 2 of the 8 patients after hardware removal. A single medial incision was used in 3 patients because of major posterosomedical HO. A single lateral incision was used in 2 patients without ulnar nerve
Subsequently, valgus, varus, and posterolateral rotatory instability testing was performed, wherein an unstable elbow signified the disruption of the medial soft-tissue structures (27 patients), the lateral soft-tissue structures (14 patients), and both the medial and lateral soft-tissue structures (4 patients) through a stress test. The collateral ligaments were avulsed from the humeral origin in all patients; accordingly, suture anchors were used to reconstruct the proximal origin, as well as repair the ligaments and muscles.8,30

The “isometric” point of the humeral condyles was pre-bored by a 2.0-mm Kirschner wire; then, the bone suture anchor (Twinfix; Smith & Nephew, Andover, MA, USA) was screwed into the lateral or medial isometric point. Subsequently, the avulsed ligaments were sutured and were reattached to the origins by a single suture. The AMCL was tightened with the elbow positioned in 45° of flexion.13 For the lateral collateral ligament, we reattached it along with the dissected common extensor origins and tightened it per standard procedure with flexion of 60° to 90°.

A running-type suture was used to strengthen the ligaments along with the common tendon or surrounding soft tissues.

We drilled a 2.0-mm K-wire from the lateral side into the distal humerus along the axis, passing through the centers of the trochlea and capitellum, preparing for the subsequent hinged external fixation before screwing in the bone anchor. After the medial and lateral soft-tissue structures were addressed as mentioned earlier, the ulnar nerve was anteriorly transposed subcutaneously in all the elbows approached medially. The wound was closed in layers, and drainages were routinely applied. Finally, the middle part of the fixator was located through the K-wire. Two 4.5-mm pins were placed 1 to 2 cm below the deltoid tuberosity on the humerus, and two 3.5-mm pins were placed on the middle ulnar shaft or on the distal part of the radius. Then, the K-wire was pulled out. The final ROM was documented as guidance for early rehabilitation. In our opinion, the conditions of the ligaments and soft tissue after complete release in severe elbow stiffness are not satisfactory, so use of the fixator would protect the reconstructed ligaments and facilitate the rehabilitation so that a more satisfactory outcome can be obtained.

Medial and lateral incisions were used in 31 patients, a posterior incision in 8, a single medial incision in 3, a single lateral incision in 2, and both posterior and lateral incisions in 2. Furthermore, 22 patients underwent additional procedures during the operation, including hardware removal in 20, autogenous iliac bone grafting for radial shaft nonunion in 1, and the Sauvé-Kapandji procedure for ipsilateral distal radioulnar joint dysfunction in 1.

Postoperative management

We encouraged patients to participate in early rehabilitation; this was planned according to the achieved ROM and the restored ligaments at 24 to 48 hours operatively. A rehabilitation protocol cycle included flexion, extension, and rotation in the pattern of active, passive, and active-assisted ROM exercises. The customized rehabilitation protocol was based on the stability achieved, as well as the pain experienced, during the exercises when performed with a schedule of 3 times a day for 30 minutes each; the ROM thus achieved was consolidated by immobilizing the arm in flexion or extension overnight with the help of a hinged external fixator. The target ROM in the first postoperative week was at least 90% of that recorded during the operation. The exercise intensity was to be gradually increased to 60 to 90 minutes each time until the hinged external fixator was removed.13 Meanwhile, extremely passive extension and flexion were to be avoided to protect the repaired ligaments.24

The hinged external fixator was removed at 6 to 8 weeks postoperatively by an outpatient procedure in the treatment room. Subsequently, a hinged brace was applied to protect the unstable

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### Table 1 Preoperative characteristics of patients

<table>
<thead>
<tr>
<th>Data</th>
<th>Gender (n)</th>
<th>Age (y)</th>
<th>Injury mechanism (n)</th>
<th>Injury type (n)</th>
<th>Associated injury (n)</th>
<th>Initial treatment (n)</th>
<th>Operation before index release (n)</th>
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<tr>
<td></td>
<td>25 male and 21 female</td>
<td>Median/mean 37/39</td>
<td>Fall from standing height</td>
<td>Distal humeral fracture</td>
<td>Nerve injury (ulnar/radial/median)</td>
<td>Open reduction and internal fixation (external fixation applied)</td>
<td>Local skin grafting</td>
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<td></td>
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<td>Range 21-64</td>
<td>Fall from &gt;2 m</td>
<td>Olecranon fracture</td>
<td>Ipsilateral clavicle fracture</td>
<td>Cast or spilt immobilization</td>
<td>Open elbow release (hardware removal at same time)</td>
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<td></td>
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<td>Vehicular accident</td>
<td>Radial head fracture</td>
<td>Ipsilateral fracture of proximal humerus</td>
<td>Ligament repair</td>
<td>Hardware removal</td>
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<td></td>
<td></td>
<td></td>
<td>Cutting injury</td>
<td>Elbow dislocation with and without fractures</td>
<td>Contralateral elbow injury</td>
<td>No treatment</td>
<td>Ulnar nerve release and anterior transposition</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Collateral ligament injury</td>
<td>Multiple fractures of body</td>
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<td>Autogenous iliac bone grafting for ulna bone nonunion</td>
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<td></td>
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<td>Humeral fracture associated</td>
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<td>Small needle knife for elbow release</td>
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<td>with ulnar fracture</td>
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<td>Median interval between initial injury and index release (range) (mo)</td>
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<td>Olecranon fracture associated with radial head fracture</td>
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<td>11 (3-240)</td>
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<td></td>
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<td>Monteggia fracture</td>
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elbow while strength training was carried out accompanied by motion exercises (Fig. 1, E and F). In addition, patients were prescribed indomethacin (25 mg) 3 times a day for 6 weeks to prevent HO. A proton pump inhibitor was used in patients with a preoperative history of gastrointestinal disorder or obvious gastrointestinal symptoms postoperatively. Furthermore, mecobalamin was routinely prescribed to all the patients.

Statistical analysis

All values were presented as mean ± standard deviation. A comparison t test was used to analyze the flexion-extension arc, range of forearm rotation, and Mayo Elbow Performance Score (MEPS) preoperatively and postoperatively. The 46 patients were classified into 3 groups: ankylosed elbow (ROM, 0°); very severely stiff elbow (flexion arc, 1°-30°); and severely stiff elbow (flexion arc, 31°-60°). The postoperative ROM, gain in the flexion arc, and rate of instability in these 3 groups were calculated. A 1-way analysis of variance was used for calculating differences among the 3 groups. A nonparametric Kruskal-Wallis H test was used to compare groups with non-normal distribution data. The χ² test and Fisher exact probability test were used to assess the intergroup constituent ratio. An independent-samples t test was used to compare the differences in motion with different incisions, between posterior incisions (n = 8) and combined medial and lateral incisions (n = 31). Significance was set at P < .05. All analyses were conducted with SPSS software (version 13.0; SPSS, Chicago, IL, USA).

Results

Stability

Preoperatively, 1 patient was diagnosed with dislocation of the elbow joint based on radiographs. At follow-up, the valgus and varus stress tests, as well as the lateral pivot-shift test, were performed to assess medial, lateral, and posterolateral rotary instability of the elbow.10 The grade of instability was scored with the MEPS.21 Laxity of varus or valgus of less than 10° was defined as moderate instability, whereas laxity greater than 10° was graded as severe instability. Violent stress was avoided during examination, and pain and fear of the patient during examination showed the tendency for instability. Moderate instability was detected in 3 elbows when the hinged external fixator was removed; however, at the last follow-up, stability had been regained in each of these 3 patients. No statistically significant difference was found for the incidence of instability among the 3 different groups (Table III).

Range of motion

At the final follow-up, at a mean duration of 24.3 months (range, 18-33 months), mean flexion was 132° (range, 105°-160°), which had improved significantly from the preoperative value of 73° (P < .001) (Fig. 1, C, D, G, and H). Mean extension improved significantly from 48° to 6° after the operation (P < .001). Thus, the mean total arc of motion increased from 25° preoperatively to 126° postoperatively (P < .001), with a mean improvement of 101°. Of the patients, 42 (91%) had a functional arc of 100° or greater, and 33 patients (72%) regained a functional arc of 30° to 130°. Mean forearm pronation and supination were 55° and 75°, respectively, preoperatively and 56° and 84°, respectively, postoperatively. Thus, a statistically significant difference in supination and gain of rotation was observed when we assessed the preoperative and postoperative values (Table II). Among the 3 patient groups, a significant difference was observed in the gain of arc (P < .001); however, no significant difference in the postoperative flexion arc was noted (P = .22) (Table III and Fig. 2). There were no statistically significant differences preoperatively and postoperatively between the posterior incision group (n = 8) and the group with combined medial and lateral incisions (n = 31) in extension (P = .412 and P = .304, respectively), flexion (P = .873 and P = .751, respectively), ROM (P = .432 and P = .459, respectively), and gain of motion arc (P = .988).

Mayo Elbow Performance Score

The mean MEPS was 63 points (range, 15-85 points) preoperatively; this was significantly increased to 91 points at
the final follow-up ($P < .001$), with an excellent result in 27 patients, good result in 15, fair result in 1, and poor result in 2. The patients with fair or poor results reported moderate or severe pain.

**Radiographic findings**

No looseness of the anchor was noted in any of the 46 patients. HO developed in 3 patients; however, at 6 months’ follow-up, it had matured and did not affect the functional arc. At the last follow-up, no signs of dislocation of the elbow were observed in the patients who had shown signs of instability at the earlier follow-up examinations.

**Complications**

At the time of the last follow-up, the ulnar nerve symptoms had resolved in 10 of the 17 patients with preoperative ulnar neuropathy. Among the remaining 7 patients, there were no changes in the 3 patients in whom the ulnar nerve was originally injured (grade 1 in 2 patients and grade 2 in 1 patient), another 3 patients had persisting sensory disturbances (grade 1), and motor symptoms developed in the ulnar nerve in the 1 remaining patient (grade 2 at final follow-up). The final evaluation is detailed in Table IV. In addition, new-onset nerve palsy developed postoperatively in 7 other patients and resolved in 3 months (the affected nerve was the ulnar nerve in 5, the radial nerve in 1, and the medial forearm cutaneous nerve in 1). None of the patients needed secondary surgery for any reason.

**Discussion**

In our study, complete release was performed in severely stiff elbows, and all the avulsed collateral ligaments were
reconstructed using suture anchors with the application of a hinged external fixator for the instability detected during surgery. At the last follow-up examination, functional mobility was achieved in most cases, and more than 91% patients had achieved a good or excellent result. The bone anchor repair of collateral ligaments is a well-developed technique with satisfactory outcomes in cases of elbow trauma.6,8,19,30 This technique appears to restore the normal mechanical function of the ligaments.8,30 Furthermore, transosseous sutures and tendon grafts have been applied for the reconstruction of torn ligaments.4,5,9 Several techniques have been described for the repair of the collateral ligaments in chronic and acute elbow instability and approved as effective treatments.7,32 However, no studies have thus far examined the efficacy of suture anchors in open-release surgery for severely stiff elbows.

Suture anchors have been applied to a small number of patients undergoing open elbow arthrolysis to reconstruct the collateral ligament, with no instability being reported.3,5,15,25 In our study, the mean gain in the flexion arc was 101°, which was higher than the gain observed in previous reports, with comparable final patient outcomes.11,13,29 Because a functional and stable arc had been restored in most of our patients at the last follow-up (range, 18-33 months), we consider that open release and repair using a suture anchor could fulfill the biomechanical needs of severely stiff elbows, with satisfactory outcomes. Overall, elbow instability developed in 3 elbows when the hinged external fixator was removed. The reason for this relatively high incidence of instability could be the complete-release surgery performed, within a large proportion of patients who required ligament repair, and the focus on identifying instability throughout the follow-up period. However, the instability was resolved in all 3 elbows after a muscle-strengthening rehabilitation program.1

In our study, the bone suture anchor was drilled into the origins. The AMCL was tightened and reattached at 45° of elbow flexion to provide appropriate tension throughout the flexion arc. Furthermore, extremely passive extension was avoided in the early rehabilitation period to prevent iatrogenic injury.23 The original avulsed lateral collateral ligament was reconstructed and sutured along with the common extensor and the surrounding muscles. Because the lateral elbow musculature affects total elbow varus-valgus stability,33 we consider that this procedure contributed further to elbow stability.

The incisions used in the elbow release are controversial. In our opinion, the wound and exposure from combined incisions are much less than those with posterior incisions. In addition, there is a risk of incision rupture during early rehabilitation in patients who receive posterior incisions, and it is difficult to reach the anterior targets of the joint through posterior incisions. Furthermore, there was no significant difference in motion between combined medial and lateral incisions and posterior incisions in this study. Thus, we confirm that combined medial and lateral incisions have advantages over posterior incisions in treating severe elbow stiffness.

We believe it reasonable and helpful to adopt a hinged external fixator in our treatment for the following reasons: First, it provides extra stability against rotatory and shearing forces, thus preserving mobility in flexion and extension; second, it creates ideal conditions for the recovery of muscle and ligaments; third, it facilitates the performance of active and passive exercises by maintaining and improving the arc of motion as a contracture

<table>
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<th>Table III Statistical analysis of 3 groups</th>
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<td>Postoperative ROM (°)</td>
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<td>Postoperative ROM (°)</td>
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<tr>
<td>Gain of arc (°)*</td>
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<td>Instability [No. of cases (%)]</td>
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* One-way analysis of variance (group comparison) yielded P < .001 for 0° versus 1° to 30° and P < .001 for 0° versus 31° to 60°.
sutures entail. However, the disadvantage of the suture structures to bone by eliminating the added dissection for infection.

environments outside the hospital to prevent pin-track care should be emphasized to the patient in environments outside the hospital to prevent pin-track infection.

A limitation of our study is its noncomparative nature. All patients underwent ligament repair with bone suture anchors and hinged external fixation. The advent of suture anchors has simplified the reattachment of soft-tissue structures to bone by eliminating the added dissection for autograft and the difficulty that bone tunnels or pullout sutures entail. However, the disadvantage of the suture anchor and hinged external fixator is the increased medical cost; therefore, surgeons should consider and balance the economic utility of the technique in each clinical setting. Another limitation of our study is that the planar radiographs were not obtained under stress. In addition, a new binary scoring system is needed in the evaluation of instability. Further studies are warranted to compare the efficacy of our method with other techniques of repair and/or reconstruction with allografts or autografts for avulsed ligaments during elbow arthrolysis. Other limitations of this study included its retrospective nature and the short-term duration of the follow-up period.

Conclusion

In complete-release surgery for post-traumatic elbow stiffness, repair of the avulsed collateral ligaments using suture anchors and the application of a hinged external fixator could effectively restore functional mobility. We consider that this could be an option for treating severely stiff elbows.

Disclaimer

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References


