ORIGINAL ARTICLE

# Outcomes of intramedullary screw fixation in pediatric proximal phalanx fractures: A prospective case series

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## ABSTRACT

**BACKGROUND:** This prospective case series aimed to evaluate the short- to medium-term radiological and clinical outcomes of intramedullary screw (IMS) fixation in pediatric patients with extra-articular proximal phalanx fractures.

**METHODS:** Eleven patients (eight boys and three girls) aged 5-15 years underwent IMS fixation between January 2020 and June 2022. Antegrade or retrograde techniques were used depending on the fracture location. Postoperatively, patients were immobilized with finger splints for 3-5 days, followed by home exercises and physiotherapy. Bone union and functional status were assessed at one and four weeks after rehabilitation. Patient satisfaction, union status, and finger range of motion were also evaluated. Satisfaction outcomes were categorized as excellent, good, fair, or poor.

**RESULTS:** The mean patient age was 9.4 years (range: 5-15), and the mean follow-up period was 29.1 months (range: 24-36). The right hand was affected in eight cases, the left hand in three cases, and the dominant hand in eight cases. Fracture distribution included four neck, four shaft, and three base fractures. The mechanisms of injury included ball-related trauma (n=5), falls (n=3), crush injuries (n=2), and punching (n=1). The average time from injury to presentation was 2.5 days (range: 0-9). Seven patients underwent surgery using the retrograde fixation technique, while four patients underwent surgery using the antegrade fixation technique. Fracture union was observed within the first month in nine patients and was complete by the end of the second month in two patients. At the last follow-up, the range of motion of the metacarpophalangeal, proximal interphalangeal, and distal interphalangeal joints of the operated finger was assessed. Deficits of 1.8 (range: 0-10), 2.7 (range: 0-10), and 0.9 (range: 0-10) were observed when compared to the contralateral side, respectively. Ten patients demonstrated excellent outcomes, while one patient exhibited a good outcome.

**CONCLUSION:** The intramedullary screw technique offers significant advantages in the surgical management of pediatric proximal phalanx fractures, particularly in rural areas with low socioeconomic status. This approach eliminates the need for pin-bottom fixation with a K-wire, significantly reduces hospitalization and additional treatment requirements, and minimizes the adverse impact of familial factors on the therapeutic process.

**Keywords:** Phalanx fracture; pediatric; intramedullary screw; proximal phalanx.

## INTRODUCTION

In pediatric hand fractures, the distal and proximal bases of the phalanx are the most common fracture sites, while fractures of the proximal neck and shaft are relatively rare.[1] Immobilization is the preferred treatment for minimally displaced or nondisplaced fractures, with generally favorable outcomes. However, displaced injuries can lead to deformities that affect hand function, necessitating surgical intervention.[2] To date, only open or closed reduction and percutaneous pinning have

Cite this article as: Ayık Ö, Bayram S, Kayık U, Taşkın M. Outcomes of intramedullary screw fixation in pediatric proximal phalanx fractures: A prospective case series. Ulus Travma Acil Cerrahi Derg 2025;31:296-302.

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Ulus Travma Acil Cerrahi Derg 2025;31(3):296-302 DOI: 10.14744/tjtes.2024.64236
Submitted: 22.09.2024 Revised: 30.11.2024 Accepted: 26.12.2024 Published: 03.03.2025
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been described for this age group.[3] There is limited literature on treatment outcomes for pediatric proximal phalanx fractures (PPPF). While generally good results have been reported in treating these fractures, complications such as early mobility reduction, pin site issues (e.g., drainage or migration), and malunion have also been observed following K-wire treatment.[3,4] The intramedullary screw (IMS) technique for treating extra-articular phalanx fractures has become a widely used surgical procedure in the adult patient population within a short period, leading to an increase in scientific studies in this field.[5] However, the use and outcomes of this technique in pediatric patients have not been previously reported. In this prospective case series, we aimed to present the short- to medium-term radiological and clinical results in pediatric patients diagnosed with extra-articular proximal phalanx fractures.

## MATERIALS AND METHODS

This study was approved by the Clinical Research Ethics Committee of Ankara University School of Medicine before data collection (Approval Number: 24.06.2021, Decision Number: 2022/02-06). Eleven patients (eight boys and three girls) diagnosed with proximal phalanx fractures underwent IMS fixation between January 2020 and June 2022.

### Inclusion Criteria:

1. Age between 5-18 years;

2. Presence of unstable fractures, rotation, shortening, or displaced fractures;

3. Fractures involving the neck, shaft, or closed physeal base;

4. Loss of reduction during conservative treatment.

### Exclusion Criteria:

1. Intra-articular fractures;

2. Fractures with associated tendon injury;

3. Opened physeal base fractures.

**Preoperative Data and Radiological and Clinical Evaluation:** Patients who visited the emergency department with suspected finger fractures were referred to our clinic following primary examinations. Pain, swelling, and deformity were documented during evaluation. Two patients presented with a Grade 1 open fracture. All patients underwent posterior-anterior, oblique, and lateral radiographs of the affected finger to confirm the displaced fracture line and determine the appropriate screw width to be used. Detailed information was provided to the patients' families, and their consent was obtained after receiving ethics committee approval for this study. The parents were informed about the surgical technique, possible complications, postoperative care, and union status. Patients who accepted the proposed technique were admitted to the ward for surgery.

**Surgical Technique:** Patients were positioned supine on an arm table under general anesthesia. A tourniquet was not used, and 30 mg/kg cefazolin was administered for surgical prophylaxis. Inverted C-arm fluoroscopy with an image intensifier was utilized. The choice of technique, antegrade or retrograde, depended on the fracture location. The retrograde technique was used for all neck and shaft fractures with open physeal plates, while the antegrade technique was applied to shaft fractures and base fractures with closed physeal plates (Fig. 1). Fracture reduction was initially attempted using gentle traction and flexion of the proximal interphalangeal joint (PIFJ). All fractures underwent closed reduction. The PIFJ was then fully flexed, and a transverse incision was made along the dorsal crest of the skin at the PIFJ to avoid scarring. If the central slip was mobilized, the approach continued from either the ulnar or radial side. If it was not mobilized, the tendon was passed through a longitudinal incision just large enough for the screw to pass (2-2.5 mm). A K-wire was inserted intramedullary under fluoroscopic guidance to serve as a guide for the screw. The screw trajectory was prepared using a 1.5-2.0 mm drill over the K-wire guide, and the screw was inserted to pass through the fracture and engage the medullary bone. The anterograde technique was used for fractures proximal to the middle half (Fig. 2). The proximal fracture was mobilized dorsally by applying volar pressure at

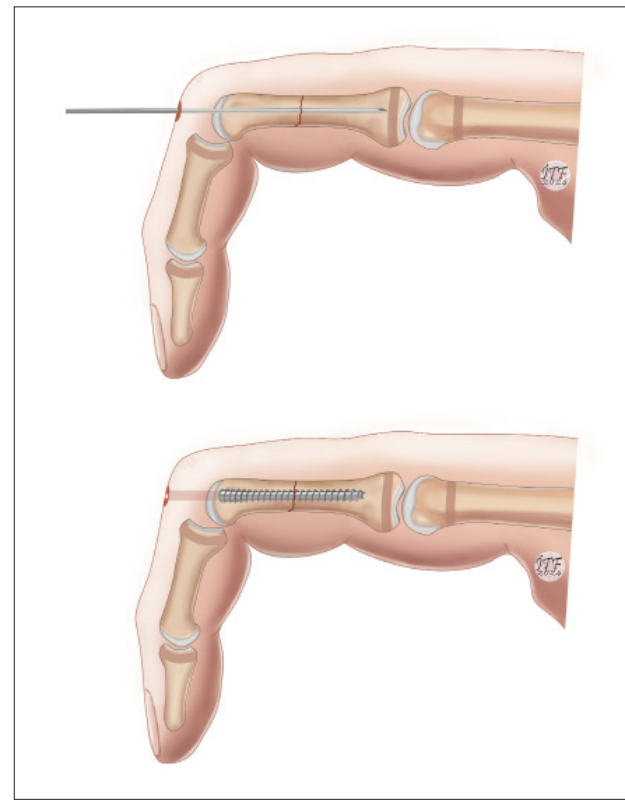

**Figure 1.** Illustration demonstrating retrograde screw insertion.

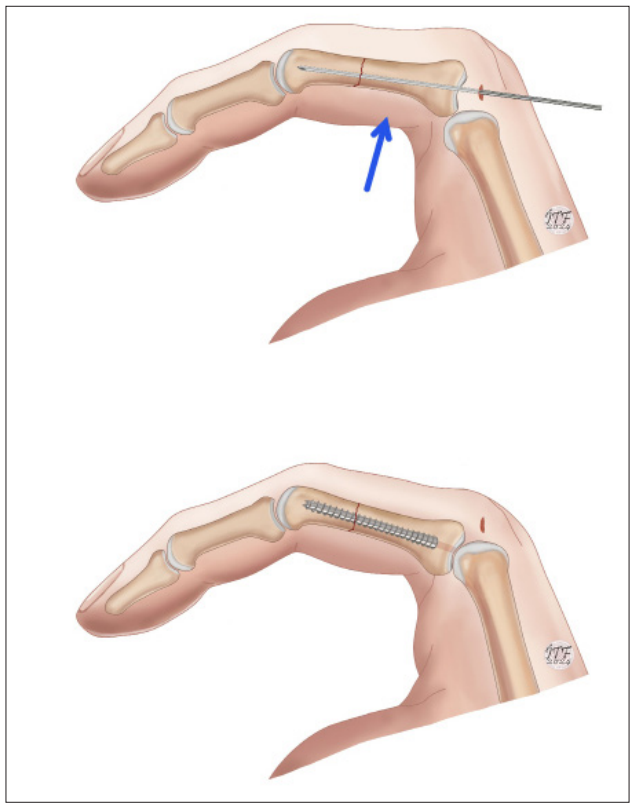

**Figure 2.** Illustration demonstrating antegrade screw insertion.

a flexion angle of approximately 70°. To guide the screw, a K-wire was placed from the mid-dorsal aspect of the metacarpal to the base of the phalanx. Screw fixation was performed by drilling over the K-wire guide. After fixation, rotational and angular deformities were assessed. In cases where the screw diameter could not be definitively determined, the canal was initially drilled with a smaller drill bit, and a smaller screw was used. If the screw advanced too easily within the intramedullary canal, with its threads failing to engage the bone and insufficient fracture stabilization, the screw was removed. The canal was then redrilled over the same guidewire using a larger drill bit, and the screw was replaced with a larger one. The skin incision was closed subcutaneously, without tendon sutures, and a sterile strip was applied to the skin.

**Postoperative Management:** All patients were discharged on the same day and followed the same postoperative protocol for one month. To prevent hematoma formation and reduce inflammation and pain, immobilization with finger splints was applied for 3-5 days. Nonsteroidal anti-inflammatory drugs and paracetamol were prescribed to all patients for pain relief. On the fifth day, standard wound care and home exercises, supervised by a physiotherapist, were initiated. Passive and active range of motion (ROM) exercised for the metacarpophalangeal (MCP), proximal interphalangeal (PIP), and distal interphalangeal (DIP) joints were performed within the patient's pain threshold. Bone union and functional status were assessed one and four weeks after the start of rehabilitation. Subsequently, different approaches were taken based on the clinical and radiological findings. In patients who had achieved near-full ROM and bone union, rehabilitation was discontinued, and no further radiographic evaluation was required. Patients who had not yet attained full ROM but were progressing as expected with home exercises, or who had not yet achieved complete bone union, continued with the same rehabilitation plan. Clinical and radiological evaluations were repeated during the second month. If, by the end of the first month, the range of motion failed to reach the required levels and the patient had not complied with the home program, the patient was referred to a rehabilitation program.

**Evaluation of Clinical Status:** Intraoperative or postoperative complications were recorded. The ROM of metacarpophalangeal, proximal interphalangeal, and distal interphalangeal joints of the operated finger was compared with that of the contralateral finger using a standard goniometer. At the final follow-up, results were classified into four groups (modified from Barton, 1979), as shown in Table 1:[6]

• Excellent result: Complete restoration of normal finger function.

• Good result: Both the patient and the surgeon are satisfied; the affected joint has only mild restriction, with no residual deformity.

• Fair result: The outcome is unsatisfactory for either the patient or the surgeon but retains some functional utility. Dissatisfaction may be due to a significant limitation in movement or a mild residual deformity.

• Poor result: The presence of nonunion, avascular necrosis, severe stiffness of the proximal interphalangeal joint, or a severe residual deformity that significantly impacts function.

Since assessing outcomes in children can be challenging, pain levels were evaluated by questioning the patients' parents using the Visual Analogue Scale (VAS). Functional and aesthetic satisfaction were also assessed using the VAS (0 = not satisfied at all, 10 = very satisfied). Grip strength was analyzed only in patients who were able to grasp objects (five patients aged >9 years).

### Statistical Analysis

All statistical analyses were conducted using SPSS version 28.0 (IBM Corp., Armonk, New York, USA). Descriptive statistical methods were applied to evaluate data. The Shapiro-Wilk test was used to assess the normality of data distribution. The significance level was set at 5%.

## RESULTS

The mean age of the patients was 9.4 years (range: 5-15), and the mean follow-up period was 29.1 months (range: 24-

36). The right hand was affected in eight cases, the left hand in three cases, and the dominant hand in eight cases. In five cases, the index finger was affected; in three cases, the middle (long) finger was affected; in two cases, the ring finger was affected; and in one case, the little finger was affected. Patient demographics are shown in Table 1. There were four neck fractures, four shaft fractures, and three base fractures. The mechanism of injury included playing ball (five cases), falls (three cases), crush injuries (two cases), and punching (one case). The average time to presentation was 2.5 days (range: 0-9).

Three patients were initially managed conservatively but later required surgery due to loss of reduction. Seven patients underwent surgery using the retrograde fixation technique, while four patients underwent surgery using the antegrade fixation technique. Fracture union was observed within the first month in nine patients and was complete by the end of the second month in two patients. At the last follow-up, the range of motion of the metacarpophalangeal, proximal interphalangeal, and distal interphalangeal joint of the operated finger was assessed. When compared with the contralateral side, the observed deficits were: MCP joint: 1.8 (range: 0-10), PIP joint: 2.7 (range: 0-10), and DIP joint: 0.9 (range: 0-10). The final follow-up assessments showed a pain VAS score of 0.09 (range: 0-1), a functional VAS score of 9.7 (range: 8-10), and an aesthetic satisfaction VAS score of 9.9 (range: 9-10). Grip strength was measured at 9.9 (range: 9-10), with a 10% (range: 0-20) deficit compared to the contralateral hand in patients over 10 years of age (Table 2). Ten patients demon-

**Table 1.** Demographic data of patients

| Patient No | Age (years) | Gender | Affected Side | Dominance | Fracture Localization | Finger | Mechanism of Trauma |
|---|---|---|---|---|---|---|---|
| 1 | 7 | Male | Right | Dominant | Neck | Index | Ball game |
| 2 | 6 | Male | Left | Non-dominant | Shaft | Ring | Ball game |
| 3 | 8 | Female | Right | Dominant | Neck | Long | Crush injury |
| 4 | 15 | Male | Right | Dominant | Base | Index | Fall |
| 5 | 14 | Male | Right | Dominant | Shaft | Little | Ball game |
| 6 | 13 | Female | Left | Non-dominant | Base | Long | Punching |
| 7 | 7 | Male | Right | Dominant | Shaft | Index | Ball game |
| 8 | 5 | Male | Right | Dominant | Shaft | Long | Fall |
| 9 | 14 | Female | Right | Dominant | Base | Index | Crush injury |
| 10 | 6 | Male | Left | Non-dominant | Neck | Index | Ball game |
| 11 | 9 | Male | Right | Dominant | Neck | Long | Fall |

**Table 2.** Patient outcomes

| Patient No | Time to Presentation (days) | Follow-up (months) | Metacarpophalangeal Joint ROM Limit (°) | Proximal Interphalangeal Joint ROM Limit (°) | Distal Interphalangeal Joint ROM Limit (°) | Satisfaction |
|---|---|---|---|---|---|---|
| 1 | 0 | 36 | 0 | 10 | 0 | Excellent |
| 2 | 1 | 34 | 0 | 0 | 0 | Excellent |
| 3 | 5 | 33 | 0 | 0 | 0 | Excellent |
| 4 | 4 | 31 | 10 | 0 | 0 | Excellent |
| 5 | 3 | 30 | 0 | 0 | 0 | Excellent |
| 6 | 1 | 28 | 0 | 10 | 0 | Good |
| 7 | 1 | 28 | 0 | 0 | 0 | Excellent |
| 8 | 0 | 27 | 0 | 0 | 0 | Excellent |
| 9 | 9 | 25 | 10 | 0 | 0 | Excellent |
| 10 | 4 | 25 | 0 | 10 | 10 | Excellent |
| 11 | 0 | 24 | 0 | 0 | 0 | Excellent |

**Figure 3.** An anteroposterior view of the patient showing intramedullary screw fixation, with no signs of joint degeneration after 36 months of follow-up.

**Figure 4.** Lateral radiograph of the same patient.

strated excellent outcomes, while one patient exhibited a good outcome.

No intraoperative complications occurred. Routine screw removal was not performed, as it would require a new incision, and the screw head would not be easily accessible inside the bone. However, at the insistent request of one patient's parents in the retrograde group, a single screw was removed. After a mean follow-up period of 29 months, screw insertion through both the proximal interphalangeal joint (retrograde) and the metacarpophalangeal joint (antegrade) did not result in joint degeneration (Figures 3 and 4).

## DISCUSSION

Hand fractures pose several surgical and postoperative difficulties due to the complex interplay of bone and surrounding soft tissues. Although children generally have an advantage over adults in terms of bone healing, reduced stiffness, and lower adhesion risk, they may still face difficulties in adapting to the postoperative rehabilitation process. The only established technique for the surgical treatment of unstable PPPF is percutaneous fixation with either closed or open reduction, followed by temporary immobilization for 3-4 weeks after wire fixation.

Few studies have reported clinical outcomes following surgical treatment for this common fracture type. In this study, we present the initial results of pediatric proximal phalanx fractures treated with intramedullary screws. Among 11 pediatric patients, with a mean age of 9.4 years and a mean follow-up of 29.1 months, we found that intramedullary screw fixation was a successful technique, demonstrating a high satisfaction rate and no complications. Research on the evaluation of proximal phalanx fractures in pediatric patients is limited, particularly regarding surgical interventions and follow-up duration. The first large-scale study on the surgical treatment of proximal phalanx fractures in children was conducted by Al-Qattan,[7] who reported the results of juxtaepiphyseal fractures at the base of the proximal phalanx in 34 children. Among these 34 patients, 18 had mild displacement, 16 had severe displacement, six patients with severe displacement underwent surgery, and the remaining received conservative treatment (reduction and immobilization). In that study, all but two patients regained full range of motion. The two exceptions experienced motion loss and developed malunion (pseudo-claw deformity). A recent study by Schutz et al.[8] compared the outcomes of 634 pediatric patients with proximal phalanx fractures, assessing those who underwent surgical treatment with K-wire versus those treated conservatively. In that study, patients were categorized into nonreduction, closed reduction, and surgical treatment. A large cohort study found that nonoperative treatment in children resulted in a low rate of sequelae and caused only clinically insignificant angular and rotational deformities. In another study, Zhi et al.[9] reported the clinical and radiographic outcomes of fractures at the base of the proximal phalanx (FBPP) in 15 children treated with closed reduction and cast immobilization (CRCI) and 19 patients treated with closed reduction and percutaneous pinning. Their findings indicated that

nonoperative treatment resulted in a better diaphyseal axis-to-metacarpal head angle than surgical treatment. However, five patients in the nonoperative group and two in the surgical group developed complications. Park et al.[10] retrospectively analyzed the clinical outcomes of 37 pediatric patients with proximal phalanx fractures treated with single or double Kirschner wire. The study included 10 children treated with single K-wire fixation and 27 treated with double K-wire fixation for proximal phalanx base fractures. The mean operative time was significantly shorter in the single K-wire group, yet there were no significant differences between the two groups regarding complication rates, range of motion, implant removal times, or functional scores. The authors emphasized that the single K-wire technique demonstrated similar efficacy to the double K-wire technique in treating proximal base fractures of the phalanx in children, with the added advantage of a shorter operative time. In our study, we report the initial results of 11 pediatric proximal phalanx fractures treated with intramedullary screws, achieving a high satisfaction rate and no complications.

The most significant advantage of the intramedullary screw (IMS) technique over the use of pins in the skin is that the screw is entirely within the medullary canal, preventing restrictions on dynamic structure movement. This allows for early initiation of range of motion exercises, as stable fixation is achieved. With the home exercise programs provided to patients, 91% achieved good outcomes, and only one patient required hospital-based rehabilitation. Since most of our patients were from rural areas with low socioeconomic status, the IMS technique provided significant benefits by eliminating the need for pin-bottom dressings, reducing the need for hospitalization and additional treatments, and minimizing the negative impact of familiar factors on treatment adherence. The most common criticism of the IMS technique since its introduction has been the potential risk of long-term osteoarthritis due to screw passage through the joint. Urbanschitz et al.[11] aimed to quantify articular surface defects and extensor tendon injuries following screw placement in the proximal phalanx of cadavers. Their study found that the defect size relative to the articular surface was significantly smaller after anterograde screw placement than after retrograde placement, as assessed via computed tomography. Boe et al.[12] conducted a cadaveric biomechanical study to evaluate metacarpophalangeal joint contact pressures using two different sizes of proximal phalangeal antegrade intramedullary fixation. They found that contact pressure increased more during extension, with peak contact pressures rising by 24% for a 2.4 mm defect and 52% for a 3.5 mm defect. Pediatric patients may be at a higher risk of cartilage damage. However, two 08-1 mm K-wires used alternatively have a combined diameter of 1 mm and create a defect similar to that of a 2-2.5 mm screw. In our study, no radiographic findings consistent with osteoarthritis were observed at the 29-month follow-up, though the sample size was limited.

This study had several limitations. Most notably, it was a retrospective study with a small sample size from a single center. Additionally, there was no control group of patients treated with other methods for proximal phalanx fractures, such as non-reduction or percutaneous K-wire fixation. The mean follow-up period was 29 months. A longer follow-up is necessary to adequately evaluate the development of arthritic changes in the PIP and MCP joints.

## CONCLUSION

The satisfactory outcomes of reduction and fixation of pediatric proximal phalangeal fractures using intramedullary screws suggest that this technique should be considered as a viable option for surgeons treating these injuries. In the surgical management of pediatric proximal phalanx fractures, particularly in rural areas with low socioeconomic status, the intramedullary screw technique offers significant advantages by eliminating the need for pin-bottom fixation with a K-wire, significantly reducing the need for hospitalization and additional treatment, and minimizing the negative impact of familial factors on the treatment process.

**Ethics Committee Approval:** This study was approved by the Clinical Research Ethics Committee of Ankara University School of Medicine before data collection Ethics Committee (Date: 24.06.2021, Decision No: 2022/02-06).

**Peer-review:** Externally peer-reviewed.

**Authorship Contributions:** Concept: Ö.A.; Design: Ö.A., U.K.; Supervision: M.T.; Data Collection and/or Processing: U.K.; Analysis and/or Interpretation: S.B.; Literature Review: Ö.A.; Writing: S.B., Ö.A.; Critical Review: U.K., M.T.

**Conflict of Interest:** None declared.

**Financial Disclosure:** The author declared that this study has received no financial support.

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ORİJİNAL ÇALIŞMA - *ÖZ*

## Pediatrik proksimal falanks kırıklarında intramedüller vida tespitinin sonuçları: Prospektif bir olgu serisi

AMAÇ: Bu prospektif olgu serisinde, eklem dışı proksimal falanks kırığı olan çocuk hastalarda intramedüller vida (İMS) ile tespitin kısa ve orta dönem radyolojik ve klinik sonuçlarının değerlendirilmesi amaçlandı.
GEREÇ VE YÖNTEM: Ocak 2020 ile Haziran 2022 tarihleri arasında 5-18 yaş arası 11 hastaya (8 erkek ve 3 kız) IMS fiksasyonu uygulandı. Kırık lokalizasyonuna bağlı olarak antegrad veya retrograd teknikler kullanıldı. Ameliyat sonrası hastalar 3-5 gün boyunca parmak atelleri ile immobilize edildi ve ardından ev egzersizleri ve fizyoterapi uygulandı. Kemik kaynaması ve fonksiyonel durum rehabilitasyondan bir ve dört hafta sonra değerlendirildi. Hasta memnuniyeti, kaynama durumu ve parmak hareket aralığı da değerlendirildi. Memnuniyet sonuçları mükemmel, iyi, orta ve kötü olmak üzere dört gruba ayrıldı.
BULGULAR: Ortalama yaş 9.4 (dağılım=5-14) yıl ve ortalama takip süresi 29.1 (24-36) aydı. Olguların 8'inde sağ el, 3'ünde sol el ve 8'inde dominant el etkilenmişti. Olguların 4'ünde boyun, 4'ünde şaft ve 3'ünde taban kırığı vardı. Yaralanma mekanizması beş oyun topu, üç düşme, iki ezilme ve bir yumruklama şeklindeydi. Hastaların bize başvurma süresi ortalama 2.5 (dağılım: 0-11) gündü. Yedi hastaya retrograd fiksasyon tekniği, dört hastaya ise antegrad fiksasyon tekniği kullanılarak ameliyat yapıldı. Kırık kaynaması 9 hastada ilk ay içinde gözlendi ve 2 hastada ikinci ayın sonunda tamamlandı. Ameliyat edilen parmağın metakarpofalangeal eklem, proksimal interfalangeal eklem ve distal interfalangeal eklem hareket açıklığı son takipte değerlendirildi; kontralateral tarafla karşılaştırıldığında sırasıyla 1.8 (0-10), 2.7 (0-10) ve 0.9 (0-10) defisit saptandı. On hastada mükemmel, bir hastada ise iyi sonuç elde edildi.
SONUÇ: İntramedüller vida tekniği, özellikle düşük sosyoekonomik durum ile karakterize kırsal bölgelerde, pediatrik proksimal falanks kırıklarının cerrahi tedavisinde önemli avantajlar sunmaktadır. Bu yaklaşım, K-teli ile pin dibi tespit gerekliliğini ortadan kaldırmakta, hastanede yatış ve ek tedavi gereksinimini önemli ölçüde azaltmakta ve ailesel faktörlerin tedavi süreci üzerindeki olumsuz etkilerini en aza indirmektedir.

Anahtar sözcükler: Falanks kırığı; pediatrik; intramedüller vida; proksimal falanks.

Ulus Travma Acil Cerrahi Derg 2025;31(3):296-302 DOI: 10.14744/tjtes.2024.64236