J Shoulder Elbow Surg (2012) ■, 1-7

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Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Floating elbow injuries in adults: prognostic factors affecting clinical outcomes

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Background: Floating elbow fractures in adults are rare and complex injuries with unpredictable outcomes. The present study was designed to assess our experience, analyze possible compilations, and illustrate prognostic factors of the final outcome.

Methods: Between 2002 and 2009, 19 patients with floating elbow fractures were treated in our department (mean follow-up, 26 months). The fractures were open in 10 patients (52.6%), and concomitant nerve palsy was present in 10 patients. Although the term "floating elbow" refers only to concomitant ipsilateral humeral and forearm shaft fractures, we also included injuries with intra-articular involvement. We categorized the patients into 4 groups: group I (10 patients) included shaft fractures of humerus and forearm, group IIa (5 patients) and IIb (1 patient) included partial intra-articular injuries, and group III (3 patients) involved only intra-articular comminuted fractures of the elbow region.

Results: Fracture healing was observed 14 weeks postoperatively, except in 2 patients, in which elbow arthroplasty was applied, and in 1 with brachial artery injury. Nine patients with nerve neuropraxia recovered 4 months postoperatively, and tendon transfers were necessary in 1 patient. Recovery in patients with nerve palsy was worse than in those without nerve injury (~~Minnesota~~ Elbow Performance Score, 73 vs 88.34; Khalfayan score, 72 vs 88.3). In addition, intra-articular involvement (groups II and III) negatively influenced the final clinical outcome compared with isolated shaft fractures (group I; ~~Minnesota~~ Elbow Performance Score, 71.1 vs 88.5; Khalfayan score, 72.67 vs 86.1).

Conclusions: Although the nature of floating elbow injuries is complex, the presence of nerve injury and intra-articular involvement predispose to worse clinical outcomes.

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

Keywords: Floating elbow; clinical outcomes; prognostic factors

In 1980, Stanitski and Micheli[17] introduced the term "floating elbow" to describe the injury pattern of ipsilateral supracondylar humerus and forearm axis fractures that "disconnect" the elbow from the remaining limb in children. This description has been extended to adults who

The Scientific Council of the "G. Papanikolaou" General Hospital approved this the project (Log No: 1970/7.13.2009).

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1058-2746/$ - see front matter © 2012 Journal of Shoulder and Elbow Surgery Board of Trustees.
http://dx.doi.org/10.1016/j.jse.2012.09.005

sustain concomitant fractures of the humerus and forearm in the same extremity.[21]

This constellation of skeletal trauma is relatively rare in both children and adults.[7,8,10-13,18-20] The spectrum of the fractures can vary greatly and depends on the force applied on the extremity and its position in space at the time of the incident. Although the term ''floating elbow'' was initially used only for humeral and forearm shaft fractures, it has been reported that concomitant articular fractures or elbow dislocation, or both, can also be present, leading to a functional joint disconnection from the remainder of the upper limb.[2,13-15,19] In this study, patients with combined humeral or forearm shaft fractures with intra-articular fractures around the elbow joint, which finally resulted in a functional ''floating elbow'', were also included.

All authors have emphasized the complexity of these injuries and the potentially unpredictable long-term functional results.[1,15] It has been well documented that surgical intervention has the most dependable clinical outcomes.[7,13,21]

The objective of this study is not only to review the treatment methods and the clinical outcome of patients treated in our department but also to identify possible prognostic factors leading to better or worse final results. Our study hypothesis is that final outcomes are not just dependent on the presence of nerve injury or open trauma, but one of the most important factors is the intra-articular extension of these fractures, limiting patient and physician expectations.

Materials and methods

Patients

Between December 2002 and January 2009, 19 patients who sustained floating elbow injury were treated in our orthopedic department. As mentioned above, we defined ''floating elbow'' trauma not only as shaft fractures of the humerus and the ipsilateral forearm bones but also as intra-articular lesions around the elbow region (distal humerus, radial head, and olecranon). Consequently, we included patients with traumatic shaft or intra-articular fractures, or both, that resulted in a functional floating elbow injury. The study excluded immature patients aged younger than 15 years, osteoporotic patients aged older than 60 years, and patients with rheumatoid arthritis, renal failure, and pathologic fractures.

The cohort comprised 19 patients (16 men and 3 women) who were a mean age of 33.7 years (range, 17-55 years). The dominant upper extremity was affected in 17 patients. Thirteen patients sustained injuries related to motor vehicle accidents, 2 had job-related injuries, and 2 fell from a significant height. A side-swipe injury in an automobile accident led to an open floating elbow in 2 patients.

Open fractures occurred in 10 patients (52.6%). In particular, 3 were open comminuted fractures around the elbow (1 type IIIA and 2 type IIIB according to Gustilo-Anderson classification for open fractures), 4 were type II and 3 were type I open fractures of the humeral or the ulnar shaft only. Finally, 1 patient sustained an open fracture of the humeral shaft and both of the forearm bones, complicated with brachial artery injury (type IIIC). All open fractures were classified according to the Gustilo-Anderson classification.[5]

Patients groups

In an effort to describe these complicated injuries, we categorized patients into 4 groups-types according to the presence or not of an intra-articular fracture (Fig. 1), in the same manner that Fraser and Hunter[3] classified ipsilateral fractures of the femur and tibia in 1978. Group I (10 patients) included a ''true floating elbow'' injury, with diaphyseal fractures only. Group-type II and III involved articular surface disruption of the elbow; more specifically, patients of group IIa (5 patients) had a humeral shaft fracture and an intra-articular fracture of the olecranon or the radial head, or both. Patients with type IIb (1 patient) injury had a forearm shaft fracture and intracondylar fracture of the humerus. Type III (3 patients) injury involved intra-articular fractures (comminuted in our case series) of the humerus and the olecranon or the radial head, or both. Q1

Surgical management

All patients were managed surgically. The preferred method of treatment for individual patients depended on the character of the fracture (Table I). All open fractures were emergently and initially treated with copious irrigation and surgical debridement.

In the 9 group I patients (patients 1, 4, 8, 10, 13, 14, 17, 18, 19), the humeral and forearm fractures were managed simultaneously with immediate internal fixation using a 4.5-mm LCP plate (Synthes, Paoli, PA, USA) to the humerus and 3.5-mm DCP-LCP plates (Synthes) to the forearm (Fig. 2). Patient 12 in group I had an open type IIIC fracture according to the Gustillo et al classification. The brachial artery was repaired, and the fractures were provisionally stabilized with external fixation. At 8 months post-trauma, the patient underwent final open reduction, internal fixation (ORIF) of the fractures with LCP plates (Synthes) and an iliac bone autograft.

The 5 group IIa patients (patients 2, 3, 7, 9, 15) were treated with internal fixation of humerus (LCP 4.5-mm) and then with ORIF of elbow fractures or with radial head replacement (patient 7).

In the group IIb patient (patient 5), we proceeded with internal fixation of the supra-intracondylar fractures of the humerus using the 3.5-mm anatomic Mayo Clinic Congruent Elbow Plate (Acumed, Hillsboro, OR, USA). The fractures of the ulnar shaft in this patient were treated with ORIF (3.5-mm LCP, Synthes).

Finally, 3 patients were included in group III (intraarticular complex multifragment fracture of the elbow joint, including humeral condyles, olecranon, and radial head). In patients 6 and 11, the open fracture was type IIIB with bone loss (condylar humerus, radial head, olecranon). These patients underwent initial stabilization of the elbow joint with external fixation. Three months later, a total elbow arthroplasty in patient 6 and an elbow hemiarthroplasty with reconstruction of the epicondyles in patient 11 restored joint movement. The last patient of this group (patient 16) underwent acute final surgical stabilization of the fractures using 3.2-mm Twinfix screws for the condyles and the radial head (Stryker Leibinger, Kalamazoo, MI, USA) and a 3.5-mm DCP-LCP plate (Synthes) for the olecranon.

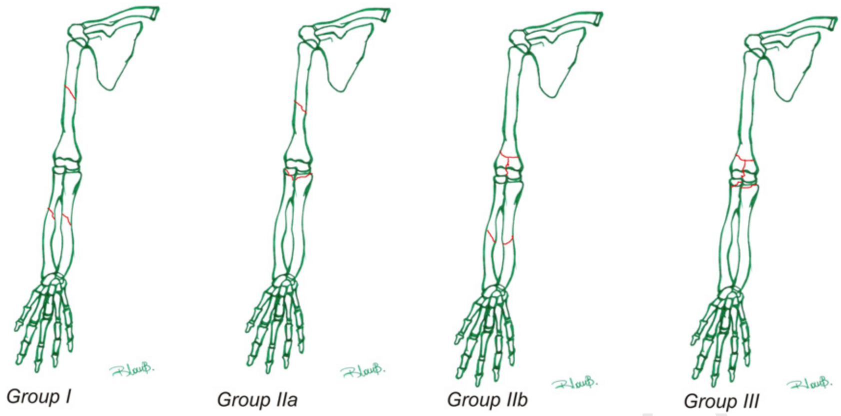

Figure 1 Patients grouped by injury type. *Group I*: diaphyseal fractures of humerus and forearm. *Group IIa*: humerus shaft fracture and an intra-articular fracture of the olecranon and/or the radial head. *Group IIb*: Forearm shaft fracture and intracondylar fracture of the humerus. *Group III*: Intra-articular fractures of the humerus and the olecranon or the radial head, or both.

Radial nerve palsy was observed in 9 patients (47.4%) during initial clinical evaluation, and nerve exploration was performed during the first surgical management of the fracture. In 8 patients, it was only neuropraxia, and function was restored within 3 to 6 months after the initial trauma. In 1 patient, although radial nerve exploration did not show any significant lesion, the nerve did not regain function during the first year of follow-up. Flexor tendons transfer was performed to restore wrist and digits extension 15 months after initial injury. Finally, ulnar neuropraxia complicated the open comminuted fracture of patient 6. Nerve function was restored 3 months post-trauma.

Rehabilitation

Rehabilitation of the elbow began early in most patients, when definitive internal fixation was achieved. Specifically, an elbow cast was applied for an average of 7 days as an initial immobilization. After this period, we encouraged passive and active uniplanar (flexion–extension) exercises of the elbow, with progressively increased range of motion. Rotational movements were allowed 8 to 14 weeks postoperatively, when callus formation was obvious. This program was modified in patients with open fractures, artery injury, or great intra-articular comminution, for example, where the provisional external fixation was replaced by total elbow or hemi-elbow arthroplasty (patients 6 and 11).

Functional evaluation

Follow-up averaged 26 months (range, 14-40 months) after the initial injury, depending on the complexity of the fracture and on further surgical interventions needed (patients 3, 6, 7, 11, and 12). All patients underwent a detailed clinical and radiographic examination by the same examiner (A.B.). Final clinical evaluation of the patients included evaluation of pain, elbow range of motion, elbow and grip strength, stability, and daily activity. For this purpose, we preferred the Mayo Elbow Performance Score (MEPS) and a standardized scoring system according to Khalfayan et al.[6]

The final score composite derived was used to grade the results as follows:

A. MEPS: excellent >90, good 75-89, fair 60-74, poor <60.
B. Khalfayan Scoring System: excellent 90-100, good 80-89, fair 70-79, poor <70.

A portable, hand-held isometric dynamometer (Isobex), a Link-German Baseline and a Jamar-Hand Dynamometer (Sammons Preston [now Patterson Medical Holdings], Bolingbrook, IL, USA) were used to measure elbow and grip strength.

Statistical analysis

Statistical analysis was performed using SPSS 18.0 software (SPSS Inc, Chicago, IL USA). In an effort to evaluate the prognostic factors of the final clinical outcomes, the analysis of variance 1-way test was used to compare group-type of the injury and the postoperative final MEPS and Khalfayan Scoring System result. We used the *t* test to compare final clinical outcomes between patients with and without nerve injury. Probability (*P*) values of less than 0.05 were considered to be statistically significant.

Results

Fracture healing was observed between 8 and 14 weeks postoperatively, except in patient 12, with open type IIIC fracture, where callus formation was obvious 12 months after the injury, after final ORIF and iliac autograft application. In addition, patients 6 and 11 underwent elbow arthroplasty 3 months after the initial injury. No deep infection or heterotopic ossification complicated fracture treatment.

The mean final arc of motion was 88.9° (range, 30°-110°), the average of elbow strength was 73.68% (range, 40%-100%), and the average of grip strength was 78.75% (range, 50%-100%) compared with the unaffected side. The final functional results of this study were as follows: 8 patients with excellent results, 3 with good, and 8 with fair results according to the MEPS. The mean score for the overall group was 80.26 (range, 60-95). According to the

Table I Details of our study population, including type of injury, treatment, complications, patient groups, and final clinical results

Patient	Age (years)	Fractures	Patient groups	Open-closed	Treatment	Nerve injuries	MEPS	Khalfayan score
1	17	Humerus shaft Radius ulna shaft	Group I	Type II -Humerus shaft	ORIF	No	95	92
2	24	Humerus shaft Olecranon	Group IIa	Type IIIA	ORIF	Radial nerve palsy	80	82
3	28	Humerus shaft Holstein fracture Radial head fracture	Group IIa	Type I	ORIF	Radial nerve palsy Tendon transfer 11 months post-op	70	70
4	29	Humerus shaft Radius ulna shaft	Group I	Type II	ORIF	No	95	94
5	33	Humerus supra-intracondylar Ulna shaft	Group IIb	Closed	ORIF	No	70	72
6	34	Distal humerus Olecranon Radial head-elbow dislocation	Group III	Type IIIB	Initially-Ex-Fix Finally-TEA	Ulnar Nerve Palsy	75	72
7	42	Humerus shaft Radial head-distal radius Elbow dislocation	Group IIa	Closed	Humerus-LCP Plate Radial head arthroplasty Wrist Ex-Fix	Radial nerve palsy	70	75
8	36	Humerus shaft Radial-ulnar shaft	Group I	Type II Ulnar Shaft	ORIF	No	90	91
9	45	Humerus shaft Olecranon	Group IIa	Closed	ORIF	Radial nerve palsy	70	72
10	32	Humerus-shaft + Galleazzi	Group I	Closed	ORIF	No	95	95
11	35	Intracondylar humerus + olecranon	Group III	Type IIIB	Initially Ex-Fix Finally hemi-elbow arthroplasty	Radial nerve palsy	70	70
12	25	Humerus shaft + ulnar shaft-radius shaft	Group I	Type IIIC	Initially Ex-Fix Finally ORIF	Radial Nerve Palsy	60	53
13	32	Humerus shaft + radius-ulnar shaft	Group I	Type I -Ulna	ORIF	No	95	93
14	20	Humerus Holstein + Galleazzi	Group I	Closed	ORIF	Radial nerve palsy	90	84
15	40	Humerus Holstein + radial head	Group IIa	Closed	ORIF	Radial nerve palsy	70	72
16	55	Humerus Hoffa + olecranon-radial head	Group III	Closed	ORIF	No	65	69
17	34	Humerus shaft + Monteggia	Group I	Closed	ORIF	No	95	95
18	42	Humerus Holstein + Galleazzi	Group I	Closed	ORIF	Radial nerve palsy	75	70
19	37	Humerus shaft + radius-ulna shaft	Group I	Type I	ORIF	No	95	94

Ex-Fix, external fixation; *MEPS*, ~~Minnesota~~ Elbow Performance Score; *ORIF*, open reduction, internal fixation; *TEA*, total elbow arthroplasty. Q3

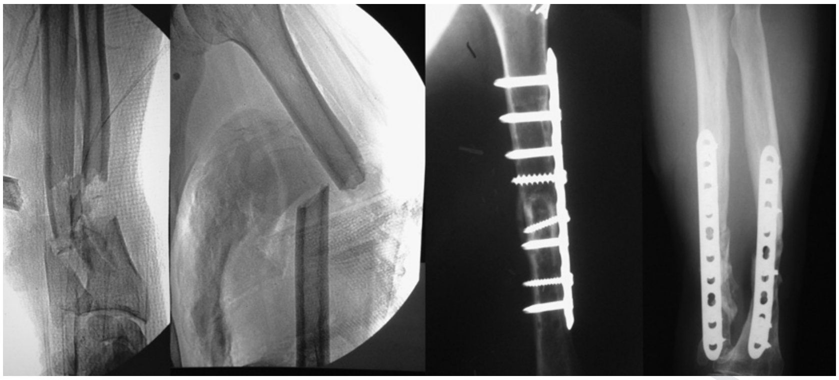

Figure 2 (**Left**) Patient with a floating elbow injury including only the humerus and forearm shaft fractures (group I). (**Right**) Fracture healing 3 months postoperatively. Q2

Table II Postoperative Mayo Elbow Performance Score and Khalfayan score according to the initial type of injury*

Group	Mayo Elbow Performance Score	Khalfayan score
I	88.5	86.1
IIa	72	73.6
IIb	70	72
III	70	71.3

* Worse clinical results in patients of group IIa, IIb, and III floating elbow injuries when articular surface is involved ($P < .001$ and $P = .01$ respectively). Q4

Khalfayan elbow scoring system, 7 patients had excellent results, 2 good, 8 fair, and 2 had poor results. The mean score was 79.73 (range, 53-95).

By Student *t* test analysis, it was evident that the presence of nerve injury (radial or ulnar nerve palsy) led to worse final functional results according to MEPS (mean, 73) and Khalfayan scoring system (mean, 72). Respectively, patients without nerve palsy recovered better (mean MEPS, 88.34; mean Khalfayan score, 88.3), and the difference was statistically significant ($P < .002$ and $P < .001$, respectively).

Group I patients with isolated shaft fractures had statistically significant better functional results (mean MEPS, 88.5; mean Khalfayan score, 86.1) compared with patients with intra-articular involvement (group IIa, IIb, III; mean MEPS, 71.1, $P < .001$; mean Khalfayan score, 72.67; $P = .01$). In particular, the mean MEPS and Khalfayan scores were, respectively, 72 and 73.6 for group IIa, 70 and 72 for group IIb, and 70 and 71.3 for group III (Table II).

The mean arc of motion was superior in group I patients (97.5°) compared with group II or III (79.4°; $P = .05$). Group-type I injuries also predispose to better overall elbow and grip strength than intra-articular group-type II and III injuries ($P < .005$). In detail, group I patients regained 86% of elbow strength and 88.7% of grip strength. At the final clinical follow-up, elbow and grip strength were 68.3% and 70%, respectively, for group II and 43.3% and 62.5% for group III patients (% uninjured side).

Open trauma injury did not generally predispose to worse functional outcomes ($P = .7$ by analysis of variance test), except in the patient with a type IIIC open fracture, who had the worst functional results.

Discussion

A floating elbow injury is a very rare fracture pattern, usually resulting from high-energy trauma. In most cases it is combined with serious soft-tissue injuries, leading to open fractures or nerve palsies with unpredictable functional outcome.[13,17,21] Few investigators, in relatively small patient series, have reported floating elbow injuries in adults,[4,7,8,11,13,19,21] and in most of the cases, their interest was focused on treatment patterns and clinical outcomes (Table III).

Treatment strategies have changed over time. In 1984, Rogers et al[13] reported a 100% nonunion rate in the humerus without rigid fixation. Since then, stable internal or external fixation of all fractures has been accepted as the treatment of choice for floating elbow injuries in adults.[15]

In addition to various methods of treatment, other reports[11,16,21] tend to identify factors that would affect final clinical outcomes. According to Pierce and Hodorski[11] and recently to Solomon et al[16] and Yokoyama et al,[21] concomitant radial nerve injuries are prone to lead to worse final clinical elbow scores. Other variables, such as vascular injuries, open fractures, soft tissue condition, or even choice or timing of fixation, failed to reveal statistically significant influence on the final follow-up. Studying our population, we also observed the negative prognostic value of nerve injury on the final MEPS ($P < .002$) and Khalfayan score ($P < .001$).

After reviewing the literature, we emphasize the fact that the initial description of "floating elbow" injuries referred only to midshaft fractures.[17,21] Concomitant articular fractures or elbow dislocation, or both, leading to a functional joint disconnection from the remainder of the upper limb, has also been reported.[2,13,14,19] Floating elbow injuries have

Table III Previously published studies with floating elbow injuries in adults

Floating elbow studies in adults	Patients, No.	Results	Negative prognostic factors
Solomon et al[15]	18	Khalfayan score Group I (n = 11): 83 Group II (n = 7): 45	Nerve injury
Rogers et al[12]	Group I (shaft fractures): 11 Group II (concomitant elbow injuries): 8	No score used	Nonoperative treatment worst results
Yokoyama et al[20]	14	Mean Khalfayan score: 79	No specific factors identified Surgical stabilization needed
Pierce et al[10]	21	No score used	No specific factors identified Frequent nerve injuries
De Carli et al[2]	Case report	Satisfactory result 130° flexion 45° extension	No specific factors identified
Sarup et al[13]	Case report	Excellent Results	No specific factors identified

only been described using the criteria of the AO Foundation/Orthopaedic Trauma Association for individual long-bone fractures.[9] In 2006, De Carli et al[2] made an effort to categorize ‘‘floating dislocated elbow’’ injuries according to severity and morphologic complexity. The authors, based on their case report and review of the literature, included only dislocated elbows and not all fracture patterns of ‘‘floating elbow.’’

In an effort to correlate final clinical outcomes and the initial trauma constellation, we categorized all patients into subgroups according to the anatomic fracture involvement. The expected clinical outcome depends on the initial articular fracture. Moreover, the differences of the final elbow scores between the 4 patient groups were statistically significant, enhancing the prognostic value of the initial combination of fracture types.

Our categorization of patients with floating elbow injuries into 4 group-types with considerable homogeneity regarding fracture type, surgical treatment options, and final clinical outcomes, constitute the strength of this study. In addition to the prospective data collection, the same 3 shoulder and elbow surgeons (K.D., P.P., P.G.), with a uniform surgical technique and a common postoperative protocol, performed all procedures, and the same examiner (A.B.) carried out all clinical follow-up examinations. However, bearing in mind the rarity of the injury pattern, we appreciate that the present case study is faced with the limitation of the relatively small study population. Conclusions should therefore be reviewed in light of the aforementioned limitation.

Conclusions

Floating elbow is a rare complex injury with unpredictable outcome, despite adhering to the rule of stable and rigid internal fixation. Beyond nerve injuries, anatomic area involvement and, especially, disruption of the articular congruency have been proved to play the most significant role on final clinical result.

Acknowledgment

We acknowledge Vasileios Blanas, graphic designer, for his drawings (Fig. 1).

Disclaimer

The present investigation did not receive any external funding.

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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