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The use of static external fixation for chronic instability of the elbow

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Background: Chronic elbow instability after trauma is a challenging problem. Clinical results of external elbow fixation in this setting are limited, with most studies focusing on hinged external fixation. A static fixator is an alternative for maintaining joint reduction. Advantages of a static frame include ease of application, decreased need for special instrumentation, and more secure maintenance of a concentrically reduced joint in the setting of bone or soft tissue instability. The primary limitation of static fixation is the potential for stiffness.

Methods: This retrospective review represents the largest reported cohort evaluating the use of static elbow external fixation for the treatment of chronic elbow instability. Twenty-seven cases treated by a single surgeon between 2004 and 2015 were identified.

Results: Twenty patients were available for a clinical evaluation, including radiographs and a physical examination at a mean follow-up of 5.8 years (range, 1.4-12.4 years). Of note, 19 of 20 were clinically obese or overweight. At final evaluation, range of motion averaged from $20° \pm 13°$ of extension to $134° \pm 9°$ of flexion. All patients had stable elbows, except 1 patient who had valgus and varus laxity on stress examination. Radiographs of this patient showed an incongruous joint. Eight patients required an additional operation after external fixator removal, 3 for infection and 5 for stiffness.

Conclusions: At almost 6 years of follow-up, static elbow external fixator resulted in a congruous joint with adequate functional and clinical outcomes in 95% of patients.

Level of evidence: Level IV; Case Series; Treatment Study
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Keywords: Chronic elbow instability; static external fixation; elbow external fixation; elbow dislocation; elbow instability; elbow stiffness

Complex fracture-dislocations of the elbow are challenging, often presenting with instability and both ligamentous and bone insufficiency. Restoration of structural and soft tissue support, while maintaining a stable joint, can be difficult. This is especially true in chronic cases, in which one can have both joint stiffness and instability. The goals of treatment in chronic instability are to restore a concentric and stable joint and to prevent stiffness.

Bone stability of the elbow is provided by the ulnotrochlear articulation as well as by the radial head, which acts with the coronoid to provide an anterior buttress

Table I Summary of demographics, initial injury, surgical procedures performed, time from injury to fixator placement, time from fixator placement to removal and follow-up, and outcome measures for all patients

	Age (yr)	BMI (kg/m^2)	Time from injury to placement (days)	Initial injury	Prior procedures	Operative procedures with frame
Patient 1	44	31.5	149	Fx-dislocation with coronoid fx		Coronoid reconstruction, LCL repair, ulnar nerve transposition
Patient 2	50	42	1533	Fx-dislocation with radial head, capitellum, and coronoid fx	ORIF with LCL repair	LCL reconstruction with graft, cubital tunnel release
Patient 3	47	41.1	224	Fx-dislocation with radial head and coronoid fx	ORIF with radial head arthroplasty, LCL repair	Revision radial head arthroplasty, LCL repair
Patient 4	44	43.4	178	Fx-dislocation with radial head and coronoid fx	ORIF with radial head arthroplasty, LCL and MCL repair, ulnar nerve transposition	Revision radial head arthroplasty, LCL repair
Patient 5	41	44.8	236	Fx-dislocation with radial head and coronoid fx	ORIF with radial head arthroplasty, LCL and MCL repair, ORIF coronoid	Revision radial head arthroplasty, LCL reconstruction with graft
Patient 6	30	37	903	Fx-dislocation with radial head and coronoid fx	ORIF with LCL repair and ulnar nerve transposition	LCL reconstruction with graft
Patient 7	44	26.8	157	Fx-dislocation with radial head and coronoid fx		Radial head arthroplasty, LCL repair, ulnar nerve transposition
Patient 8	35	29.4	420	Fx-dislocation with coronoid fx	ORIF with LCL repair	LCL repair
Patient 9	51	31.5	133	Fx-dislocation with radial head and coronoid fx	ORIF with radial head arthroplasty, LCL repair, ulnar nerve transposition	Revision radial head arthroplasty, coronoid reconstruction, LCL repair
Patient 10	49	27.5	32	Fx-dislocation with coronoid and proximal ulna fx	ORIF	ORIF with ulnar nerve transposition
Patient 11	43	40.3	298	Fx-dislocation with radial head and capitellar fx	ORIF with LCL repair	LCL reconstruction with graft
Patient 12	22	19.7	265	Fx-dislocation with radial head and coronoid fx		LCL repair and ulnar nerve transposition
Patient 13	23	33.3	58	Fx-dislocation with radial head and coronoid fx		ORIF with LCL repair and ulnar nerve transposition
Patient 14	56	51.5	125	Fx-dislocation with radial head and coronoid fx	ORIF with radial head arthroplasty, LCL repair and ulnar nerve transposition	LCL repair
Patient 15	40	57.9	51	Fx-dislocation with coronoid fx		LCL repair and ulnar nerve transposition
Patient 16	47	40.6	47	Fx-dislocation with coronoid and radial head fracture	ORIF with radial head arthroplasty, LCL and MCL repair	Revision radial head arthroplasty, LCL repair with ulnar nerve transposition
Patient 17	55	33.8	198	Fx-dislocation with coronoid and proximal ulna fx		ORIF with LCL repair and ulnar nerve transposition
Patient 18	61	35.3	35	Fx-dislocation with radial head and coronoid fx	ORIF with radial head arthroplasty, LCL repair and ulnar nerve transposition	LCL repair
Patient 19	56	30.5	39	Fx-dislocation with coronoid fx		ORIF with LCL repair and ulnar nerve transposition
Patient 20	51	38.1	29	Fx-dislocation with radial head and proximal ulna fx	ORIF with radial head arthroplasty	Revision ORIF with LCL repair

BMI, body mass index; *Quick DASH*, Quick Disabilities of the Arm, Shoulder, and Hand; *fx*, fracture; *LCL*, lateral collateral ligament; *ORIF*, open reduction–internal fixation; *MCL*, medial collateral ligament.

Table I Summary of demographics, initial injury, surgical procedures performed, time from injury to fixator placement, time from fixator placement to removal and follow-up, and outcome measures for all patients   (*continued*)

Duration of frame (days)	Additional procedures	Follow-up from frame removal (yr)	Final extension (°)	Final flexion (°)	Final arc of motion (°)	Final grip strength (kg)	Quick DASH score	Mayo Elbow Performance Score	Broberg and Morrey X-ray grade
40		5.0	40	135	95	44	6.8	100	2
46		4.2	0	140	140	33	4.5	100	1
47	Elbow release with ulnar nerve transposition; irrigation and débridement	3.7	35	140	105	16	68	50	3
42	Elbow release with revision ulnar nerve transposition	2.1	15	135	120	28	6.8	75	2
40	Elbow release with ulnar nerve transposition	1.4	5	130	125	54	15.9	100	2
40	Irrigation and débridement	1.1	20	140	120	24	38.6	85	1
33		7.6	35	145	110	31	4.5	100	1
33		6.9	15	130	115	45	27.3	85	1
44		6.4	20	140	120	36	61.4	40	3
33	Elbow release	12.4	30	110	80	20	31.9	95	2
40		10.5	10	140	130	29	6.8	100	1
19		9.8	25	125	100	30	11.4	100	2
28		9.4	10	135	125	53	0	100	1
40		9.1	40	135	95	24	18.2	95	2
33		7.9	5	135	130	46	13.7	95	2
29	Elbow release; irrigation and débridement	6.6	15	120	105	28	47.8	85	3
33		3.5	5	140	135	31	2.3	100	1
43		2.7	35	135	100	18	15.9	85	1
40		2.4	30	140	110	29	9.1	85	2
34		1.6	20	135	115	42	2.3	100	1

to the elbow, resisting posteriorly directed forces. Ligamentous stability is further provided by the medial collateral ligament and lateral collateral ligament, which prevent valgus and posterolateral instability, respectively.[2,10] Complex fracture-dislocations about the elbow disrupt the ligamentous and soft tissue stabilizers as well as the inherent bone stability of the joint.[7]

External fixation has been proposed to treat elbow fracture-dislocations that remain unstable after traditional surgical repairs.[4,5] It has also been recommended as an adjunct in the setting of chronic elbow instability.[4,16] Previous reports have focused on dynamic frames that allow elbow motion while protecting the joint from subluxation.[6,7,9-15] As opposed to hinged external fixators, static external fixators can also be used in cases of recurrent instability and failed repairs. Maintaining the elbow in a static, reduced position allows optimal bone and soft tissue protection during healing. The advantages of a static frame include availability, ease of application, and less complexity with respect to rehabilitation. To date, there are no clinical reports on the use of static external elbow fixation in cases of complex or chronic elbow instability. This study represents a cohort of patients who underwent static elbow external fixation in the setting of chronic elbow instability.

Materials and methods

This study is a case series. All cases of elbow external fixation used for elbow instability during a 12-year period from 2004 to 2015 at a single institution were studied. Twenty-seven cases were identified, all treated by a single surgeon. Patients' records were reviewed for indications, previous surgical history, age, sex, operative history, and range of motion.

All patients presented for treatment of chronic elbow instability with a stiff and incongruous joint. All had suffered fracture-dislocations of the elbow, and 13 of 20 had previously undergone surgical treatment (Table I). Because of the presence of a chronically subluxated joint with instability, a decision was made to augment joint reconstruction with external fixation. This was due to prior cases of recurrent instability experienced by the senior author in such cases treated with traditional reconstruction alone. The indications for the external frame in this series were a dislocated elbow >4 weeks out from the original injury with associated ligamentous insufficiency and incongruity of the joint surfaces requiring reconstruction (eg, radial head, coronoid).

Twenty patients were available for a final clinical evaluation (74%); 6 were lost to follow-up (22%) and 1 had died. All patients were seen at follow-up by an independent examiner for the sole purpose of this study. Evaluations included visual inspection, active range of motion, varus and valgus stress testing, grip strength testing, complete neurovascular examination, and radiographs of the elbow (frontal, lateral, and oblique). Outcome measures included the Disabilities of the Arm, Shoulder, and Hand (DASH) score and the Mayo Elbow Performance Score. Elbow radiographs were analyzed for arthritis and joint congruity by independent radiologists.

Surgical technique

All patients had placement of a medium external fixator (Synthes, Paoli, PA, USA). Early in the series, an attempt was made to place one or both of the humeral pins proximally through an extension of the main lateral incision used to expose the joint. However, this left the distal pin often close to the joint or intra-articular. One patient had a joint infection, and at the time of washout, the infection was found to be in continuity with the distal humeral pin. As such, in later cases, the humeral pins were inserted through a separate proximal lateral incision along the mid-diaphysis of the humerus. Blunt dissection was carried down to the bone, and care was taken to identify and to protect the crossing radial nerve in the majority of cases. When the nerve was not easily identified, Hohmann retractors were carefully placed around the humerus to protect the soft tissues. Before drilling for the half-pins, a provisional 0.062-inch wire was placed into the humerus in the center of the incision. This was used to judge the best angle of pin placement relative to the skin incision. With use of this wire as a guide, a 2.5-mm bit with a drill sleeve was used to drill parallel paths for the half-pins at the proximal and distal aspects of the wound. The 4-mm half-pins were then placed by hand, with fluoroscopy assistance to ensure that the tips were just through the medial cortex. The skin around the pins was then loosely closed, and the 0.062-inch wire was removed.

The ulnar pins were placed in a similar fashion through an incision lateral to the ulna and well distal to the joint. Blunt dissection was carried through the posterior aspect of the extensor carpi ulnaris to expose the ulnar shaft. With Hohmann retractors protecting the soft tissues, two 4-mm half-pins were then inserted into the ulna under fluoroscopy guidance. Short radiolucent 8-mm-diameter bars were then attached to the posterior aspects of the humeral and ulnar pins using bar to pin clamps. An oblique bar was then loosely attached to complete the frame, using bar to bar clamps.

The frames were placed and assembled after all bone and joint work was completed. However, the lateral soft tissue repair was finalized after frame placement and a concentric joint reduction was obtained. To achieve this, the patient's arm was placed across the body. Using posteriorly applied pressure and gravity assistance, care was taken to document that the elbow was concentric. This was confirmed visually and with fluoroscopy guidance. At this point, the frame was tightened at approximately 90° of elbow flexion. With the elbow reduced and stabilized, the soft tissue repairs were then completed, including advancement of the collateral ligaments and tendon origins to their humeral origins. A transosseous repair was used, and the suture arms were tied over the posterior humeral column. A second radiolucent bar was then added posteriorly for stability, connecting the humeral to the ulnar pins (Fig. 1).

Results

Mean follow-up was 5.8 years (range, 2.0-12.4 years). Patients ranged in age from 22 to 61 years (Table I). Sixteen of 20 were obese, with a body mass index (BMI) >30 kg/m^2. Of this subgroup, the average BMI was 39.5 kg/m^2. Three of the remaining 4 patients were overweight, defined as having a BMI of 25-29.9 kg/m^2

(Table I). No patients reported additional surgery for instability after treatment by the senior author. Patients underwent external fixator placement at a mean of 36 weeks after the initial injury (range, 4-129 weeks; Fig. 2). Thirteen of them had undergone at least 1 surgical procedure before the placement of the fixator. Procedures performed at the time of frame placement included lateral ligament repairs (if there was an adequate soft tissue sleeve remaining; 15 patients) or graft reconstructions (4 patients); radial head replacement (6 patients); open reduction and internal fixation of the coronoid, radial head, or ulna (5 patients); coronoid reconstruction with allograft (2 patients); and ulnar nerve transposition (10 patients). The ulnar nerve was addressed in all patients who had not previously undergone nerve decompression and who had residual nerve sensitivity to percussion, nerve tension signs, or extension contractures. All patients had an extensive release of the joint with removal of interposed soft tissue and capsular adhesions. The triceps and the brachialis were freed from surrounding tissues.

The external fixators were left in place for an average of 37 days (range, 19-47 days; Table I). After fixator removal, 7 patients (35%) required an additional operation. Three of these were for infection. In total, 6 patients developed an infection; 3 of these were superficial involving the pin sites and were successfully treated with antibiotics alone, and 3 were deep or joint infections requiring joint lavage and a course of intravenous antibiotics. All deep infections were treated successfully in this manner. Two patients developed a transient high radial nerve palsy, presumably related to nerve retraction during humeral pin placement. Both resolved over time at an average of 15 weeks postoperatively. One patient developed a postoperative deep venous thrombosis in the upper extremity treated successfully with oral anticoagulation.

Five patients required additional surgery for stiffness at an average of 21 ± 8 weeks after frame removal (Table I). The final elbow motion in this group averaged $19° \pm 14°$ of extension and $127° \pm 5°$ of flexion. Total elbow motion in this group improved from an average of $55°$ preoperatively to $108°$ at final follow-up after joint release ($P < .001$).

At final evaluation, elbow range of motion for the entire cohort averaged $20° \pm 13°$ of extension to $134° \pm 9°$ of flexion. Compared with the contralateral, unaffected side, extension was still significantly diminished ($P < .001$). Grip strength averaged 33 ± 11 kilograms vs. the contralateral side of 38 ± 13 kilograms. These differences were not significant ($P = .23$). All patients had stable elbows, except 1 patient who had valgus and varus laxity on stress examination (patient 9). This patient had undergone a coronoid reconstruction with an allograft coronoid that failed to unite. The joint eventually became unstable. Fortunately, further surgery was not necessary, and the elbow functioned similar to a resection arthroplasty (Fig. 3). No patients had measurable nerve dysfunction at final follow-up.

Figure 1 Clinical photograph demonstrating static external fixator in place.

Elbow radiographs at final follow-up were graded by the Broberg and Morrey classification.[1,8] Of 20 patients, 9 (45%) had grade 1 changes, characterized by slight joint space narrowing with minimal osteophyte formation (Fig. 2); 8 (40%) had grade 2 changes with moderate joint space narrowing and moderate osteophyte formation; and 3 (15%) had grade 3 changes with severe degeneration of the joint. Two of these 3 patients were patients who had developed a deep infection and underwent irrigation and débridement.

The average Mayo Elbow Performance Score was 89 ± 17 points. All patients had a good or excellent result as assessed by this measure. The average QuickDASH score was 20 ± 20 points (range, 0-68 points). Of 20 patients, 17 answered the optional work module of the QuickDASH, with an average score of 9.6 ± 18 points; 7 of 20 patients answered the optional sports/performing arts module of the QuickDASH, with an average score of 26 ± 39 points. No patients were still under the care of a physician for the elbow at the time of final follow-up.

Discussion

Complex elbow fracture-dislocations with chronic instability represent a unique problem. In this setting, there is often bone and soft tissue insufficiency in addition to joint stiffness and muscle contractures. In treating these patients, the senior author had cases of recurrent instability after joint and ligament reconstruction alone when the elbow was dislocated for several weeks or months. This was despite the belief that a "stable joint" had been obtained at the time of surgery under anesthesia. This is presumably, in part, due to chronic myostatic contracture of the triceps,

Figure 2 (**A**) Anteroposterior and (**B**) lateral radiographs of a patient who presented 6 months after suffering an elbow fracture-dislocation treated surgically. Note the ulnohumeral joint widening on the frontal projection indicating joint incongruity. (**C**) Sagittal computed tomography section through the ulnohumeral articulation demonstrating chronic joint subluxation. (**D**) Frontal and (**E**) lateral radiographs after revision radial head arthroplasty, joint reduction, lateral ligament reconstruction, and external fixator application. (**F**) Anteroposterior and (**G**) lateral radiograph at 3.1 years of follow-up depicting a concentric joint.

biceps, brachialis, and other soft tissues around the joint in the dislocated state that contributed to recurrent subluxation postoperatively. As such, a decision was made in patients in this cohort with chronic joint instability for 1 month or more out from injury to add an external fixator. The goal of the frame was to neutralize the forces that could lead to recurrent joint subluxation and to maintain the elbow in a concentrically reduced position.

The benefit of adjuvant external fixation in chronic instability is highlighted in the setting of obesity. In these

Figure 3 (**A**) Anteroposterior and (**B**) lateral radiographs of a patient who presented with chronic instability after being treated surgically for a fracture-dislocation of the elbow 5 months previously. Note the dislocated radial head implant and the joint subluxation. (**C**) Sagittal computed tomography section through the ulnohumeral joint showing coronoid insufficiency and joint incongruity. (**D**) Frontal and (**E**) lateral radiographs after revision elbow surgery including coronoid reconstruction with allograft, lateral ligament reconstruction, and application of a static external fixator. (**F**) Final anteroposterior and (**G**) lateral appearance of the elbow at 6.4 years of follow-up. This patient had gross instability with failure of the reconstruction.
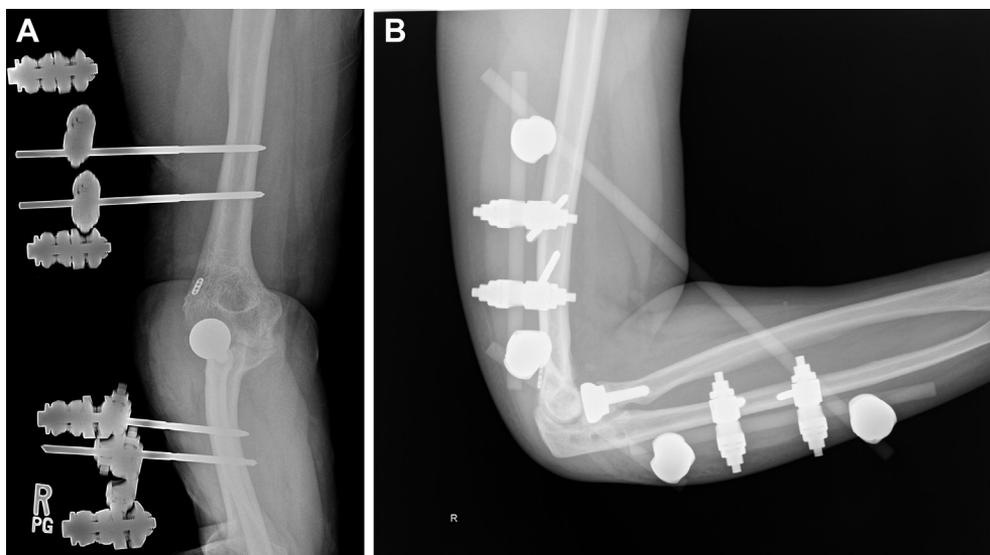
Figure 4   (**A**) Anteroposterior and (**B**) lateral radiographs of a patient who presented with chronic elbow instability treated with a radial head arthroplasty, lateral ligament reconstruction, and static external fixator. Note the proximal position of the humeral pins. This technique, in which the pins were placed through a separate incision to isolate them from the distal reconstruction and the elbow joint, was used later in the series.

individuals, the frame resists the large varus forces on the elbow that occur with shoulder abduction, which can lead to recurrent joint subluxation. In fact, this condition may predispose patients to recurrent instability after elbow fracture-dislocations as 19 of 20 patients in this series were overweight or obese.

This is the first case series describing outcomes of static external fixation in this setting. At almost 6 years of follow-up, 95% of patients achieved a stable, congruous joint. In addition, patients were able to regain functional range of motion and grip strength. Frame-specific complications did occur, but none resulted in long-term morbidity specifically as a result of frame use.

Dynamic external fixators have previously been described for the treatment of chronic elbow instability. These devices allow elbow range of motion while maintaining a congruous joint. Sørensen and Søjbjerg[13] described 20 patients with persistent instability at a mean of 11 weeks after fracture-dislocation treated with hinged external fixation after internal reconstruction. They found, at an average 44-month follow-up, that 10 of 17 patients had good or excellent results with a range of motion of 96°. They had no recurrent dislocations, although 8 of 17 had radiographic evidence of arthrosis at final follow-up. In addition, they reported a 41% complication rate with dynamic frame use, including 3 infections (including 1 that led to a humeral amputation), 1 ulnar nerve palsy, 1 radial nerve palsy, and 1 humeral fracture through a pin site hole. Potini et al[10] evaluated 7 patients with chronic elbow fracture-dislocations treated with a dynamic frame at an average of 8 months after injury. At final follow-up, range

of motion improved to an average of 26°-120°. Six of 7 of their patients had Broberg and Morrey grade 2 arthritis or greater. Four of 7 patients developed an infection, 3 requiring surgery. One patient was eventually converted to a total elbow arthroplasty, and 1 patient was converted to a fusion using a transarticular plate.

The use of a dynamic external fixator does increase the complexity of the operation and the rehabilitation. Cheung et al[3] reported specifically on the complications of hinged external fixation in 100 patients. They found that 15 patients had minor complications including local erythema and nonpurulent drainage with a need for skin release to decrease tension. Ten patients had major complications, including purulent pin site drainage, fixator malalignment and resultant joint incongruity, pin loosening, and deep infection. The senior author abandoned the use of dynamic external fixators early in practice because of the difficulty of application and the difficulty of identifying and maintaining the true joint axis. Because of this, despite a frame, a concentric joint was often lost postoperatively, leading to recurrent instability. In addition, although anecdotal, a greater degree of pin problems due to increased skin tension on the pins that occurred from movement of the elbow was observed.

Whereas static fixation is theoretically simpler to apply and to care for after surgery, the major limitation of static fixation is the potential for postoperative stiffness. This should affect only the ulnohumeral joint, as even with a static frame in place, patients can still work on unrestricted forearm rotation. Interestingly, our results show that elbow stiffness in flexion and extension was infrequent in this

population of patients, despite an average frame application time of >5 weeks. In this cohort, only 5 (25%) patients required a second operation for stiffness. This may in part be related to the extensive joint and capsular release procedures performed at the time of joint reduction and stabilization. Before the frame was applied, the elbow joint was completely débrided and released, including any adhesions of the brachialis and triceps muscles. Any interposed bone or soft tissue that might block a concentric reduction was removed. For the 25% of patients who did require a secondary joint release procedure for motion, the index operation and static frame led to a stable and congruous joint. Fortunately, a final average motion arc of 19°-127° was able to be obtained in these patients after a subsequent joint release. Thus, any stiffness related to the frame was reversible.

The complication rate does deserve mention. Two patients had transient radial nerve palsies presumably from traction applied during external fixator pin placement. In addition, we had 3 infections related to the external fixator pins (15%). Fortunately, these all cleared with antibiotics alone. More important, we had 3 cases of deep infection in the joint (15%). Although probably multifactorial, this is most likely in part related to the complexity of these cases, involving chronic joint instability, stiffness, and incongruity. In addition, all joint infections involved patients who had undergone at least 1 previous surgical procedure to the elbow. Obesity may also play a role, especially in relation to the pin track infections, as most of our patients were obese. Of note, an early joint infection was found to be in continuity with the distal humeral pin. Although it is unclear whether this pin contributed to the joint infection, this case led to a change in the technique of frame placement, whereby all humeral pins were subsequently placed through a second, proximal incision at the diaphyseal level of the humerus (Fig. 4). In this way, any possible pin track infection would not be in continuity with the elbow joint. Regardless, patients with chronic elbow instability after fracture-dislocations must be counseled on the severity of the condition, with the potential for complications and additional surgical procedures.

Last, the ulnar nerve is not infrequently a source of morbidity in these patients. It can become scarred down after the initial injury or after additional surgical insults to the elbow. Surprisingly, we had no ulnar nerve dysfunction at follow-up. However, 17 of the 20 patients had the ulnar nerve decompressed and transposed during the clinical course (Table I). We released the nerve in any patient with chronic instability who had an extension contracture, nerve dysfunction, nerve sensitivity, or nerve traction signs.

This study has several limitations. It is a retrospective review with a relatively small sample size and a lack of a control group. In addition, joint congruity and arthritic changes were assessed by plain radiographs alone. Advanced imaging, such as computed tomography, would have provided greater detail of bone congruency and arthritis.

Conclusion

This is the first case series describing the use of static elbow external fixation in cases of complex elbow fracture-dislocations and chronic instability. At final follow-up, most patients had a stable joint with a functional range of motion.

Acknowledgments

Disclaimer

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