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ORIGINAL ARTICLE • HAND - OSTEOSYNTHESIS

Comparison of low-profile plate-screw and Kirschner-wire osteosynthesis outcomes in extra-articular unstable proximal phalangeal fractures

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Abstract

Background We aimed to present the radiological and clinical results of Kirschner-wire (K-wire) fixation and low-profile plate-screw fixation applied to unstable proximal phalangeal fractures without extension to the joint.

Methods Clinical and radiological data of 22 patients who underwent fixation with open reduction and low-profile 1.5-mm titanium mini plate and unlocked screws and 18 patients who underwent fixation with K-wire due to closed, unstable extra-articular proximal phalangeal fractures were retrospectively examined. All evaluation and statistical analyses were based on sixth postoperative month evaluation parameters. Active and passive metacarpophalangeal joint and interphalangeal joint range of motions, total joint range of motion, measurement of grip strength for fractured and healthy hands, visual analog scoring, disabilities of the arm, shoulder, and hand scores, measurement of distance between the pulpa and palmar curve in the operated finger, Belsky score, reoperation, and complications were evaluated.

Results Radiological union was achieved in all patients in a mean duration of 4.2 (3–6) weeks. When the functional results of the patients were evaluated, the mean active metacarpophalangeal joint flexion was 87.3° (75°–90°), mean proximal interphalangeal joint flexion was 94.3° (65°–100°), mean distal interphalangeal joint flexion was 77.6° (75°–80°), and mean total range of motion was 259° (210°–270°). The grip strength of the fractured hand was 52.7 (40–58) kgW, whereas that of the healthy hand was 54.4 (42–60) kgW. The mean value of visual analog score was 0.8 (0–2), mean score for disabilities of the arm, shoulder, and hand was 7 (2–27), and mean distance between the finger pulpa and finger curve was 3 (0–8) mm.

Conclusion Plate-screw osteosynthesis in the extra-articular, unstable fractures of the proximal phalanx, which is "small" compared with the body but has a "major function" for the hand and upper extremity, allows for rigid fixation, short immobilization, and early motion in spiral/oblique-fragmented fractures. K-wire fixation, an alternative treatment modality, applied to selected fracture patterns with appropriate indications can achieve good–excellent results radiologically and functionally.

Keywords Phalanx · Extra-articular · Unstable · Fracture · Rehabilitation

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Introduction

Proximal phalangeal fractures together with metacarpal fractures constitute approximately one-third of all finger fractures [1]. Fracture type, stability of fracture, and sustainability of stability are the main determinants of the fracture treatment [2]. In proximal phalangeal fractures, the fracture line is under the deforming effect of interosseous muscles and flexor and extender tendons. Stable (transverse) and unstable (spiral, oblique, and fragmented) fractures occur due to the impact of these deforming forces on the fracture line [3]. Conservative treatment methods are commonly preferred in stable fractures. Unimpaired periosteal continuity in these fractures contributes to stability. However,

anatomic reduction and stabilization should be maintained in displaced, rotational fractures that cannot be reduced in a closed manner [3, 4]. Early mobilization and union by stable and sustainable detection methods have been the main goals of previous studies [5, 6]. In surgical treatment, closed reduction, Kirschner-wire (K-wire) fixation, screw fixation, intramedullary screw fixation, external fixation, open reduction, and plate-screw fixation are the commonly used methods [6–10].

Optimal surgical treatment of extra-articular proximal phalangeal fractures is still under debate [10–13]. The advantages and disadvantages of each method have been reported. In this study, we aimed to compare the radiological and functional results of 40 patients treated with K-wire and plate-screw fixation due to extra-articular, unstable proximal phalangeal fractures.

Materials and methods

Clinical and radiological data of 22 patients who underwent fixation with open reduction and low-profile 1.5-mm titanium mini plate and unlocked screws (ORIF) (plate group) and 18 patients who underwent osteosynthesis with K-wire (K-wire group) due to closed, unstable, extra-articular proximal phalangeal fracture in Erzurum Training and Research Hospital, Orthopedics and Traumatology Clinic and Hand Surgery Clinic, between January 2014 and February 2018 were retrospectively evaluated. Informed consent was obtained from all patients preoperatively. This study was approved by the Institutional Review Board. Patients who were surgically treated for closed, extra-articular, unstable (spiral, long oblique, and communicated), and transverse fractures for which we could not ensure acceptable reduction by closed reduction, with at least 6 months of follow-up, were included in the study. Patients with ipsilateral, open, intra-articular, thumb, and pathological fractures and those with an open epiphysis line were excluded from the study.

Fracture types were classified according to AO [12] fracture classification. All evaluations and statistical analyses were based on the sixth postoperative month control parameters. Goniometric measurement of active and passive metacarpophalangeal joint (MP), joint-interphalangeal (IP), joint range of motion, total joint range of motion (TAM), grip strength for fractured and healthy hands (SAEHAN Hydraulic Hand Dynamometer [SH5001]), visual analog scale (VAS) evaluation, DASH measurement [14], measurement of distance between the pulpa and palmar curve in the operated finger (mm), Belsky score (Table 1) [15], reoperation, and complications were evaluated. Conglutination, angulation, and shortness were assessed via posteroanterior, lateral, and 30°–45° pronation and/or supination oblique radiographs, respectively, taken during the first and sixth postoperative months. This evaluation was performed by other surgeons who contributed to the study in addition to the operating surgeon.

Table 1 Belsky score evaluation criteria

	Criteria
Excellent	Free of pain
	No deformity
	PIP > 100°
	TAM > 215°
Good	Free of pain
	Minimal deformity
	PIP > 80°
	TAM > 180°
Poor	Worse

Surgical method and postoperative protocol

All patients were operated in the supine position, under infraclavicular block anesthesia, and with tourniquet application. Operations were performed by three different surgeons. In plate-treated patients, a longitudinal incision was made from the finger dorsal in forearm pronation. Extensor tendon was split in the middle line. Periosteum was also split in the same way, providing sufficient visibility for plate-screw fixation to the fracture line. Fracture ends were cleaned, soft tissue interposition was prevented, and anatomic reduction was achieved using a reduction clamp. Low-profile 1.5-mm titanium mini plate (TriMed®, Phalanx plate, Ankara, Turkey) was applied dorsally. A minimum of two screws were applied so that at least four cortices could be passed on each side of the fracture line. Interfragmentary screws were applied first in long oblique or spiral fractures suitable for interfragmentary screwing. Angulation fluoroscopy assistance was checked via anatomic and rotational alignment. Periosteum and extensor tendon repairs were performed after ORIF (Fig. 1a–d). All patients were treated with short-arm splint in intrinsic plus position for 5 days until postoperative edema and pain decreased. After the fifth day, passive exercises were initiated in splints that freed the proximal interphalangeal (PIP) joint. After the second week, splints were only used at night to provide early mobilization to the MP joint. Splint usage during the night was terminated after the fourth week, and active motion was allowed. At the end of the eighth week, challenging daily activities were allowed.

In patients who underwent surgery with K-wire, anatomic and rotational alignment and angulation were checked by fluoroscopy using traction–contraction. All patients were treated with short-arm splint in intrinsic plus position for 1 week until postoperative pain and edema decreased. After the first week, passive exercises were initiated in splints

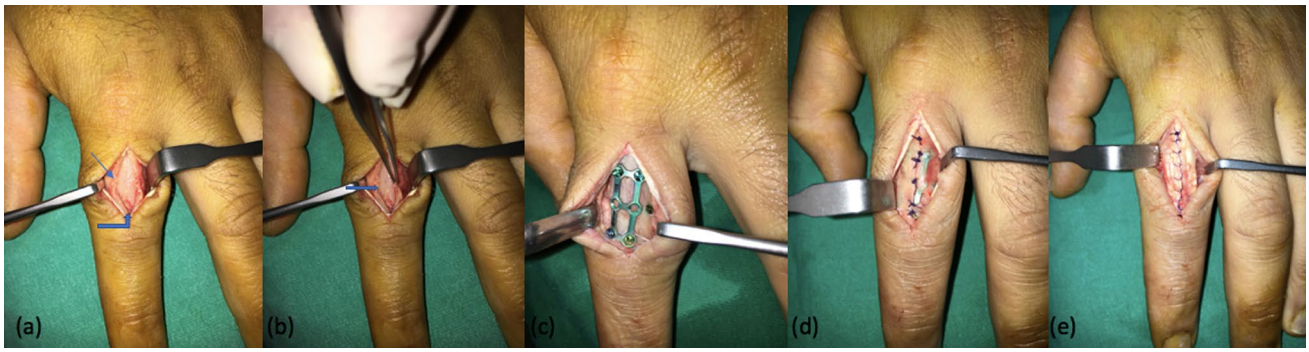

Fig. 1 Dorsal approach to second proximal phalangeal fracture in the left hand of a 54-year-old patient (**a**), periosteal dissection and fracture line (**b**), plate and free screw application (**c**), optimal periosteal repair (**d**), complete view of tendon repair (**e**)

that freed the PIP joint. After the third week, splints were only used at night to provide early mobilization to the MP joint. Splint usage during the night was terminated after the fourth week, and active motion was allowed. At the end of the eighth week, challenging daily activities were allowed. K-wire was removed after 4 weeks after union was achieved.

Results

Overall, 31 patients were males and 9 were females. The average age of patients was 39 (18–66) years. In 20 patients, the fracture was in the right hand, whereas it was in the left hand in another 20 patients. The right hand was dominant in 38 patients, whereas the left hand was dominant in 2 patients. The 2nd phalanx was fractured in 9, 3rd phalanx was fractured in 8, 4th phalanx was fractured in 9, and 5th phalanx was fractured in 15 patients. When fracture etiology was examined, it was observed that 23 cases were caused by falling, 4 by assault, 3 by blunt trauma, 3 by dropping a heavy object on the hand, and 10 by other factors such as in-vehicle traffic accident, work accident and door accident. Overall, 19 patients had diaphyseal (shaft) fracture, 17 had proximal metaphyseal fracture, and 4 had distal metaphyseal fracture. Fracture pattern was communal in 12 patients, spiral/oblique in 12, and unstable transverse in 16 patients. The mean time from the admission of patients to the hospital until operation was evaluated as 50 (8–168) h. Twenty-two patients were smokers, whereas 18 were nonsmokers. We performed splint immobilization for an average of 16 (10–28) days postoperatively.

All patients were followed up for an average of 16 (6–30) months. Radiological union was obtained in an average of 4.5 (3–6) weeks (Figs. 2a–h, 3a–g). When the functional results of the patients were evaluated, the mean MP joint flexion was 84° (70°–90°), mean proximal IP joint flexion

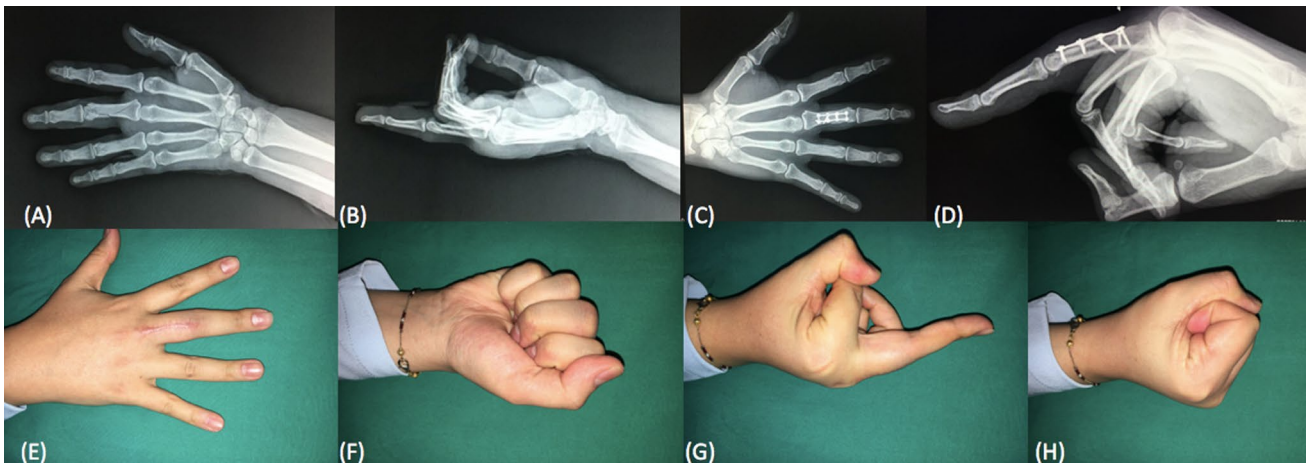

Fig. 2 Anteroposterior direct graphy of a shaft, spiral-fragmented fracture on third proximal phalanx in the left hand caused by falling (**a**), lateral graphy (**b**), sixth postoperative month anteroposterior direct graphy (**c**), lateral direct graphy (**d**), images showing functional joint movements; dorsal incision scar, finger and elbow extension (**e**), volar fist position (**f**), isolated third finger extension (**g**), and lateral fist position (**h**)

was 87° (45°–100°), mean distal IP joint flexion was 76° (65°–90°), and mean TAM was 247° (170°–275°). The mean passive MP joint flexion was 85° (70°–90°), mean proximal IP joint flexion was 90° (60°–100°), and mean distal IP joint flexion was 77° (65°–90°). Grip strength was measured to be 45 (23–58) kgW in the fractured hand and 48 (30–60) kgW in the healthy hand. The mean distance between the finger pulpa and palmar curve was measured to be 4 (0–23) mm. The mean VAS was 1 (0–5). The mean DASH score was 8 (2.27–34.09). There were complex regional pain syndromes in two patients postoperatively. Due to PIP joint contracture caused by adhesion, two patients had tenolysis and one patient had tenolysis and implant extraction. According to the Belsky score, poor results were obtained in 3, good results were obtained in 19, and excellent results were obtained in 18 patients. Two patients had Sudeck's atrophy continuing for an average of 4 and 8 weeks. We achieved improvement with physical therapy, contrast bathing, and medical treatment. There were no complications of nonunion, late union, superficial and deep infection, or tenosynovitis. No material extraction was performed in the plate group except for the patient treated with tenolysis, and all wires were removed after union in the K-wire group. No patients developed soft tissue and skin irritation. Radiologically, no displacement, angulation, or rotational deformity was observed. The demographic data and radiological and functional results of all patients are presented in Table 2 as the plate and K-wire groups.

Based on the results of statistical analyses, there was a significant difference between active and passive MCP, PIP, and DIP flexion angles, TAM values, time until operation, grip strength, and union time between the plaque and K-wire groups ($P < 0.05$), whereas no difference was found in the distance between the finger pulpa and palmar curve, VAS, and DASH values between the two treatment groups ($P > 0.05$) (Table 2). There was no significant correlation between the treatment choice and the AO fracture type, Belsky score, complex regional pain syndrome, fractured finger, smoking, trauma etiology, and reoperation ($P > 0.05$), whereas a significant correlation was found between the fracture pattern and treatment modality ($P < 0.05$) (Tables 3, 4).

Statistical methods

Statistical analyses were performed by SPSS.20 computer software. Data were presented as number, percent, mean, and standard deviation. Shapiro–Wilk test was used to determine whether the data was normally distributed or not. The relationship between the treatment modality and active and passive MCP, PIP, DIP flexion angles, TAM, union time, distance between the finger pulpa and palmar curve, and grip strength and the relationship between VAS and DASH were analyzed by test. The relationship between the treatment choice and AO fracture type, fracture pattern, Belsky score, and complex regional pain syndrome was analyzed by test (samples *t*, Mann–Whitney *U*, Ki-kare, Fisher's Exact). Significance level was considered at $P < 0.05$.

Discussion

Proximal phalangeal fractures are frequently encountered orthopedic injuries [12, 16]. Fracture stability evaluation is the first recommended treatment choice [17]. Positive results can be obtained with conservative treatment methods (short-arm splint application and fixation to neighboring finger) in stable fractures [4, 7, 18]. It has been reported that more stiffness may develop in a finger that has undergone trauma than a finger that has undergone surgery [19]. Therefore, early mobilization cannot be achieved by conservative methods applied regardless of fracture stability. In addition, conservative methods applied in unstable fractures can cause high functional losses [11]. At this stage, surgical treatment should be planned depending on the location and type of fracture. The major focus is to determine the shortness and rotational deformity that may occur in fragmented, longitudinal, spiral, and oblique fractures by anatomic and sustainable fixation methods [20]. Rigid fixation should be performed to obtain early mobilization and a functional hand [2, 5, 6].

An optimal surgical treatment for proximal phalanx fractures is still under debate. Appropriate treatments for the localization and type of fracture in the bone have been proposed. K-wire or screw fixation in intra-articular base fractures, K-wire fixation in extra-articular transverse base fractures, K-wire, plate, or screw fixation in transverse or short oblique fractures, K-wire or screw fixation in spiral or long oblique fractures, multiple K-wire or plate-screw fixation in fragmented diaphyseal fractures, and K-wire or screw fixation in condylar fractures have been recommended. Although K-wire fixation results in less soft tissue damage, contracture, and stability than the screw or plate fixation, it is not superior in terms of functional outcomes. Screw fixation allows for the earliest rehabilitation, followed by plate-screw and K-wire fixation [2, 11, 21, 22]. In this study, splint immobilization was applied at an average of 16 (10–28) days [mean: 22 (21–28) days in the K-wire group and 11 (10–16) days in the plate group] in all patients. There was a significant difference between the two groups in terms of splint immobilization time ($P = 0.0$). Depending on the effect of the applied osteosynthesis on stability, faster mobilization and early onset of movement was obtained in the plate group. We attributed the significant difference in the functional joint motion angles, grip strength, and union time to the

Table 2 Demographic data of patients according to treatment groups, mean radiological and functional results and complications

	All patients	Plate-screw group	Kirschner-wire group
Age	39 (19–66)	39 (19–61)	39 (19–66)
Fractured hand/dominant hand			
Right	20/38	10/22	10/16
Left	20/2	12/0	8/2
Fractured finger			
2	9	5	4
3	8	5	3
4	9	6	3
5	13	6	7
Sex (female/male)	9/31	1/21	8/10
Trauma etiology			
Falling	23	12	11
Assault	4	0	4
Blunt trauma	3	0	3
Other (traffic accident, work accident, door)	10	10	0
AO fracture type			
Shaft	19	12	7
Proximal metaphysis	17	8	9
Distal metaphysis	4	2	2
Fracture pattern			
Transverse	16	5	11
Fragmented	12	11	1
Spiral/oblique	12	6	6
Complex regional pain syndrome	2	1	1
Active/passive flexion			
MCP	84/85	88/88	79/82
PİP	87/90	94/96	78/84
DIP	76/77	78/79	74/75
TAM	247	260	232
Finger pulpa–curve distance (mm)	4	2.8	5.7
Grip strength (treated/healthy extremity) (kgW)	45/48	53/55	36/39
VAS	1	1	1
DASH	8	6.5	10
Time until operation (h)	50	33	71
Splint immobilization time (days)	16	22	11
Belsky score			
Poor	3	1	2
Good	13	8	5
Excellent	24	13	11
Union time (weeks)	4.5	4.2	4.8
Follow-up (months)	16	16	16
Contracture	3	2	1

optimal periosteal repair with open reduction and early mobilization after stable detection. The fact that there was no difference in VAS, DASH, Belsky score, reoperation rate, complication rate, and finger pulpa–curve distances between both treatment options suggested that both methods accomplish the primary objectives in the treatment of proximal phalangeal fractures.

The dorsal approach allows for anatomic and rigid fixation with wide exposures, although it increases the risk of adhesion. Optimal periosteal repair and rigid stabilization allow early mobilization and have a positive effect on union while minimizing adhesion and contracture. Surgical scar is also a significant disadvantage of the procedure [19]. K-wire is a cost-effective treatment method compared with

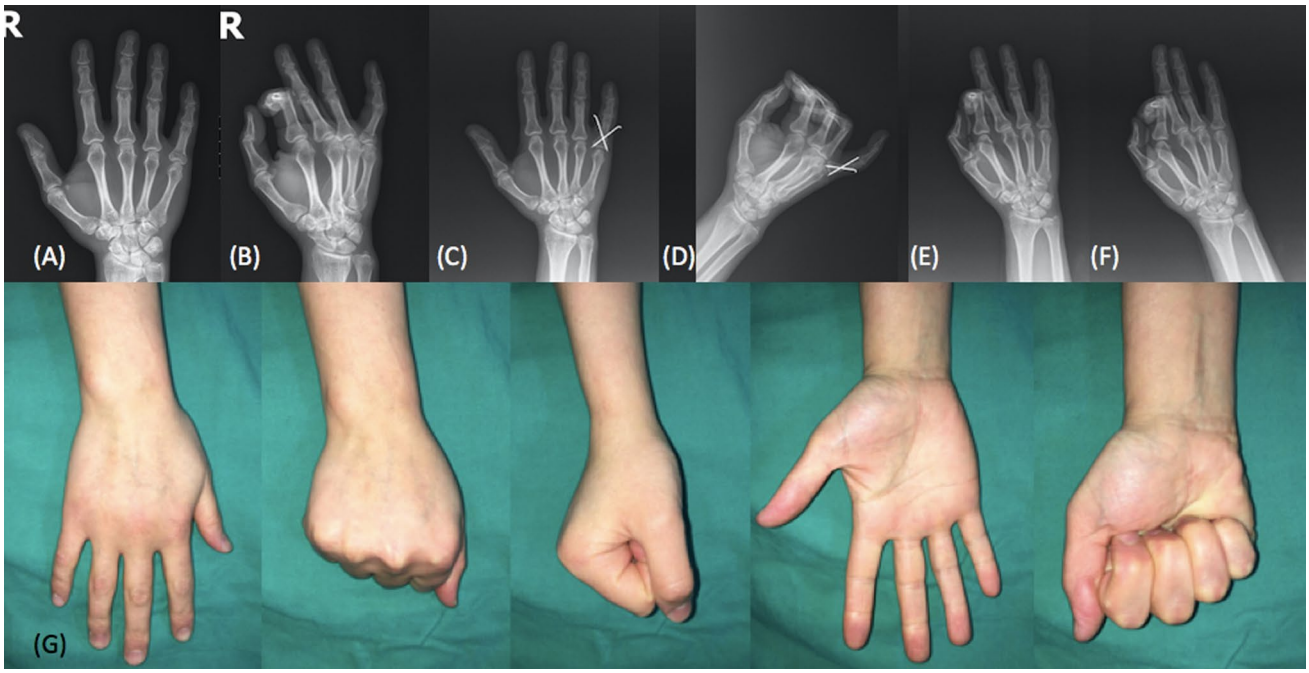

Fig. 3 Preoperative anteroposterior and lateral direct graphy images of the right hand fifth finger proximal phalanx, proximal metaphyseal displaced fracture in a 37-year-old patient caused by falling (**a**, **b**), first postoperative day anteroposterior and lateral direct graphy images (**c**, **d**), sixth month anteroposterior lateral direct graphy images (**e**, **f**), sixth month hand functions of the patients (flexion, extension, and fist positions) (**g**)

Table 3 Statistical analysis of the relationship between active and passive MPC, PIP, DIP flexion angles, TAM value, time until operation, grip strength, union time, distance between finger pulpa and palmar curve, VAS, and DASH in plate-screw and K-wire groups according to ki kare and Fischer's exact test

	Kirschner-wire group				Plate-screw osteosynthesis group				*P*
	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum	
Active MCP flexion	79.44	10.42	60.00	90.00	39.41	13.34	19.00	61.00	0.006
Active PIP flexion	78.33	15.53	45.00	100.00	87.73	4.29	75.00	95.00	0.000
Active DIP flexion	74.44	8.02	60.00	90.00	94.09	7.50	65.00	100.00	0.018
Total active motion	232.22	32.14	170.00	275.00	77.82	2.79	70.00	80.00	0.004
Passive MCP flexion	81.94	8.60	60.00	90.00	259.55	13.32	210.00	270.00	0.014
Passive PIP flexion	83.89	12.19	60.00	100.00	87.73	2.55	85.00	90.00	0.000
Passive DIP flexion	75.00	7.48	65.00	90.00	95.68	3.55	90.00	100.00	0.013
Finger pulpa and palmar curve distance (mm)	5.72	7.34	0.00	23.00	78.45	2.02	75.00	80.00	0.446
Fractured hand grip strength (kgW)	35.61	8.87	23.00	50.00	2.77	2.65	0.00	8.00	0.000
VAS	1.17	1.50	0.00	5.00	0.82	0.50	0.00	2.00	0.904
DASH score	9.94	10.00	2.00	34.00	6.77	4.82	2.00	27.00	0.534
Time until operation (h)	71.33	43.26	24.00	168.00	32.73	22.78	8.00	72.00	0.002
Splint immobilization time (days)	21.78	2.26	21.00	28.00	10.82	1.82	10.00	16.00	0.000
Union time (weeks)	4.89	0.83	4.00	6.00	4.23	0.69	3.00	6.00	0.013

plate-screw fixation. However, it does not offer adequate rotational stability in spiral/oblique and fragmented fracture patterns; hence, additional fixation material is required. Therefore, the duration of immobilization is extended and mobilization is delayed.

In this study, unstable, extra-articular proximal phalangeal fractures were fixed with low-profile titanium plate-screw and K-wire. Adequate stability was obtained in all patients, and early motion was initiated. All patients successfully returned to their preoperative jobs. Displacement,

Table 4 Statistical analysis of the relationship between treatment choice and type of AO fracture, Belsky score, complex regional pain syndrome (CRPS), smoking, fracture pattern, and treatment type based on Mann–Whitney *U* test

	Fracture pattern	CRPS	Reoperation	Smoking	Belsky score	Complication	AO fracture type
Kirschner-wire group (*P*)	0.006	1	0.579	0.565	1	0.31	1
Plate-screw osteosynthesis group (*P*)							

angulation, and rotational deformity did not develop in any patient. There are studies suggesting that the dorsal approach is a risk factor for tendon adhesion and therefore recommend a dorsolateral approach. Depending on the surgical treatment and mobilization performed in proximal phalangeal fractures, poor functional outcomes may occur due to extensor tendon adhesion or joint stiffness, and material extraction may sometimes be required [11, 22–24]. We believe that optimal soft tissue dissection and periost repair reduces adhesiveness in surgical application. Tenolysis was performed in two patients, and material extraction was performed in one patient due to PIP joint contracture in the plate group. In the K-wire group, tenolysis was performed in one patient due to contracture. No statistical difference was observed between reoperation and complication rates ($P > 0.05$).

Although malunion is the most common bone complication in the treatment of proximal phalangeal fractures, nonunion, arthrosis, and infections can also be seen [11, 25]. In this study, radiological union was obtained in an average of 4.5 (3–6) weeks. In the literature, it has been reported that union is achieved in an average of 4–8 weeks [11, 26]. In terms of union time, the plate group was statistically superior to the K-wire group ($P < 0.05$). We attributed this result to the periosteal repair and early mobilization. Healing with better functional outcomes is achieved in patients with rigid fixation that allows for early postoperative rehabilitation [11]. In this study, we performed tenolysis in three patients. Sudeck's atrophy was observed in two patients treated with tenolysis. A significant difference was found between the grip strengths of two groups ($P > 0.05$). Functional evaluation parameters [VAS 0.8 (0–2), DASH 7 (2–27), and finger pulpa and finger curve distance 3 (0–8) mm] were similar to other comparative studies in the literature [11, 22]. According to Belsky score, we obtained excellent results in 18 patients, good results in 19 patients, and poor results in 3 patients. Cold intolerance and Sudeck's atrophy are among the uncommon complications that can develop in phalangeal fractures. Although immobilization time was different in both groups, Sudeck's atrophy was observed in one patient in both groups.

The current study had certain limitations such as being retrospective, having a short follow-up period, and a heterogeneous fracture pattern. However, to eliminate postoperative bias, all evaluations were performed by different surgeons. We believe that conducting prospective, randomized, controlled, and preferably multicenter studies with homogeneous fracture patterns will contribute more to developing a standardized algorithm for treatment approach.

Conclusion

Patients with extra-articular proximal phalangeal fractures should regain function in a short time. Indication for surgery is transverse, communicated, longitudinal, spiral, and oblique fractures with unsustainable stability. Anatomic localization of fracture and most importantly pattern of fracture are the main determinants of method of fixation. K-wire fixation can be preferred for transverse fractures, plate fixation can be preferred for comminuted fractures, and both can be preferred for oblique and spiral fractures.

Plate-screw osteosynthesis in the extra-articular, unstable fractures of the proximal phalanx [16], which is "small" compared with the body but has a "major function" for the upper extremity, allows for rigid fixation, short immobilization, and early motion in spiral/oblique-fragmented fractures. The use of K-wire fixation, an alternative treatment modality, for selected fracture patterns with appropriate indications can achieve good–excellent results radiologically and functionally.

Compliance with ethical standards

Conflict of interest The authors report no conflict of interest.

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