International Journal Dental and Medical Sciences Research
Volume 6, Issue 5, Sep - Oct 2024 pp 255-261 www.ijdmsrjournal.com ISSN: 2582-6018

Floating Elbow in Adults: A Review of Outcomesin 22 Patients with Floating Elbow

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Submitted: 01-10-2024 Accepted: 10-10-2024

Objective: To assess functional outcomes and predictors of success in floating elbow injuries.
Design: Retrospective clinical review.
Setting: Level 1 trauma center.
Patients: Eighteen patients with floating elbow injuries seen at the trauma center from 2022-2024
Intervention: All injuries were managed surgically. Each forearm fracture was managed with open reduction and internal fixation. Humerus fractures were managed with either open reduction and internal fixation or intramedullary nail. Definitive fixation was performed in all cases within 48 hours of arrival at the trauma center.
Main Outcome Measurements: Twenty two patients were available for follow-up at a minimum of 1 year and consented to enroll in the study. Each patient was evaluated with a standardized elbow score based on a 100-point scale. These scores were correlated with injury features including age, severity of fracture (AO classification), open fractures, nerve injuries, vascular injuries, type of fixation on the humerus, and the presence of concomitant intra-articular elbow injuries.
Results: The average elbow score was 68/100. Outcomes were divided into two groups. Eleven patients had a score greater than 75 (group I), with a meanscore of 83, and were considered to have a good or excellent result. Seven patients had a score less than 75 (group II), with a mean score of 45, and wereconsidered to have a satisfactory or poor result. The distribution of outcomes revealed two statistically distinct clusters. Additionally, there was a significantly higher incidence of nerve injuries in group 2 compared with group1.
Conclusions: Functional outcomes in floating elbow injuries tend to cluster into two groups—patients with good or excellent results and patients with poor results. Patients with associated nerve injuries have lower functional outcomes at a minimum of 1-year follow-up.

Diaphyseal fractures of the ipsilateral humerus and forearm are termed as floating elbow injuries.[1] These injuries are comparatively rare in adults and children.[2–5] It has been well demonstrated in the literature that these injuries are treated most effectively with surgical stabilization of the humerus and the forearm.[2,4,6] Studies have emphasized the complexity of these injuries and the potential for long-term disability.[7–10] The objective of this study was to review the functional outcomes of patients treated at our institution for a floating elbow injury. We aimed to identify factors associated with the injury or treatment that influenced these outcomes.

I. MATERIALS AND METHODS

We identified 26 patients treated at our Level 1 trauma center for a floating elbow injury since 2022 (Table 1). Hospital charts, x-rays, and clinic notes were reviewed with approval from the Institutional Review Board on each of these 26 patients. Demographic data, time to union, complications, types of fixation, and concomitant injuries were noted. Of these patients, 22 were available for a functional evaluation at least 12 months after their injury. The elbow scores of these 22 patients comprise the outcome portion of this study (see later).

The injury was defined as ipsilateral fractures of the humeral, radial, and ulnar shafts. (Figs. 1 and 2) All except two patients were treated by the same surgeon within 36 hours of their admission to the trauma center. Each of the forearm fractures was treated with open reduction and internal fixation (ORIF).The humerus fractures were treated with either ORIF or an intramedullary (IM) nail. This decision was made by the attending surgeon and was based primarily on the integrity of the soft tissues at the time of injury. Patients with more severely injured soft tissues were treated with IM fixation. Three patients with grossly contaminated open fractures were managed with external fixation of the humerus and the forearm on admission, followed by definitive fixation within 48 hours. Three of the patients had concomitant intra-articular elbow fractures that were treated simultaneously. These fractures are classified in Table 1 and include an open olecranon fracture, an intra-articular distal humerus fracture, and one articular fracture of the proximal radius and ulna.[11]

There were 15 male patients and 11

International Journal Dental and Medical Sciences Research
Volume 6, Issue 5, Sep - Oct 2024 pp 255-261 www.ijdmsrjournal.com ISSN: 2582-6018

female patients, with a mean age of 36.9 years. There were a total of 14 open fractures in 11 patients with at least one isolated open fracture, 11 patients had at least one peripheral nerve or brachial plexus injury, 1 patient had a vascular injury requiring repair for limb salvage, and 2 patients developed an associated compartment syndrome. All open injuries were classified according to Gustillo et al.[12] There were four open humeri, which included two type II, one type IIIA, and one type IIIB. Ten forearm fractures were open; these included two type I, one type II, four type IIIA, two type IIIB, and one type IIIC. Three of these patients had open fractures of the humerus and the forearm. Six patients had associated closed

TABLE 1 : Patient Demographics

Patient	Age	Fracture	Treatment	Neurovascular Injury	FEE	Follow-Up (mo)
Group I						
1	20	12-A3/open II 22-B3/closed	ORIF ORIF	None	93	18
2	14	12-B2/closed 22-C3/open IIIC	ORIF ORIF	Ulnar art. vein graft; med. nerve palsy; compartment syndrome; groin flap	83	14
3	42	12-B3/closed 22-B2/closed	IM nail ORIF	None	75	16
4	34	12-B3/closed 13-A1/open IIIA 21-B1/open IIIA 22-C1/open IIIA	IM nail ORIF ORIF ORIF	None	79	21
5	60	12-C2/open IIIB 22-B3/open II	ORIF ORIF w/ abx spacer (ulna)	Radial nerve end plate avulsion	80	16
6	52	12-B2/closed 22-A2/open I	ORIF ORIF	None	88	16
7	71	12-B2/closed 22-B3/closed	ORIF ORIF	Radial nerve palsy	75	18
8	35	12-C2/closed 22-C2/open IIIA	ORIF ORIF	None	86	12
9	38	12-B1/closed 22-A2/closed	ORIF ORIF	None	92	12
10	54	13-C2/closed 22-C1/open IIIB	ORIF ORIF	None	84	13
11	19	12-B2/closed 22-B3/closed	ORIF ORIF	None	82	12
12	33	12-B3/closed 22-B3/closed	ORIF ORIF/ICBG	Radial nerve palsy	80	14
13	26	12-B3/closed 22-B2/closed	ORIF ORIF	None	79	12
Group II						
1	56	12-B2/closed 22-C2/open IIIB	ORIF ORIF	Radial and ulnar nerve palsies; BEA	51	26
2	39	12-A2/closed 22-A2/closed	ORIF ORIF	Ulnar nerve palsy	55	20
3	20	12-A2/closed 22-A3/closed	IM nail ORIF	None	37	14
4	25	12-A3/closed 22-B3/closed	IM nail ORIF	Brachial plexus avulsion	42	18
5	47	12-B2/open II 22-C3/open IIIA 21-C2/open IIIA	ORIF ORIF ORIF	Radial nerve palsy; ulnar nerve lac.; brachial plexopathy	20	14
6	22	12-B2/closed 22-B3/closed	ORIF ORIF	Radial nerve palsy; musculocutaneous nerve palsy	61	17
7	56	12-A3/closed 22-A3/closed	ORIF ORIF	Media, radial and ulnar nerve palsy	37	22
8	62	12-A2/closed 22-A2/closed	ORIF ORIF	Ulnar nerve palsy	46	14
9	43	12-C1/closed 21-C3/Open I	ORIF ORIF	Radial nerve palsy	54	18

Group III (lost to follow-up)*						
1	33	12-B3/closed 22-B3/closed	ORIF ORIF/ICBG	Radial nerve palsy	0	0
2	43	12-B3/closed 13-C2/closed 22-B1/closed	ORIF ORIF ORIF	None	0	0
3	23	12-C1/closed 21-C3/Open I	ORIF ORIF	Radial nerve palsy	0	0
4	26	12-C3/closed 22-A1/closed	IM nail Non-op	None	0	0

head injuries, and 19 of 26 patients had associated orthopaedic injuries requiring surgical intervention. The nerve injuries were varied. Six radial nerve injuries included one end plate avulsion into the extensor pollicis longus, which was treated with a tendon transfer; one transection above the elbow requiring sural nerve grafting; and four above-elbow neurapraxias. Two median nerve injuries included one 15-cm segmental loss in the forearm and one below-elbow neurapraxia with partial recovery. Four ulnar nerve injuries included one below-elbow segmental loss and three below-elbow neurapraxias. There was one musculocutaneous neurapraxia with partial recovery and two brachial plexus injuries, including one root avulsion and one mixed brachial plexopathy. One patient had segmental bone loss in the ulna that was treated with an antibiotic-impregnated cement spacer and delayed reconstruction. Average time to union of all three fractures was 11.8 weeks (range 7–17 weeks). Four patients required iliac crest bone grafts acutely, and there were no non unions in the study.Two patients had compartment syndromes of the forearm on presentation, which were acutely decompressed.

Complications included deep infections in three patients, which were treated with irrigation and debridement, and cellulitis in one patient, which responded to intravenous antibiotics. One patient required revision of a brachial artery vein graft and a free flap to the forearm on different occasions. One patient had a wound slough that required debridement and VAC dressing for delayed closure. None of the patients in this study developed post-traumatic arthritis of the elbow within the follow-up period.

Post operatively, patients began active and passive range of motion within 1 week when soft tissues would allow.[13] Postoperative protocols were individualized, however, in patients who required vascular repair, soft tissue coverage, or tendon repair/transfer.

FUNCTIONAL EVALUATION

After obtaining approval from our institutional review board, patients were contacted and asked to return for a functional evaluation of their elbow. This examination included evaluation of pain, strength, range of motion, and ability to function during activities of daily living. This examination was used to generate an elbow score based on a 100-point system as described by Khalfayan et al14 (Fig. 3). In this system, a score greater than 90 defines excellent results, 80–89 defines good results, 70–79 defines fair results, and less than 70 defines poor results. Of the 26 patients, 22 were contacted and consented to enroll in the study. The remaining four patients were lost to follow-up and could not be contacted.This left 22 patients in whom functional evaluation was performed. Average length of follow-up in these 22 patients was 24.3 months (range 12–54 months).

FIGURE 1. Anteroposterior upper extremity x-ray in a patient with floating elbow with diaphyseal fractures of the humerus, radius, and ulna (group I, patient 7 in Table 1).

II. RESULTS

The final functional results for the entire study were as follows: three patients with excellent results, seven with good results, four with fair results, and eight with a poor functional outcome according to the elbow score employed in this study. The mean score for the overall group was 68.4 (range 20–93 and SD 21.4). Average elbow motion was 17–115°, and the grip strength averaged 35% of the uninjured side. The overall ranges for extension were 0–50°, flexion 55–145°, and grip strength 0–77% of the uninjured side. Four patients were treated with an IM nail in the humerus and ORIF on the radius and ulna. The remaining patients were treated with ORIF of the humerus, radius, and ulna. The specifics of each patient's injury are outlined in Table 1.

The functional outcomes were divided into two groups (Fig. 4). Patients in group I (n = 13) had a score greater than 75 and were considered to have a good or excellent result. The mean score in group I was 83.4 (SD 5.8); the median in this group was 83. Six patients were men, and seven were women. The average age in this group was 39.9 years (range 14–71 years). Elbow motion averaged 15–131°, and mean grip strength was 47% that of the uninjured extremity. The ranges of extension were 0–45°, flexion 100–145°, and grip strength (% uninjured side) 12–77%.

Group II (n = 9) comprised patients with an elbow score less than 75. Scores less than 75 correlate to fair or poor out comes in the scoring system employed. The mean score in group II was 44.9 (SD 12.5); the median was 48. There were seven men and two women in this group with an average age of

37.9 years (range 20–56 years). In this group, elbow motion averaged 20–89° with grip strength 14% of the uninjured extremity. The ranges of extension were 0–50°, flexion 55–120°, and grip 0–38%. The elbow scores in these two groups were statistically different using a median test with a P exact< 0.001.

FIGURE 2. X-rays of the patient from Figure 1 taken 8 months postoperatively reveal open reduction and internal fixation of the humerus, radius, and ulna.

We compared these two groups of outcomes with respect to various factors associated with the injury, including age, incidence of open fractures, incidence of nerve injuries, incidence of vascular injuries, incidence of closed head injuries, development of heterotopic bone, the presence of an associated intra-articular elbow injury, whether an IM nail or ORIF was used to treat the humerus fracture, and the presence of associated major skeletal injuries (Fig. 5).

The mean elbow score in group I was 83.4 (SD 5.8 and range 75–93). The incidence of open fractures in this group was 8 of 13 patients (64%). Four of the 13 patients (27%) had closed head injuries; one patient (9%) had a vascular injury that required repair, and two patients (18%) had associated intra-articular elbow injuries. Two patients (18%) were treated with an IM nail in the humerus. None of the patients in group I developed heterotopic ossification during the study period. Of the four patients (27%) with nerve injuries, one had segmental loss of the median nerve in the forearm and an above-elbow radial nerve neurapraxia. One patient had a radial nerve end plate avulsion into the extensor pollicis longus, and the third patient had an above-elbow radial nerve neurapraxia. Seven of the patients in group I had significant associated musculoskeletal injuries requiring surgical intervention.

The mean elbow score mean in group II was 44.9 (SD 12.5 and range 20–61). The incidence of open fractures was three of nine patients (29%). One of the seven patients in this group (14%) had a closed head injury, no patients had a vascular injury, eight (86%) had other skeletal injuries requiring surgery, and one (14%) had an associated, ipsilateral elbow injury. One patient was treated with an IM nail in the humerus.Two patients developed heterotopic ossification—one of whom had the closed head injury. Of the eight patients (86%) who had nerve injuries, one had radial and ulnar nerve neurapraxias below the elbow, one had an acute ulnar nerve neurapraxia with partial recovery, and

International Journal Dental and Medical Sciences Research
Volume 6, Issue 5, Sep - Oct 2024 pp 255-261 www.ijdmsrjournal.com ISSN: 2582-6018

one had a brachial plexus nerve root avulsion. One patient hada mixed brachial plexopathy and a radial nerve neurapraxia above the elbow, an ulnar nerve laceration, and a median nerve neurapraxia below the elbow. One patient had above-elbow radial and musculocutaneous nerve neurapraxias, and the final nerve-injured patient had an above-elbow radial nerve neurotmesis with sural nerve graft and median and ulnar nerve neurapraxias below the elbow with partial recovery.

Using a Fisher exact test, the only variable studied that was statistically significant was the incidence of nerve injuries (27% in group I versus 86% in group II) with a P value of 0.024 (Fig. 5). Using these results, we then looked at the occurrence of any nerve injury as an independent variable in the prognosis of outcomes after a floating elbow injury. The study patients were divided into two groups—patients with a nerve injury of any type in the injured extremity and patients without a nerve injury—and their functional outcomes werecompared. Patients with a nerve injury (n = 11) had a mean elbow score of 56.0 (SD 21.1). Patients with no nerve injury (n = 11) had a mean elbow score of 79.6 (SD 16.8). This difference was statistically significant using an unpaired Student t test with P = 0.019.

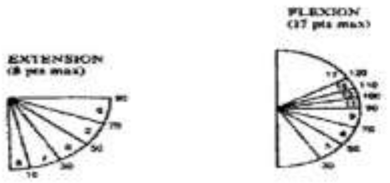
III. DISCUSSION

A floating elbow results from high-energy trauma and is a rare injury. There is a high incidence of associated injuries in the involved extremity, including neurovascular trauma, soft tissue loss, and open fractures.[1,3–6,15]

The treatment of this combination of injuries is complex and fraught with complications.[3,4,9,11] Since 1982, when Rogers et al[6] reported a 100% nonunion rate in the humerus on floating elbow injuries treated without rigid fixation in the humerus, it has been accepted that rigid fixation of the forearm andhumerus fractures was the treatment of choice for this injury. More recent reports have attempted to identify factors that would predict success or failure in the treatment of this injury.[9,15] To our knowledge, this is the first study to identify statistically any associated injury or treatment variable as a

A. Pain (maximum points 30)
Score = (points divided by 30) X 25
None (30); slight, with continuous activity, no medication (25); moderate, with occasional activity, some medication (15); moderately severe, much pain, frequent medication (10); severe, constant pain, markedly limited activity (5); complete disability.

B. Motion (maximum points 37)
Score = (points divided by 37) X 25



PRONATION/SUPINATION
(pt) = 0.1 per degree
(6 pts max each)

C. Strength (maximum points 18)
Score = (points divided by 18) X 25

1. Elbow Strength (10 Points)
5 = normal; 4 = good; 3 = fair; 2= poor; 1 = trace; 0 = paralysis;
N/A = not available

		Flex.	Ext.	Pro.	Sup.
Normal	5	(5)	(4)	(3)	(3)
Good	4	(4)	(3)	(2)	(2)
Fair	3	(3)	(2)	(1)	(1)
Poor	2	(2)	(1)	(0)	(0)
Trace	1	(1)	(0)	(0)	(0)
None	0	(0)	(0)	(0)	(0)

Index X 0.67 = Elbow Strength Points

2. Grip Strength (8 Points)
Percentage of uninjured extremity: ≥ 90% (8); ≥ 80% (7); ≥ 70% (6); 60% (5); ≥ 50% (4)

D. Function (maximum points 12)
Score = (points divided by 12) X 25
Normal (1); Mild compromise (0.75); difficulty (0.5); with aid (0.25); unable (0);
N/A = not applicable

1. Use back pocket
2. Rise from chair
3. Perineal care
4. Wash opposite axilla
5. Eat with utensil
6. Comb hair
7. Carry 10-15 pounds with arm at side
8. Dress
9. Pulling
10. Throwing
11. Do usual work
12. Do usual sport

FIGURE 3. Form showing the scoring of the evaluation of the elbow

prognostic indicator in floating elbow injuries. In this study, sustaining a nerve injury of any type predicted a worse outcome in patients with a floating elbow. The other variables studied, including vascular injury, open fractures, associated elbow injuries, and choice of fixation on the humerus, failed to reveal statistical differences. According to the elbow score employed in this study, patients with floating elbow injuries tend to have a bimodal distribution of long-term outcomes. At a minimum of 1 year, some patients had recovered

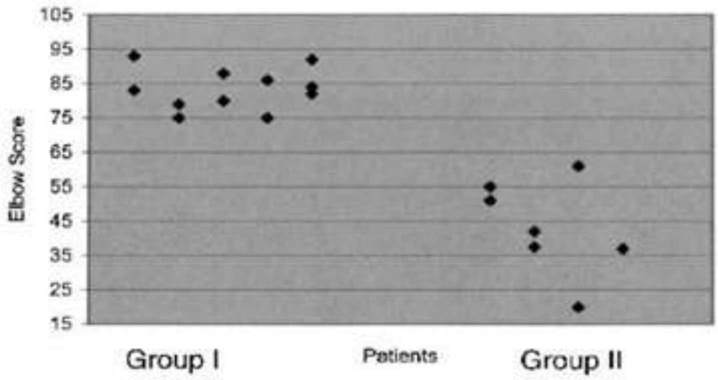


FIGURE 4. Functionalelbow scores revealedtwo statistically distinct clusters of outcomes.

as if they had had an isolated fore arm or humerus fracture, whereas others recovered with significant upper extremity disability. This finding led to the data analysis attempting to identify the factors that could help predict outcomes. In 1979, Pierce and Hodorski[4] reported a series of 21 cases in which there were ipsilateral fractures of the humerus, radius, and ulna. Although only six of these cases were diaphyseal injuries of all three bones, and treatment methods varied, the authors concluded that residual nerve damage was a significant predictor of poor results based on their own method of obtaining functional and subjective outcomes. More recently, Yokoyama et al[15] reported on 15 floating elbows in 14 patients. Using methods similar to the study presented here, their data did not reveal a statistical difference between patients with acceptable and unacceptable outcomes when evaluating incidence of neurovascular injuries, open fractures, immediate versus delayed fixation, or average injury severity score. These authors concluded, however, that patients with an associated brachial plexus injury, peripheral nerve injury, or multisystem injury have the potential to result in poor functional outcomes. This conclusion echoed Simpson and Jupiter's review article[9] that described the complex nature of the floating elbow injury and noted that concomitant neurovascular trauma potentially could lead to long-term functional disability. As with previous reviews of this rare injury, our study is limited by size and follow-up in a trauma population.

Our data support what has been suspected in the literature—that sustaining a nerve injury is a poor prognostic indicator in the small population of patients with floating elbow injuries. Although the term nerve injury represents a broad spectrum of nerve damage, further stratification of the type and location of nerve injury in our study failed to realize significant differences. Additionally, many other associated factors studied here and in previous reports have failed to show a statistical correlation with functional outcomes. The results of this study also reveal the irregular distribution of outcomes after a floating elbow injury. Poor out comes surely have a multifactorial origin, and the exact combination of injuries and complications that lead to long-term disability is varied. We hope that this study will help orthopaedic surgeons more accurately counsel their patients and their patients' families regarding the long-term outcomes of floating elbow injuries and the implication of a concomitant nerve injury.

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