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The plate fixation in the treatment of complex forearm open fractures

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ABSTRACT

Objectives: We aimed to evaluate the safety and outcomes of plate-screw fixation used for the immediate treatment of type-IIIC open fractures of forearm bones with complex soft tissue injuries.

Methods: A total of 22 patients (mean age: 31.6, range: 24-60) treated between 2004-2010 were retrospectively analyzed. All injuries resulted from high-energy traumas and fractures were classified using AO classification. All patients had vascular and nerve injuries, and four had skin defects associated with double fractures of the forearm. All patients were operated on within the first eight hours following injury. Six patients with comminuted fractures or with bone defects underwent primary bone grafting, and one patient was treated with shortening. Primary skin closure was achieved in 17 patients and three patients underwent immediate repair using skin grafts, while two patients were repaired with immediate transposition flaps. Bony unions, complications, and functional results via a DASH questionnaire were investigated.

Results: Mean follow-up was 28 months (range: 14-70). In all patients, radius bone union was achieved. Two patients underwent a Sauve-Kapandji procedure, utilizing the fractured segment of the ulnar diaphysis as a graft for radius. In one patient, osteosynthesis was repeated after 6 months because of nonunion. Mean period to bony union was 4.59 months (range: 3-6). Superficial infection developed in three patients after the operation, and was resolved with antibiotic therapy. The mean DASH score after surgery was 25.6.

Conclusion: In high nergy traumas of the upper extremity associated with complex injuries and Type-IIIC forearm fractures, severity of soft tissue injuries determined the functional results in patients, demonstrating it is possible to achieve a safe and efficient fixation with immediate plate-screw osteosynthesis.

Key words: *Forearm; open fracture, complex fracture, plate fixation*

Introduction

For high quality of life of patients, forearm functionality is very important. In complicated forearm injuries resulting from occupational accidents, the most appropriate recovery of upper extremity function should be sought and therapy should be planned accordingly. To ensure an efficient and safe post-operative rehabilitation with the protection of soft tissues repaired during the operation, stable fracture fixation should be the goal [1-5].

In the treatment of open fractures, primary therapeutic goals may be summarized as bone union, prevention of infection and restoration of function. In the cases where vascular injury accompanies open frac-

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tures (Gustilo-Anderson type IIIC and Tscherne type III), the primary goal is to maintain the vitality of the extremity [1-4,6].

Use of internal fixation methods for both baseline and late treatment for open fractures is a contradictory issue [5-8]. However, there are significant differences between open bone injuries of the upper and lower extremity in terms of treatment plans [1]. In this study, we aimed to evaluate the safety and outcomes of plate-screw fixation used for the immediate treatment of subjects with forearm Gustilo-Anderson type IIIC and Tscherne type III open fractures from occupational accidents.

Patients and Methods

A total of 22 patients (21 men, 1 woman, mean age: 31.6, range: 24-60) treated between 2004 and 2010 as a consequence of Gustilo-Anderson type IIIC and Tscherne type III open fractures in the forearm were retrospectively studied. The injuries were located in the right extremity in eight patients (36.5%). All injuries resulted from high-energy traumas (Figures 1a, 2a). Injuries came about from being crushed under a heavy object, in a roller or in a pressing machine in 12 patients (55.6%) and from accidents caused by cutting or blender caterpillars in 10 patients (45.4%). 13 patients had double fractures, five patients had isolated radial fractures and four patients were determined to have isolated ulnar fracture (Figure 1b, 2b). Fractures were classified via AO classification as well as with anatomic localization [9]. While all patients had vascular and nervous lesions, four patients had skin defects accompanying double fractures of the forearm (Figures 1a, 1b) (Table 1). The mean duration between the occurrence of the injury and the time of admission to the hospital was 4.2 hours (range: 1-7 hours). All patients were operated on within the first eight hours after the occurrence of injury. During the follow-up, development of complications, union status and functional results were evaluated. In X-rays obtained during the follow-up period, disappearance of fracture line and the presence of bridging trabeculae were considered a complete union. For the evaluation of functional outcomes, the DASH scoring system was used [10]. Mean duration of follow-up was 41.4 months (range: 29-70).

Figure 1. (A) 39-year-old man with type IIIC open fracture at the radius and ulna diaphysis with excessive soft tissue damage in the right forearm. **(B)** Preoperative X-ray view shows the comminuted fractures at the radius and ulna diaphysis. **(C)** Postoperative 1st day antero-posterior (AP) and lateral X-ray views.

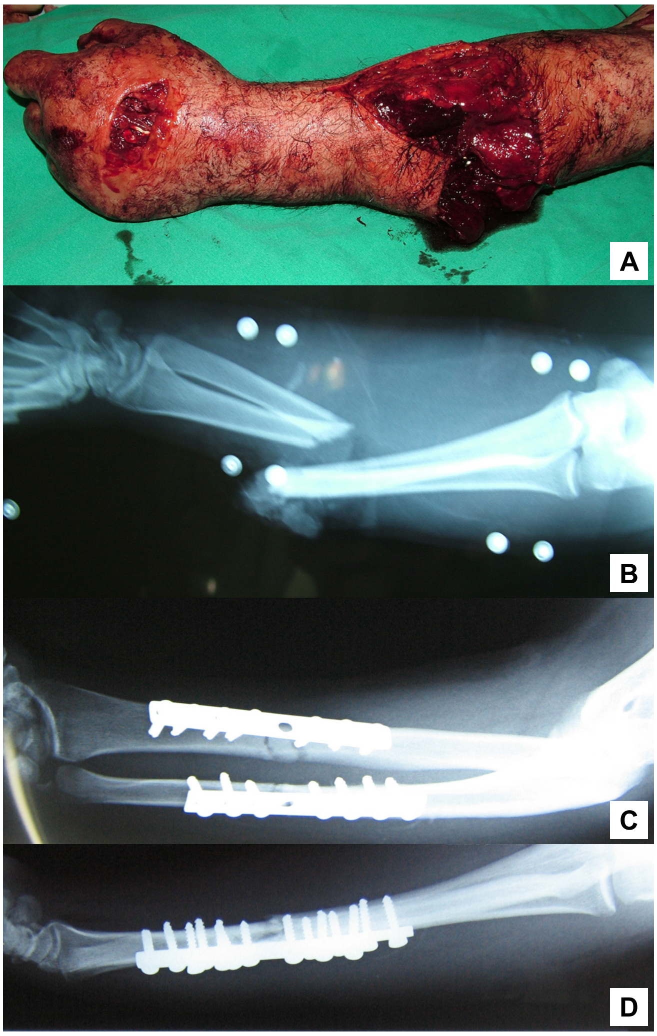

Figure 2. (A) 29-year-old man with a crush injury that occurred after an occupational accident. **(B)** Preoperative AP X-ray views. **(C-D)** Postoperative 1st day AP and lateral X-ray views.

Surgical Technique

Patients accepted in the emergency department were initially evaluated for the presence of other life-threatening injuries before orthopedic intervention. Bleeding was always immediately controlled. All patients were administered triple antibiotic therapy (cephalozin sodium - 4x1 g/day, gentamicin - 1x160 mg/dayand ornidazole - 2x500 mg/day) and tetanus prophylaxis. Of the patients who were transferred to the operation room, 19 were provided with axillar block and three were put under general anesthesia. The injured area was irrigated with at least 3000 cc saline. All devitalized tissues were removed by debridement. Bone fixation was performed using steel AO-type DCP plates (Figures 1c, 2c, 2d). In two patients, the segment of the ulna diaphyseal fracture was transposed to the radial defect as a bone graft and the Sauve-Kapandji procedure was applied to the distal ulna in these patients [11]. Four patients with multi-fragmentary or defective fractures underwent primary bone grafting and one patient was provided with acute shortening. In two of these four patients, the olecranon, and in the other two, iliac bone, was used as a donor site for the autograft region. After bone fixation, arterial, venous and nervous anastomoses were performed. After the repair of the tendon or muscle, the skin was primarily closed in suitable subjects. Of the patients with skin defects, the repair was performed by using transposition flaps in two (9%) patients and skin grafts in three (13.6%) patients. In the patients without the additional finding of infection, antibiotic prophylaxis was maintained for five days. In all patients, enoxaparin 0.6 ml/day was administered for anti-aggregation. Beyond six weeks, the patients were followed up with a rehabilitation program that included active movement and reinforcement protocols.

Results

At the end of the follow-up period, complete union of the radius was achieved in all patients. In one patient, ulna pseudoarthrosis occurred and so they were continued to be followed up with (Table 2). Mean duration time to union was 4.6 months (range: 3-6). In one patient with radius pseudoarthrosis, osteosynthesis was repeated with bone grafting at the 3rd month based on union deficiency (Table 2). Synostosis was not detected during the last follow-up appointments in any of the patients that underwent bone grafting.

The superficial infection rate was 13% after the operation and easily resolved with the use of antibiotherapy. In the wound culture, P. aeruginosa was detected in two patients and S. aureus was detected in one patient (Table 2).

In the follow-up from the primary operation, 18% of patients had skin problems (Table 2). Skin defects were repaired using local flap in one patient, free flap in another patient and skin grafts with partial thickness in two patients. The implants were not removed from any of these patients. During the last monitorizations, the mean DASH score was 25.62 (Table 2).

Discussion

High-energy upper extremity traumas often result

Table 1. Patients' age, gender, side data, fracture region and type and accompanying injuries.

No	Age	Gender	Side	Fractured bone	Anatomic fracture region	AO Classification	Arter injury	Nerve injury	Tendon injury	Skin defect	Additional lesion
1	60	Male	L	R	1/3 middle-proximal	22-B2	Radial + ulnar	Median + ulnar	FDS, FDP (2,3,4,5)	-	
2	32	Male	R	R+U	1/3 middle-distal	22-B3	Radial + ulnar	Median	BR, FCR, FDS,	-	
3	28	Male	L	R+U	1/3 middle-distal	22-A3	Radial	Radial	FCR, EDC, EİP, EDM	-	Right humerus diaphysis fracture
4	50	Male	L	R+U	Radius distal 1/3 ulna 1/3 middle-distal	22-C2	Radial	Median	FCR	-	
5	28	Fe-male	R	R+U	1/3 distal	22-C3	Radial + ulnar	Median	FCR,PT	-	
6	34	Male	R	R	1/3 middle	22-B2	Radial	Radial nerve superficial branch	FCR, ECRL, ECRB, APL, EPB, EDC	-	
7	27	Male	R	R+U	1/3 middle-proximal	22-A3	Radial	Radial	FDS, FDP, EDC	-	
8	27	Male	L	R+U	1/3 middle-proximal	22-C3	Multiple-sided radial + ulnar	Median + ulnar	FDC, FDS (2,3,4), FPL, FCR,	-	3. finger proximal phalan-ges + 4.metacarp diaphysis fracture + 1.finger amputation
9	27	Male	L	R+U	1/3 middle-distal	22-A3	Ulnar	Ulnar	EDC	+	Wrist luxation+ 4. and 5. metacarp diaphy-sis fracture
10	46	Male	L	R+U	1/3 distal	22-C3	Multiple-sided radial + ulnar	Median + ulnar	FCR, EPL, FPL, FDP, EPB, APL	+	Wrist luxation
11	42	Male	L	R+U	Comminuted segmenter fracture	22-C3	Radial	Median	-	+	
12	24	Male	L	R+U	1/3 middle	22-C3	Radial + ulnar	Median + radial + ulnar	Flexor group, ECRB, ECRL	-	
13	33	Male	L	U	1/3 proximal	22-A1	Radial + ulnar	-	Flexor group + Brachio-radialis muscle rupture	-	
14	47	Male	R	R	1/3 middle-distal	22-B2	Radial	Radial nerve superficial branch	EPL, APB, APL, BR, EPB, ECRL, ECRB, FPL, FCR	-	
15	31	Male	R	R+U	1/3 middle-distal	22-C2	Radial	Radial nerve superficial branch	-	+	2.metacarp neck fracture
16	45	Male	L	U	1/3 distal	22-B1	Ulnar	Ulnar	ED (4,5), EDM, ECU, FCU	-	
17	24	Male	L	R	1/3 middle-proximal	22-B2	Radial ulnar	Median + ulnar + radial	Flexor group muscle injury	-	
18	43	Male	L	U	1/3 middle-distal	22-B1	Ulnar	Ulnar	FCU, ECU, EDM, EDC (4,5)	-	
19	25	Male	L	R+U	1/3 middle	22-A3	Ulnar	Ulnar	Biceps, brevis muscle injury, ED (2,3,4,5), EPL	-	Left humerus diaphysis fracture + radial nerve injury + 4.finger distal phalanges subtotal amputation, 2.metacarp fracture, scafoid fracture
20	34	Male	R	U	1/3 middle-distal	22-A2	Ulnar	Ulnar	ED (4,5), EDM, ECU, FCU	-	
21	42	Male	L	R+U	1/3 middle-distal	22-C2	Radial ulnar	-	Multiple flexor group	+	
22	45	Male	R	R	1/3 middle-distal	22-B1	Radial ulnar	-	-	-	

Table 2. Patients' superficial infections, skin necrosis, pseudoarthrosis and DASH scores at the last follow-up.

No	Superficial enfection	Skin necrosis	Pseudoar-throsis	DASH score
1	P. aerogiosa			18.18
2				27.27
3		+ (Local flap)		11.36
4				36.36
5				22.72
6				38.63
7				22.72
8				34.09
9			Ulna	29.54
10		+ (Skin graft with partial thickness)		20.45
11			Radius	34.09
12				25.00
13				22.72
14				38.63
15	P. aeroginosa			20.45
16		+ (Skin graft with partial thickness)		11.36
17				36.36
18		+ (Free flap)		6.81
19				25.00
20				22.72
21	S. aureus			34.09
22				25.00

from industrial injuries or traffic accidents. While the risk for encountering polytraumatized patients, especially with injuries resulting from traffic accidents, isolated upper extremity injuries are more commonly seen from occupational accidents. All the patients in this study had isolated upper extremity injuries because of occupational accidents, where open fracture was accompanied by vascular and nerve injuries. In the classification developed by Gustilo and Anderson, open fractures accompanied by vascular injury are classified as type IIIC [4]. In this subgroup of fractures, historical infection rates varied between 25% and 50% [12].

In open fractures, the primary approach of internal fixation is a controversial issue [5-8]. With immediate administration of internal fixation, the most important problem appears to be deep infections that cause osteomyelitis. Rates or deep infections observed concurrent with open fractures are reported with a frequency between 2% and 16.5% [7,12]. Risk for infection is lower in the cases of upper extremity fractures compared to those of the lower extremity [2,13,14]. Chapman suggests that the indications of internal fixation in patients with open fractures include intra-articular fractures, massive traumatized extremities, vascular injuries, patients with a long bone fracture from multiple system trauma and very old patients [3]. However, it should be noted that there are significant differences between open bone injuries of the upper extremity and lower extremity in terms of therapeutic plans. In the studies performed, nonunion rates were lower in upper extremity fractures compared to those of the lower extremity. This may be explained by excessive blood circulation within the upper extremity [5]. In our opinion, complex functional structures and the requirement of postoperative rehabilitation are important characteristics of upper extremity fractures, requiring more anatomic and stabilizing osteosynthesis, notably distinguishing them from lower extremity fractures.

Potential for increased infection rates as a result of the use of internal fixation has guided surgeons to the use of an external fixator for open fractures. However, in the literature, it was put forth that, especially in fragmentary fractures, with the use of external fixators, it is difficult to ensure adequate stability and loss of reduction may result in increased rates of nonunion, delayed union or malunion [7]. In the upper extremity have a more complex anatomy and functional ability versus lower extremity, possible difficulties arise through placement of an external fixator, another factor that disinclined us to use one. Despite these disadvantages, external fixation would be suitable in patients with excessive soft tissue damage where defects that occur after debridement could not be appropriately closed as well as in those with severely contaminated injuries.

In the literature, the number of the publications that support the safe use of internal fixation for open fractures has gradually increased over last number of years. In a study performed by Moed et al., among 50 patients with forearm open diaphysis fracture treated with internal fixation, the rate of favorable and excellent outcomes was 85% [2]. With this, the majority of patients with poor outcomes demonstrated nonunion [2]. Yokomaya and Shindo described the deep infection rate being 4.5% as ascertained from a patient group treated with immediate internal fixation encompassing the lower and upper extremity [7]. All patients that developed deep infection had Gustilo-Anderson type III open fractures [7]. Jones et al. conducted a study on patients with type III open fractures, internal fixation resulting in a deep infection rate of 5% and a superficial infection rate of 11% [5]. Azam et al. determined that internal fixation performed along with aggressive debridement, prophylactic antibiotic therapy, early soft tissue closure, and, at an appropriate time point, bone grafting during the gold period that they defined as within 6-24 hours for Gustilo-Anderson type IIIA and IIIB fractures, provided satisfactory results [8].

Internal fixation decreases the risk for malunion and nonunion by ensuring a more stable fixation [1,5,7]. A stable and permanent fixation is particularly required to robustly protect the vascular anastomosis realized in patients that undergo revascularization. In addition, internal fixation is important for the maintenance of periosteal and endosteal blood supply by protecting the integrity of the soft tissues surrounding the fracture area [7]. Functional expectations and rehabilitation protocols are clearly different between the upper and lower extremity. For post-traumatic reconstructions of the upper extremity, early and active rehabilitation is necessary for the recovery of hand movements, central to quality of life of patients [5]. During all movements of the forearm, it is difficult to ensure stability between fractured segments using external fixation. When carrying out internal fixation, special caution is required to avoid causing additional damage to soft tissues and to limit periosteal dissection. To ensure successful bone union, a compression should be formed between the fragments of the fractures during the plate fixation. Especially for segmented and defective fractures, bone grafting is best used [2,5,8]. In our study, we administered primary bone autografting in four patients with multifragmentary or defective fractures and shortening in one patient. As a graft, we used cancellous autografts obtained from iliac crests in two patients and grafts obtained from defective segmentary ulnar fractures in two patients. To make certain intra-fragmentary compression in forearm fractures takes place, acute shortening is an alternative method [15-17].

The most effective measures taken to prevent infection in open fractures are debridement and irrigation with antibiotic prophylaxis. Several studies have revealed that, in addition to mechanical cleaning from debridement and irrigation, antibiotic prophylaxis also decreases the infection rates [12,18]. In the study we present here, all patients had irrigation with at least 3000 cc saline and debridement was maintained until all devitalized tissues had been removed. Triple antibiotic prophylaxis was administered with cephasoline sodium for five days and with gentamicin and ornidazole for three days. In the treatment for open fractures, another factor that seemed to affect the outcomes was operation timing. In the studies performed previously, it was demonstrated that, principally in patients that had surgical interventions within the first six hours, infection rates were significantly decreased [12,19]. However, there are also various publications that suggest the risk for infection is not correlated with the duration of surgical debridement [20]. Our opinion about this issue is that, especially for type III open fractures and in patients in whom internal fixation will be carried out, operation timing is very important. In our series, all patients were operated within the first eight hours following trauma.

For open fractures, wound closure may be achieved using primary sutures as well as grafting or flap administration in defective subjects. Selection of wound closure method varies by the size and severity of the injury, the structure of the defect and functional expectations [12]. In this study, wound closure was performed using primary sutures in subjects that had no tension on wound lips, using primary transposition flaps in two and with skin grafting in one patient with defects. Timing of wound closure is another contradictory issue. In addition to immediate closure of open fracture injuries, its monitorization without applying closure is another recommended method [21]. In our view, it would be appropriate to primarily close the injuries to accelerate wound healing and prevent additional contaminations. In the study performed by Rosental et al., late complication rates were found to be associated with wound closure at baseline [1]. From additional literature, there are also authors that advise redebridement within the first 24-48 hours as routine practice [1,5]. In our patients who exhibited the signs of necrosis or superficial infection, redebridement was performed and we secondarily repaired the skin defects that occurred during this procedure using local flap in one patient, free flap in another patient and skin graft in two patients.

In complex forearm injuries, functional outcomes seem to be correlated with the severity of concomitant soft tissue injuries rather than bone union [1]. Jones et al. showed a rate of favorable and excellent outcomes in patients with a complex forearm injury of 66% and reported that the majority of subjects with inferior outcomes were those that underwent nerve repair [5]. For more proximal and complete nerve lesions, healing was relatively poor [5]. Concomitant hand injuries are also determinants for functional outcomes. In our study, the great proportion of patients with poor functional outcomes had serious hand injuries and nerve lesions.

All patients in this study were determined to have cases of Gustilo-Anderson-type IIIC and Tscherne-type III fractures resulting from occupational accidents. Lack of a comparison group is a definite limitation of our study.

Ultimately, the severity of trauma, patients' general status, a simple or complex nature of a fracture and the extent of wound contamination should be considered when selecting therapy. Therefore, examination at baseline should be performed with caution and concomitant lesions other than fracture should also be recorded. An appropriate trauma unit and experienced surgical staff will increase the likelihood of success. At the centers where the required conditions are met, together with cautious irrigation and debridement, provided that regular wound monitorization and prophylaxis is ensured, internal fixation is a safe and efficient therapeutic choice in the immediate treatment of complex forearm type IIIC open fractures.

Conflict of interest statement

The authors have no conflicts of interest to declare.

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