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Outcomes of low-profile plate-screw osteosynthesis in unstable extra-articular fractures of the proximal phalanx

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ABSTRACT

In this study, we aimed to present radiologic and functional outcomes of extra articular proximal phalangeal fractures treated with low profile plate and screw osteosynthesis. The study included 20 patients who had undergone osteosynthesis with low profile plate and non-locking screws due to extra-articular closed proximal phalangeal instable fractures. Clinical and radiologic data were evaluated retrospectively. Postoperative 6th month follow up data were obtained and statistically analyzed. Active and passive range of motion of the metacarpophalangeal and interphalangeal joint; total active motion grip strength of injured and uninjured visual analog scale for pain DASH score have been evaluated, distance between pulpa and palmar curve is measured. Belsky score, presence of reoperation and complications were noted. The mean time to radiologic union was 4.2 (3-6) weeks. Functional evaluation of the patients revealed a mean MCF flexion of 87.3 (75-90), a mean PIP flexion of 94.3 (65-100), mean DIP flexion of 77.6 (75-80), mean total active motion of 259 (210-270) degrees. Grip strength in the injured hand was 52.7 (40-58) kgw, and in the uninjured hand it was 54.4 (42-60) kgw. There was no statistically significant difference in grip strenght ($p<0.05$). The mean visual analogue scale score was 0.8 (0-2). The mean DASH score was 7 (2-27) and the mean distance between pulpa and palmar curve was 3 (0-8) mm. Open reduction and low-profile plate and screw fixation of proximal phalangeal fracture in treatment of unstable extra-articular fractures of the proximal phalanx with early rehabilitation yields satisfactory functional and radiologic outcomes.

1. Introduction

Proximal phalangeal fractures are common finger fractures (Drenth and Klasen, 1998). Fracture type, stability and sustainability of the fracture are major determinants in the treatment (Le Nen, 2014). In proximal phalangeal fractures, the fracture fragments are acted on by deforming forces of the interosseous muscles, flexors and extensors. The effects of deforming forces on the fracture fragments result in stable (transverse) and unstable (spiral, oblique, and fragmented) fractures (Kurzen et al., 2006). Stable fractures are usually treated by conservative methods. Ensuring periosteal continuity contributes to stability of these fractures. However, it is essential to provide anatomic reduction and maintain stabilization in unstable fractures (Lins et al., 1996; Kurzen et al., 2006).

The main objective is to enable early mobilization and union through stable and rigid fixation (Robinson et al., 2017). Closed reduction, Kirschner (K)-wire fixation, screw fixation, intramedullary screw fixation, external fixation, open reduction, and plate–screw fixation are commonly used methods in surgical treatment (Kozin et al., 2000; Kamath et al., 2011; Faruqui et al., 2012; Franz et al., 2012; Gaston and Chadderdon, 2012).

However, advantages and disadvantages have been reported for each method and there is still debate over optimal surgical treatment of extra-articular proximal phalangeal fractures (Ebinger et al., 1999; Lee and Jupiter, 2000; Gaston and Chadderdon, 2012; Desaldeleer-Le Sant et al., 2017). In this study, we aimed to discuss radiological and clinical results of plate–screw fixation, which we performed in 20 cases with extra-articular unstable fracture of the proximal phalanx.

2. Material and method

We retrospectively reviewed the clinical and radiological data of 20 patients, who underwent open reduction and low-profile fixation (ORIF) using a 1.5-mm titanium mini-plate and non-locking screws for closed, unstable, extra-articular fractures of the proximal phalanx. Informed consent was obtained from all patients preoperatively. Approval was granted by the institutional review board. Patients, who underwent closed reduction for closed, extra-articular, unstable (spiral, long oblique, and comminuted) fractures and patients, those who underwent ORIF for transverse fractures for which an acceptable reduction and stability was not achieved, and those who were followed up for a minimum of 6 months were included in the study. Patients with ipsilateral fractures, open fractures, intra-articular fractures, thumb fractures, and pathological fractures and those with an open epiphysis were excluded from the study. The Local Ethics Committee approved the study (Erzurum BEAH KAEK Ethical Committee (19/02/2018, No: 2018/04–23)).

Fracture types were classified according to the AO fracture classification system (Lee and Jupiter, 2000). Evaluations and statistical analyses were performed on the basis of the evaluated parameters at 6 months after surgery. The active and passive metacarpophalangeal (MP) joint range of motion (ROM), interphalangeal (IP) joint ROM, total active motion (TAM), grip strength (kgW) in the affected and unaffected hands (SAEHAN Hydraulic Hand Dynamometer [SH5001], Gyeongnam, South Korea), visual analog scale (VAS) score, DASH score (Hudak et al., 1996), the distance between the pulp and palmar crease in the operated finger (mm), the Belsky score (Belsky et al., 1984), reoperation status and complications were evaluated. Bone union, angulation and shortness evaluations were made with posteroanterior, lateral and 30°- 45° pronation and/or supine oblique radiographs taken at 1st, 2nd, 3rd and 6th month after surgery. The evaluation was performed by other surgeons who contributed to the study other than the operating surgeon.

Surgical method and postoperative protocol

All of the patients were operated by a single surgeon. All patients were operated in the supine position, under infraclavicular block anesthesia and with tourniquet application. A longitudinal incision was made on the dorsal aspect of the finger with the forearm in full pronation. The extensor tendon is split longitudinally for exposure. The periosteum was similarly dissected to sufficiently expose the fracture line for subsequent plate–screw fixation. The fractured ends were cleaned and anatomic reduction was achieved with a reduction clamp while preventing interposition of soft tissues. A low-profile 1.5-mm titanium mini-plate (TriMed®, Phalanx plate, Ankara, Turkey) was placed dorsally. A minimum of two screws were placed on each side of the fracture line in a way that at least four cortices would be passed through. We first placed interfragmentary screws in the long oblique or spiral fractures appropriate for interfragmentary screw fixation. We then performed plate–screw fixation. Anatomical and rotational alignment and angulation were confirmed under fluoroscopic guidance. After ORIF, we performed meticulous periosteal and extensor tendon repair (Figs. 1A-D). After surgery, all patients were kept in short-arm splints up to the proximal IP joint until edema and pain resolved. After the first week, passive exercises were initiated. After the second week, the splint was only used at night with an intention of early MP joint mobilization. Night splinting was terminated after the fourth week, and active motion was allowed. At the end of the sixth week, intense daily activities were allowed.

Fig. 1. A–D. Plate application to the 3rd proximal phalanx fracture in the right hand of a 43-year-old male patient (A), periosteal repair (B) and image of the completed repair (C), periosteal repair and image of the completed repair of the tendon (D).

3. Results

Nineteen patients were male and one patient was female. The mean age was 38.9 (19–61) years. Nine patients had fracture in the right hand, whereas 11 patients had fracture in the left hand. All patients were right-handed. Five patients had a fracture in the 2nd phalanx, 4 patients in the 3rd phalanx, 5 patients in the 4th phalanx and six patients in the 5th phalanx. When the etiology of the fracture was examined, the cause of fracture was blow by a heavy object in three patients, falls in 11 patients, slamming the hand in a door in two patients, road traffic accident involving passengers in three patients and work accident in one patient. Ten patients had diaphyseal (shaft) fracture and 10 patients had proximal metaphyseal fracture. The fracture pattern was comminuted fracture in eight patients, spiral-oblique in six patients and unstable transverse fracture in six patients. The mean time from admission of the patients to the hospital to surgery was 33 (8–72)h. Eleven patients were smokers and nine patients were nonsmokers. We performed splint immobilization for 7 days after surgery. All demographic data of the patients are presented in Table 1.

Table 1. Demographic Data of Patients (R: Right, L: Left, M: Male, F: Female)

PATIENT	AGE	SIDE	FRACTURED PHALANX	GENDER	TRAUMA TYPE	OCCUPATION	AO FRACTURE TYPE	FRACTURE PATTERN	TIME UNTIL OPERATION	IMPLANT REMOVAL	SMOKING STATUS
1	43	R	3	M	Blow by heavy object	Worker	Shaft	Fragmented	48	No	No
2	54	L	2	M	Fall	Retired	Proximal metaphysis	Long oblique	72	No	Yes
3	35	R	2	M	Fall	Worker	Proximal metaphysis	Long oblique	24	No	Yes
4	26	L	3	F	Fall	Student	Shaft	Fragmented	24	No	No
5	21	L	5	M	Fall	Student	Shaft	Fragmented	48	No	Yes
6	61	R	4	M	Thresher machine	Farmer	Shaft	Fragmented	8	Yes	Yes
7	54	L	2	M	Fall	Retired	Proximal Metaphysis	Transvers	12	No	No
8	19	L	5	M	Slamming in a door	Asker	Distal Metaphysis	Long oblique	72	No	Yes
9	39	R	5	M	Blow by heavy object	Worker	Proximal Metaphysis	Long oblique	48	No	No
10	33	L	4	M	Fall	Farmer	Shaft	Fragmented	12	No	No
11	40	R	3	M	Fall	Worker	Proximal metaphysis	Transvers	48	No	Yes
12	37	L	4	M	Road traffic accident as a passenger/driver	Worker	Shaft	Fragmented	24	No	Yes
13	42	R	2	M	Road traffic accident as a passenger/driver	Farmer	Shaft	Transvers	12	No	Yes
14	21	L	5	M	Fall	Student	Shaft	Fragmented	48	No	Yes
15	61	R	4	M	Road traffic accident as a passenger/driver	Farmer	Shaft	Fragmented	8	No	Yes
16	54	L	2	M	Fall	Retired	Proximal metaphysis	Transvers	12	No	No
17	19	L	5	M	Slamming in a door	Asker	Distal metaphysis	Long oblique	72	No	Yes
18	39	R	5	M	Blow by heavy object	Worker	Proximal metaphysis	Long oblique	48	No	No
19	33	L	4	M	Fall	Farmer	Shaft	Fragmented	12	No	No
20	46	R	3	M	Falls	Retired	Proximal metaphysis	Transvers	12	No	No

All patients were followed up for a mean duration of 16 (6–30) months. Radiological union was achieved in a mean duration of 4.2 (3–6) weeks (Figs. 2A-H). When functional results of the patients were evaluated, the mean MP joint flexion was 87.3° (75°–90°), the mean proximal IP joint flexion was 94.3° (65°–100°), the mean distal IP joint flexion was 77.6° (75°–80°), and the mean TAM was 259° (210°–270°). The mean passive MP joint flexion was 87.5° (85°–90°), the mean proximal IP joint flexion was 95.8° (90°–100°) and the mean distal IP joint flexion was 78.3° (75°–80°). Grip strength in the fractured hand was 52.7 (40–58) kgW, whereas it was 54.4 (42–60) kgW in the intact hand. There was no statistically significant difference in terms of grip strength ($p<0.05$). The mean VAS score was 0.8 (0–2), the mean DASH score was 7 (2–27), the mean distance between the finger pulp and palmar curve was 3 (0–8) mm. The Belsky score was excellent in 12 patients, good in seven patients, and poor in one patient (Table 2). We performed tenolysis in one patient for flexion contracture. Implant removal was also performed in the same patient. Sudeck's atrophy was observed in the same patient which lasted for approximately 4 weeks. We achieved improvement with physical therapy, contrast bath therapy and pharmacological treatment. There were no complications such as nonunion, late union, superficial or deep infection and tenosynovitis. There were no patients in whom implant removal was performed, with the exception of patient who underwent tenolysis. No patients developed soft-tissue and skin irritation. Displacement, angulation or rotational deformity were not observed radiologically in any patient.

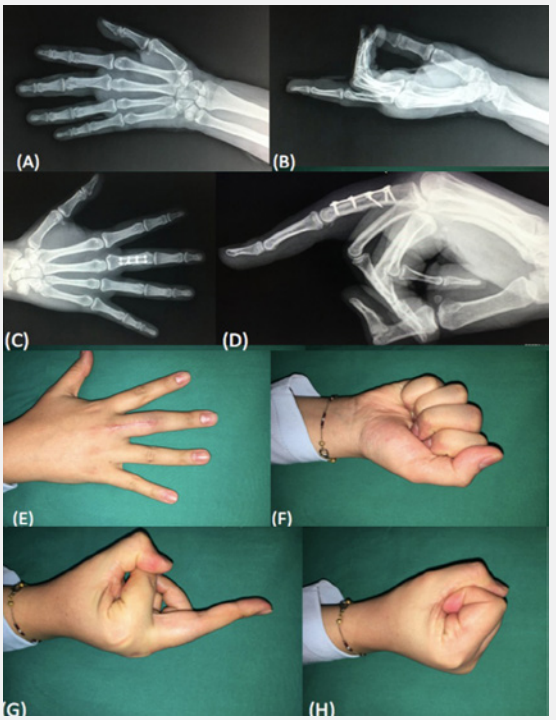

Fig. 2. A-H. Plain anteroposterior radiograph of the 3rd proximal phalanx shaft, spiral fragmented fracture due to a fall on the left hand (A), lateral radiograph (B), postoperative 6th month anteroposterior direct radiograph (C), plain lateral radiograph (D), images demonstrating functional joint movements; dorsal incision scar, extension of the finger and the hand (E), volar fist position (F), isolated 3rd finger extension (G) and image of the lateral fist position of the hand (H).

Table 2. Functional and Radiological Results of Patients (MP: Metacarpophalangeal, IP: Interphalangeal, VAS: Visual analog scale, DASH: Disabilities of the arm, shoulder, and hand score)

PATIENT	MP JOINT ACTIVE/ PASSIVE FLEXION (°)	PROXIMAL IP JOINT ACTIVE/ PASSIVE FLEXION (°)	DISTAL IP JOINT ACTIVE/ PASSIVE FLEXION (°)	TOTAL ACTIVE RANGE OF MOTION (°)	FRACTURED HAND GRIP STRENGTH (kgw)	HEALTHY HAND GRIP STRENGTH (kgw)	VAS	DASH	DISTANCE BETWEEN FINGER PULP AND FINGER CURVE	BELSKY SCORE	FOLLOW-UP PERIOD (WEEK)	UNION PERIOD (WEEK)	REOPERATION
1	85/85	90/90	75/75	250	57	59	1	9.09	3	Good	6	3	No
2	85/85	95/95	78/78	258	46	45	1	4.54	3	Good	9	4	No
3	90/90	100/100	80/80	270	44	46	0	4.54	0	Excellent	12	4	No
4	85/85	95/95	76/76	256	40	42	1	6.81	2	Good	12	4	No
5	90/90	95/95	80/80	265	53	56	1	4.54	2	Excellent	24	5	No
6	75/85	65/90	70/78	210	46	54	2	27.27	8	Poor	16	6	No
7	90/90	100/100	80/80	270	54	55	1	4.54	0	Excellent	14	4	No
8	85/85	95/95	76/76	256	58	59	1	9.09	3	Good	20	3	No
9	85/85	95/95	75/75	254	57	59	1	6.81	4	Excellent	12	4	No
10	90/90	100/100	80/80	270	55	54	0	4.54	0	Excellent	12	4	No

11	90/90	100/100	80/80	270	52	53	0	2.27	0	Excellent	12	4	No
12	85/85	90/90	76/76	251	58	60	0	4.54	4	Good	22	4	No
13	85/85	90/90	75/80	250	48	48	1	6.81	5	Good	30	5	No
14	90/90	95/95	80/80	265	53	56	1	4.54	2	Excellent	14	4	No
15	95/90	90/95	80/80	265	55	60	1	4.54	8	Excellent	16	5	No
16	90/90	100/100	80/80	270	54	55	1	4.54	0	Excellent	12	4	No
17	85/85	95/95	76/76	256	58	59	1	9.09	3	Good	18	5	No
18	85/85	95/95	75/76	254	57	59	1	6.81	4	Excellent	18	4	No
19	90/90	100/100	80/80	270	55	54	0	4.54	0	Excellent	22	4	No
20	90/90	100/100	80/80	270	54	55	1	4.54	0	Excellent	12	4	No

Statistical methods

SPSS software package was used in the analysis of the data. The data were presented as number, percentage, mean and standard deviation. Variables included in the analysis were tested whether they showed normal distribution using the Kolmogorov–Smirnov Test. Spearman's correlation analysis was used to evaluate the correlation between the parameters. The correlation between the handgrip strength in the fractured hand and in the intact was evaluated using the Mann–Whitney U-test. The correlation between the grip strength in the treated hand, MP joint flexion and IP joint flexion was assessed by the Spearman's correlation analysis. The level of significance was set to $p<0.05$.

4. Discussion

Proximal phalangeal fractures are common orthopedic injuries (Lee and Jupiter, 2000; Lögters et al., 2017). The first step that is recommended in the management is to evaluate stability of the fracture (Rajesh et al., 2007). Positive results can be obtained in stable fractures through conservative treatment methods (short-arm splint application, buddy taping) (Lins et al., 1996; Kozin et al., 2000; Held et al., 2013). It was reported that a finger that has undergone a trauma might develop more stiffness than a finger that has undergone surgery (von Kieseritzky et al., 2017). For this reason, early motion cannot be achieved by conservative methods that will be applied independently of the stability of the fracture. In addition, conservative methods that are applied in unstable fractures can lead to functional losses to a great extent (Desaldeleer-Le Sant et al., 2017). At this stage, surgical treatment should be planned depending on fracture site and type. The main objective is to perform fixation using an anatomic and sustainable fixation method so as to avoid shortening and rotational deformity that may occur in comminuted, long spiral-oblique fractures (Henry, 2008). Rigid fixation should be applied to obtain a functional hand and to allow early motion (Kamath et al., 2011; Le Nen, 2014; Robinson et al., 2017).

The optimal surgical treatment of proximal phalangeal fractures remains controversial. Treatment recommendations have been made depending on the localization of fracture in the bone and type of fracture. K-wire or screw fixation have been recommended in intra-articular base fractures; K-wire fixation has been recommended in extra-articular transverse fractures of the phalangeal base; K-wire, screw or plate fixation have been recommended in transverse or short oblique fractures; K-wire or screw fixation has been recommended in spiral or long oblique fractures, multiple K-wire or plate fixation has been recommended in partial diaphyseal fractures, and K-wire or screw fixation has been recommended in condylar fractures. There are limited number of studies comparing different treatment methods in proximal phalangeal fractures. Advantages and disadvantages of different fixation methods have been reported. One of the major advantages of plate and screw fixation is providing sooner rehabilitation resulting in better functional outcomes (Meals and Meals, 2013; Le Nen, 2014; Li et al., 2015; Desaldeleer-Le Sant et al., 2017). In this study, unstable, extra-articular proximal phalangeal fractures were operated using low-profile titanium plates and as per AO guidelines (Lee and Jupiter, 2000). Adequate stability was achieved in all patients and early motion was initiated. It was ensured that all patients returned to their preoperative activities. Displacement, angulation and rotational deformity did not develop in any patient. There are studies suggesting that dorsal approach is a risk factor for tendon adhesion, because of which dorsolateral approach should be preferred. Depending on the surgical treatment method employed and mobilization in proximal phalangeal fractures, extensor tendon adhesions and joint stiffness

may lead to poor functional outcomes and this may sometimes necessitate implant removal (Page and Stern, 1998; Li et al., 2015; Onishi et al., 2015; Desaldeleer-Le Sant et al., 2017). We believe that, careful handling of soft tissues and meticulous periosteal repair during surgery decrease adhesions. None of the patients, except the one patient that underwent tenolysis, required implant removal.

Malunion is the most common osseous complication after treatment of proximal phalangeal fractures, but nonunion, arthritis, and infections can also be observed (Başar et al., 2015; Desaldeleer-Le Sant et al., 2017). In this study, radiological union was achieved in a mean duration of 4.2 (3–6) weeks. Studies in the literature reported that union occurs in a mean duration of 4–8 weeks (Horton et al., 2003; Desaldeleer-Le Sant et al., 2017). Better functional outcomes and recovery are achieved in patients treated with rigid fixation methods that allow early postoperative rehabilitation (Desaldeleer-Le Sant et al., 2017). In the study, there was no patient that developed adhesions and had poor functional outcomes except one patient who underwent tenolysis. In the comparison of grip strength, there was no statistically significant difference between the affected hand and unaffected hand ($p<0.05$). Functional evaluation parameters [VAS 0.8 (0-2), DASH 7 (2-27), finger pulp and finger curve distance 3 (0-8) mm] were similar to the comparative studies in the literature (Li et al., 2015; Desaldeleer-Le Sant et al., 2017). The Belsky score was excellent in 12 patients, good in seven patients, and poor in one patient. Cold intolerance and Sudeck's atrophy are among rare complications that may occur. Although the duration of immobilization was similar among patients, there was no patient that developed Sudeck's atrophy other than the patient who underwent tenolysis.

Retrospective study design, inclusion of patients that underwent fixation using a single fixation material and heterogeneous distribution of fractures were the limitations of the study. The operations in the present study were performed by a single surgeon; however, postoperative evaluations were performed by different surgeons in order to avoid bias in the postoperative evaluation. In this context, there is a need for multicenter, prospective and controlled studies on homogeneous fracture patterns using different fixation materials.

The treatment of extra-articular proximal phalangeal fractures should allow restoring functional status. In selected patients with appropriate indications (unstable transverse, comminuted, and long spiral-oblique fractures), dorsal approach provides sufficient exposure and anatomical and rigid fixation can be achieved. Meticulous periosteal repair minimizes adhesion and prevents contracture. Rigid fixation allows early motion while accelerating soft-tissue healing and bone union (Lögters et al., 2017). In treatment of extra-articular and unstable fractures of the proximal phalanx successful radiological and functional outcomes can be obtained with open reduction, a low-profile plate–screw fixation and early rehabilitation.

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