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Open reduction and low-profile plate and/or screw fixation in the treatment of phalangeal fractures

Falanks kırıklarında açık düzeltme ve mini plak ve/veya vida ile tespit yönteminin yeri

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Amaç: Açık düzeltme ve mini plak ve/veya vida ile tespit uygulanan falanks kırıklarının fonksiyonel sonuçları ve yöntemin etkinliği değerlendirildi.

Çalışma planı: Çalışmaya, eklemi ilgilendirmeyen falanks kırığı olan 17 hasta (5 kadın, 12 erkek; ort. yaş 33±10; dağılım 17-48) alındı. Bir hastada iki parmakta kırık vardı. Kırıkların 14'ü proksimal, dördü orta falankstaydı. Kırıkların yedisi oblik, dördü spiral, biri transvers, altısı parçalı kırık idi. Kırıkların hepsi kapalıydı. Hastalar kırık oluştuktan ortalama 2.6±2.9 gün (dağılım 0-11 gün) sonra ameliyat edildi. Açık redüksiyondan sonra, yedi kırıkta mini plak ve vidalar, 11 kırıkta sadece mini vidalar ile tespit sağlandı. Fonksiyonel sonuçlar için parmaktaki toplam aktif eklem hareket açıklığı (TAEHA) ve kavrama gücü ölçüldü ve Q-DASH (Quick-Disabilities of the Arm, Shoulder and Hand) sorgulaması uygulandı. Hastalar ortalama 35±20 ay (dağılım 12-75 ay) takip edildi.

Sonuçlar: Tüm hastalarda ortalama 4.5 ayda kaynama elde edildi. Son kontrollerde ortalama TAEHA değeri 200±39.5° (dağılım 160°-260°) hesaplandı. Bu açıdan, altı parmakta (%33.3) mükemmel, beş parmakta (%27.8) iyi, yedi parmakta (%38.9) orta sonuç alındı. Mini vidalar ile tespit sağlanan 11 kırığın sekizinde (%72.7), mini plak ve vidalar ile tespit sağlanan yedi kırığın üçünde (%42.9) mükemmel veya iyi TAEHA elde edildi. Ameliyat edilen elde kavrama gücünde sağlam tarafa göre ortalama %7.5 (dağılım %0-%20) azalma görüldü. Q-DASH skoru ortalama 3.4±4.4 bulundu. Page ve Stern sınıflamasına göre, yedi önemli (%38.9), altı hafif (%33.3) komplikasyon görüldü. İki parmakta (%11.1) kaynama gecikmesi gözlendi.

Çıkarımlar: Cerrahi müdahale gerektiren falanks kırıklarında açık redüksiyon ve plak ya da vida tespiti ilk seçenek değildir. Eğer açık düzeltme ve internal tespit yapılması gerekliyse, mümkün olan en minimal invaziv yöntem (vida tespiti gibi) kullanılmalıdır.

Anahtar sözcükler: Kemik plağı; kemik vidası; parmak falanksı/yaralanma/cerrahi; kırık tespiti, internal/enstrümantasyon.

Objectives: We evaluated the functional results and the effectiveness of open reduction and low-profile plate and/or screw fixation in the treatment of phalangeal fractures.

Methods: The study included 17 patients (5 women, 12 men; mean age 33±10 years; range 17 to 48 years) with closed, non-articular phalangeal fractures. One patient had two phalangeal fractures. There were 14 proximal and four mid phalangeal fractures, including seven oblique, four spiral, one transverse, and six comminuted fractures. The mean duration from injury to surgery was 2.6±2.9 days (range 0 to 11 days). Following open reduction, seven fractures were treated with a mini plate and screws, and 11 fractures with mini screws. For functional evaluations, total active motion (TARM) and grip strength were measured and the Q-DASH (Quick-Disabilities of the Arm, Shoulder and Hand) questionnaire was administered. The mean follow-up was 35±20 months (range 12 to 75 months).

Results: Union was obtained in all the patients in a mean of 4.5 months. At final assessments, TARM ranged from 160° to 260° (mean 200±39.5°), showing excellent, good, and moderate results in six fingers (33.3%), five fingers (27.8%), and seven fingers (38.9%), respectively. An excellent or good TARM was obtained in eight fingers (72.2%) treated with mini screws, and in three fingers (42.9%) treated with plate-screw fixation. The mean grip strength decreased by 7.5% (range 0 to 20%) on the affected side. The mean Q-DASH score was 3.4±4.4. According to the classification of complications proposed by Page and Stern, seven major (38.9%) and six minor (33.3%) complications were seen. Two patients (11.1%) had delayed union.

Conclusion: Our findings do not justify open reduction and low-profile plate and/or screw fixation as the first choice in the treatment of phalangeal fractures. If plate and screw fixation is necessary, the most minimally invasive method such as screw fixation should be preferred.

Key words: Bone plates; bone screws; finger phalanges/injuries/surgery; fracture fixation, internal/instrumentation.

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Phalangeal fractures of the hand are generally treated using conservative methods. However, the outcome of conservative therapy is not satisfactory in cases of displaced, unstable or rotated phalangeal fractures. In such fractures, surgery should be the primary treatment.[1] Various techniques have been defined for the surgical treatment of phalangeal fractures and different complication rates have been reported.[2,3,4,5,6,7,8]. Among possible complications are infection, nonunion and malunion. Even when union is achieved, patients may still suffer from stiffness in finger joints and permanent swelling. In addition, implants may also cause problems. The outcome of therapy and emergence of complications are primarily determined by the following parameters: the location of the fracture, degree and severity of injury, intra-articular involvement, surgical technique used, suitability of fixation materials, strength of fixation, patient's age, option of rehabilitation, and the degree of soft tissue injuries that accompany the fracture.[9,10,11,12,13]

This study aims to report our experience of using low-profile plate and screw fixation in the surgical treatment of phalangeal fractures of the hand. To this end, the functional outcomes of patients were assessed retrospectively. Additional inferences were made by evaluating the complications that emerged and their possible underlying risk factors.

Patients and method

The study included 33 patients who were treated for extra-articular mid and proximal phalangeal fractures with open reduction low-profile plate and/or screw osteosynthesis in the Hand and Upper Extremity Surgery Center of Acıbadem Kadıköy Hospital, Department of Orthopedics and Traumatology between 2001 and 2007. The study group comprised a total of 18 phalangeal fractures belonging to 17 patients whose records were reviewed and follow-up ended (5 females, 12 males; mean age 33,4±10 years; range 17-48 years). The fracture was on the right hand in 11 patients, and on the left in 6. Etiological reasons included falling in 13 patients, contusion in 1, and spraining in 3. For 12 patients, injury was on the dominant side. Of the 18 phalangeal fractures treated with low-profile plate or screw fixation, 14 involved the proximal phalanges and 4 involved the mid-phalanges. The fracture was in the second finger in 3 patients, third finger in 1, fourth finger in 6, fifth finger in 6, and fourth and fifth fingers in 1. Radiological findings showed 7 oblique, 4 spiral, 1 transverse, and 6 comminuted fractures. All fractures were extra-articular and closed (Table 1).

The mean duration from injury to surgery was 2,6±2,9 days (0-11 days). Multiple fractures, cases where reduction could not be achieved or maintained with closed methods, malalignment and existence of rotational deformity were considered indications for open reduction and internal fixation.[1] All surgeries were performed under general anesthesia, in sterile conditions, under scopic control and by using air tourniquet. The fracture area was reached with dorsal longitudinal incision and dorsoulnar or dorsoradial approach without separating the extensor tendon. In this way, the extensor mechanism was protected. The fracture line was revealed with minimal dissection and periostal stripping. Following the open correction of the fracture, fixation was performed by using standard AO methods. While 7 phalangeal fractures were treated with low-profile plate and screws (Combo Set Leibinger, Freiburg, Germany or Trimed, Ankara, Turkey), fixation was achieved in 11 fractures by the use of mini screws between fragments. In the postoperative stage, a splint was used for edema control and maintenance of fixation. The use of splint was terminated on week 3 at the latest, depending on the pain tolerance of patients, and passive joint movements were initiated. The stitches were removed on postoperative day 14, at the latest. Depending on union, active and resistant finger exercises started after week 4. Carrying of heavy loads and heavy work was allowed after the third month. The patients were invited for a follow-up on the first, second, fourth and eighth weeks, third month and at the end of the first year. In these follow-up sessions, patients were radiologically assessed for injury recovery, union and joint movements. Insufficient radiological union findings after a duration of three months was accepted as delayed union, and as nonunion after a duration of 6 months.[13,14] Patients were followed up between 12 and 75 months, or a mean duration of 35±19,8 months.

For functional results, total active range of motion (TARM) and grip strength of the finger were measured and quickDASH scores were identified. TARM values were established by using a hand goniometer. In order to do so, the ranges of motion of the fractured phalanges in the metacarpophalan-

Figure 1. Graphs of 22-year-old male patient (3) prior to **(a,b)** and after **(c,d)** surgery. Fixation was achieved with minimal dissection and 3 mini screws.

geal joint (normal range: 0-85 °), proximal interphalangeal joint (normal range: 0-110 °), and distal interphalangeal joint (normal range: 0-65 °) were measured and added up. A sum between 260-220° was classified as excellent; one between 219-180° as good; one between 179-130° as moderate, and one below 130° as poor.[11] Grip strength was measured by using a hand dynamometer (Jamar, Preston, USA). Any loss in grip strength was compared to the healthy hand and established in percentages. QuickDASH scoring, which was adapted for use in Turkey by Hacettepe University's School of Physical Therapy and Rehabilitation, was utilized for the subjective assessment of the patients.[15] It directs 11 questions to the patients about difficulties in daily activities, limitations in work and social life, and pain. The responses are scored, with a higher overall score indicating a worse outcome.

Complications experienced by the patients in this study were classified according to the Page and Stern system.[9] This system divides complications into two according to their severity: major and minor complications. Complications which cause significant malfunctioning or require additional surgical procedures for their treatment are classified as major complications. To illustrate, a loss of extension above 35° in the finger, a TARM value below 180°, nonunion, deep infection, tendon rupture and a plate which needs removal are considered major complications. On the other hand, a loss of extension between 15 and 35°, a TARM value below 195°, malunion without functional loss, delayed union, loosened plate which does not need removal or plate breakage, and surface infection are classified as minor complications.

Results

Union was achieved in all of our patients. There were no incidents of early or late infection, malalignment, problems related with injury recovery, implant insufficiency, malunion, reflex sympathetic dystrophy, or tendon rupture. No patient experienced loss of sensation in the finger. Improvement in range of motion was achieved in 14 patients (82.3%) with postoperative physical therapy and rehabilitation. Three patients did not receive physical therapy and rehabilitation support. Final TARM values were excellent in 6 fingers (33,3%), good in 5 (27,7%) and moderate in 7 (38,8%). Proximal phalanges were fractured in 5 of the 7 fingers (71,4%) assessed as moderate (TARM<180°; mean 164,2°; range 160-170°), and mid phalanges were fractured in the remaining 2 (28,5%). Mean TARM value of all patients was 200±39,5° (range 160-260°) and evaluated as good.

The 11 fingers which achieved excellent and good TARM values constituted 61,1% of all fingers. Excellent and good TARM values (mean TARM 210,9°) were achieved in 8 (72,7%) of the 11 fractures where fixation was performed with mini screws between fragments, and in 3 (42,8%) of the 7 fractures where fixation was performed with low-profile plates and screws (mean TARM 182,8°). A mean decrease of 7,5% (0-20%) was observed in grip strength in the operated hand when compared to the healthy hand. Mean QuickDASH score of all patients was 3,4±4,4. This value was 2.27 in 3 patients (17,6%), 4.54 in 1 patient (5,8%), 9.09 in 3 patients (17,6%), 11.36 in 1 patient (5,8%), and 0 in 9 patients (52,9%).

In 7 fractures (38,8%), no complications emerged during the postoperative stage or follow-up. In 11 fractures (61,1%), at least one or more complications were seen. Permanent swelling occurred in the surgery area in 4 fingers (22,2%), and joint stiffness causing difficulty of use and permanent swelling around the surgery area in 7 fingers (38,8%). Delayed union was observed in 2 fingers (11,1% of all fingers). Both of these fingers were fixed with low-profile plates and screws and both had been fractured in the proximal phalanges. While one of these patients had a fragmented fracture, the other had been operated on day 6 of the injury. Union was achieved in the fractures in a mean duration of 4,5 months.

Tenolysis was performed to alleviate limited mobility in 4 fingers (22,2%). Materials were also removed in the same surgeries performed on these patients. According to the Page and Stern classification system, 7 major (TARM<180°; 38,8%) and 6 minor (TARM between 180 and 195° in 4 patients and delayed union in 2 patients; 33,3%) complications were identified. Major complications occurred in 3 (27,2%) of the 11 fingers fixed with screws, and in 4 (%57,1) of the 11 fingers which received plate screw fixation. Four patients who had permanent swelling in their fingers were not included in the assessment as they had no place in the classification system (Table 2).

Discussion

Even though phalangeal bones are classified as small bones, their fractures can cause serious problems. These bones require a clear and sensitive balance between stability, alignment and mobility. Their small size and the weakness of the surrounding soft tissue support make it difficult to control and fix the fracture against the pulling strength of the tendons, and the close proximity of bones and tendons increases the risk of complications. The thickness and maladaptation of the material used in open reduction and plate or screw fixation may particularly prevent the sliding movement of the tendons. Soft tissue dissection which is necessary for open reduction may result in additional surgical injury and lead to the adherence of tendons or delayed union/nonunion due to circulation problems.[1,9,12,13]

Even though improvement has been noted with the thinner and easier-to-shape titanium materials produced in recent years, success has still not been achieved with open reduction and plate screw fixation in phalangeal fractures. In a study published in 1986, Dabezies and Schutte fixed 27 metacarpal and 25 phalangeal fractures with plates and reported successful outcomes.[16] The following year, Stern et al. reported less successful results in a similar study and quoted a complication rate of 67% for phalangeal fractures.[10] Later publications about open reduction and plate screw fixation in metacarpal and phalangeal fractures have mostly focused on their complications. Pun et al. reported an equally unsuccessful rate of 27% for good outcomes following plate fixation in phalangeal fractures.[17] In a retrospective study of 105 metacarpal and phalangeal fractures fixed with a plate, Page and Stern found an excellent and good outcome rate of 11% for joint range of motion.[9] Recent studies also emphasize accompanying problems. Freeland and Orbay [12] reviewed innovative techniques in hand fractures, and reported complications such as adherence, finger stiffness and delayed union when low-profile plate screws were used for hand fractures. Trevisan et al. [18] used low-profile plate screw fixation for 56 metacarpal and phalangeal fractures in 44 patients and reported a mean TARM of 251° and mean grip strength loss of 5.2% in phalangeal fractures, at the end of a 24-month follow-up period. They found a complication rate of 45% and, upon seeing more complications in phalangeal fractures, concluded that outcomes were less successful. The most appropriate study for comparison with ours was conducted by Kurzen et al.[13] They assessed 64 mid and proximal phalangeal fractures which received plate fixation, and found 37,5% finger stiffness (TARM<180°) and a major complication rate of 52%.

Many of the previous studies investigated phalangeal fractures under the heading of hand fractures and together with metacarpal fractures.[9,10,11,12,16,18,19] Some studies which compared the two fracture types concluded that phalangeal fractures yielded less successful outcomes with plate screw fixation.[9,10,18] It is obvious that two anatomic structures as distinct as metacarpal and phalangeal will respond differently to the same treatment. Thus, we are of the opinion that phalangeal fractures should be assessed on their own, separately from metacarpal fractures. Previous studies mention the initial state of the fracture and the state of the surrounding soft tissue among the factors which influence plate screw fixation outcomes in the treatment of phalangeal fractures.[9,17] With the purpose of studying similar types of fractures, we admitted extra-articular, closed, mid and proximal phalangeal fractures to our study.

Finger joint movements are used for the functional assessment of metacarpal and phalangeal fracture treatments. As a result, various classifications based on total range of motion have appeared.[9,11,20,21] However, a single and commonly accepted classification does not exist as of yet. A review of previous studies shows that TARM below 180° is generally considered as stiffness causing serious loss in finger functions. Therefore, Duncan et al.'s classification system was used in our study[11] and TARM values below 180° were considered to be unsatisfactory. However, despite the loss of joint range of motion, these fingers were stable, well aligned, painless, without infection, and had sufficient sensation and circulation. Despite the difficulty of use, these fingers made a certain amount of contribution to hand functions. Our functional assessment showed that excellent TARM was achieved in 6 fingers (33,3%), good TARM in 5 fingers (27,7%) and moderate TARM in 7 fingers (38,8%) (<180°). Mean TARM for all patients was 200±39,5°, thus indicating good values. The 11 patients who achieved excellent and good TARM formed 61,1% of all patients. When compared to more recent studies, our results suggest similar functional outcomes.[9,13,18] The thin, easy-to-shape, bone-compatible titanium materials used in our study have led to successful outcomes.[2,3] However, open reduction and plate screw fixation of phalangeal fractures are not yet at a satisfactory level. Despite the recent developments in material production, the risk of complications such as stiffness and nonunion still continue due to the proximity of phalanges and tendons and the weakness of subcutaneous support tissue.

A significant cause of patient dissatisfaction in our study was permanent swelling in the operated fingers (11 fingers; 61,1%). Although this was not mentioned as a complication in previous studies, a high rate of patient dissatisfaction was observed in our study. Six of the 7 fingers fixed with plate screws had permanent swelling, while 5 of the 11 fingers fixed with screws had the same problem (Table 2). Considering that we mostly used plate screw fixation in fragmented fractures, the two factors which may have led to permanent swelling seem to be fragmentation and the size of the surgical method used.

The most common complication in our study was finger stiffness which mostly accompanied permanent swelling. In 7 of the 18 fingers studied (38,8%), TARM was below 180°. This finding is in line with the results reported by Kurzen et al. (37,5%). The mean TARM of 11 fractures fixed with mini screws was 210,9°, whereas that of 7 fractures fixed with low-profile plates and screws was 182,8°. Overall, fragmentation in the fracture and plate screw fixation seems to adversely affect TARM. However, no significant relationship was observed between the fracture type and surgical procedure used in patients with a TARM below 180° (Tables 1 and 2). Achieving excellent and good TARM of 72,7% in patients who underwent mini screw fixation indicates the success of smaller surgical procedures in phalangeal fractures. However, considering that excellent and good TARM was achieved in 42,8% of patients who underwent low-profile plate and screws, it becomes evident that finger stiffness cannot be explained solely by fragmentation in the fracture and the surgical method used. Other additional reasons must also lead to finger stiffness. Five of the 7 fingers which resulted in stiffness and difficulty of use in our study had proximal phalangeal fractures. These fractures cause finger stiffness owing to their anatomy as well.[11] Duration until surgery was 3,28 days in patients with stiffness, and 2,27 days in patients without. The facts that all patients who experienced stiffness were male and older (mean age 39,2) than other patients without stiffness (mean age 30,7) also offer meaningful clues about the reasons for finger stiffness.[22] Last but not least, patient-related factors which were not included in this study, such as genetic predisposal and compa-

tibility with the treatment, should also be considered.

Following open reduction and low-profile plate or screw fixation in phalangeal fractures, and in order to recover joint mobility, controlled passive exercises started after the sutures were removed, and active exercises started after week 4. While the majority of patients did their exercises under a physiotherapist's supervision, a few chose to do them on their own. Despite this, 7 patients suffered from finger stiffness (Table 2). In 4 of the patients, tenolysis and implant removal surgery was used and a certain recovery was achieved (22,2% of all patients). A need for tenolysis may appear following open reduction and screw/plate fixation performed due to phalangeal fractures. It would be appropriate to inform patients properly prior to surgery.

In our study, delayed union was observed in 2 fractures (11,1% of all fingers). Open reduction and screw/plate fixation in phalangeal fractures may result in delayed union or nonunion.[12,13,23] Both cases of delayed union had been fixed with low-profile plate and screws and both had been fractured in the proximal phalanges. While the fracture in one of these patients was fragmented, the other was operated on day 6 after injury. In the presence of these factors, delayed union is only a natural result. Therefore, the most basic precaution to be taken against nonunion/delayed union is to avoid larger resection in phalangeal fractures, and when this is not possible, to perform fixation with minimal stripping of the bone and peripheral tissue.

Overall, 7 major (38,8%) and 6 minor (33,3%) complications were identified among patients. A significant increase was seen in the rate of major complications with plate screw fixation (57,1%), while a decrease was observed with smaller resection practices such as screw fixation (27,2%). Using plate screw fixation in phalangeal fractures thus involves a high risk of complications.

Although the small number of our patients and the resulting lack of statistical analyses constitute limitations for our study, certain inferences can still be made:

1- Open reduction and plate/screw fixation should not be the first alternative in phalangeal fractures in need of surgery. Closed methods should be used in these fractures whenever possible.

2- If open reduction and internal fixation is necessary, the most minimalist method available, i.e. screw fixation, should be used (Figure 1), and fixation should be achieved without excessive bone and tissue stripping.

3- The patients should be informed before the procedure about the high rate of complications such as finger stiffness and permanent swelling seen after the procedure, and they should be told that implant removal and tenolysis may be needed in the follow-up.

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