Use of a Multivector Mandibular Distractor for Treatment of Pediatric Proximal Interphalangeal Joint Pilon Fractures: A Case-Based Review

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Abstract

Background The difficulties in surgical treatment of pilon fractures of the finger include fragment reconstitution and posthealing stiffness. In adults, external fixation with traction and early active range of motion (AROM)/passive range of motion (PROM) during healing is considered necessary for avoiding joint stiffness and attaining realignment. The authors present a unique approach to pediatric pilon fractures that uses open reduction and multivector external fixation with delayed AROM/PROM. Initial immobilization and significant traction allowed for joint realignment and prevented noncompliance with staged distraction. The authors believe this immobilization leads to a superior outcome because, unlike adults, children tend to avoid stiffness and a larger distraction force allowed for sufficient joint realignment to regain range of motion (ROM).

Methods A right-handed 13-year-old boy sustained a right ring finger fracture and presented 12 days later. Radiographs revealed a comminuted Salter-Harris 4 fracture of the middle phalanx. The patient underwent open reduction and placement of multivector external fixation using a pediatric mandibular distractor/fixator. Significant traction was applied to distract the finger to length.

Results Hardware was removed 6 weeks postoperatively and AROM was initiated after splinting. The patient started PROM 8 weeks postoperatively. Strengthening was initiated 2 weeks later. ROM improved and rehabilitation was continued. The patient exhibited nearly equal grip strength 12 weeks postoperatively. At 14 months follow-up, radiographs showed complete healing and joint realignment. There was no deformity or pain and finger length was restored.

Conclusion Management of pediatric pilon fractures is rarely described and presents unique considerations. Early-stage traction and immobilization using a multivector mandibular fixator/distractor is suitable in a child because noncompliance is avoided and there is a decreased risk for stiffness. Combining early immobilization with subsequent-staged AROM, PROM, and strengthening resulted in no loss of ROM and maintained articular symmetry.

Keywords

- proximal interphalangeal joint
- fracture
- pilon fracture
- pediatric hand
- external fixation
- mandibular fixator

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Introduction

Treatment of comminuted fractures of the phalanges involving the proximal interphalangeal (PIP) joint presents many challenges and the potential for significant long-term morbidity. The severity and type of fracture depend on the degree, location, and direction of the causative force as well as involvement of associated ligaments and muscles.¹ Pilon fractures, those involving the dorsal and palmar lip of the proximal middle phalanx, are particularly difficult to treat as they exhibit the greatest amount of joint disruption, central depression, and demonstrate both sagittal and coronal splay of the articular surface of the base.^{2,3} The pilon fracture pattern is generated with accidental extreme loading or blunt force on the tip of a finger.⁴ Depending in the severity of the comminution and the stability of the PIP joint, treatment of these fractures may be surgical or nonsurgical. An unstable fracture merits surgical intervention and is defined as involving greater than 40% of the articular surface at the base of the middle phalanx.^{5,6} Ultimately, pilon fractures are nearly always unstable and are challenging to clinically manage as they are associated with stiffness, decreased range of motion (ROM), recurrent instability, and residual pain.⁷ Pediatric patients with pilon fractures present unique treatment considerations. Fractures in children may compromise growth plates and children are less compliant; however, younger patients heal more quickly and may avoid joint stiffness.⁸

The major difficulties inherent to treatment of pilon fractures include small fragments of interphalangeal joint fracture that cannot be reconstituted anatomically and the fibroblastic reaction around the PIP joint during healing that can produce stiffness.^{4,9} Several treatment modalities have been reported in the literature, including extension block splinting, open reduction with internal fixation, external fixation, and dynamic traction splinting.⁴ Treatment with splint immobilization alone has been shown to impede restoration of normal ROM resulting in poor outcomes.³ Open reduction with internal fixation using Kirschner pins is associated with a more satisfactory prognosis in terms of regaining full function of affected digit and avoiding posthealing arthritis; however, it is technically demanding and patients have reported increased pain during the extended recovery period.¹⁰ Thus, the current gold standard treatment is the use of external fixation. This permits early joint mobility, thus reducing stiffness and loss of ROM. A variety of methods and devices have been developed to achieve external fixation, including coiled springs, complexes of Kirschner pins, and the compass hinge.^{4,11–15} The most common device currently used is the Suzuki modification of the pins and rubber traction system; however, stabilization of pilon fractures is by no means standardized and many institutions lack access to these devices. Here the authors present a case report detailing a unique approach to treatment of a pilon fracture of the middle phalanx using open reduction and multivector external fixation in a pediatric patient.¹⁶

Clinical Report

A right-hand dominant 13-year-old boy with no pertinent past medical history presented to the emergency department with trauma to the right ring finger after falling directly on the finger in gym class. The injury was splinted and the patient presented to the clinic of the senior author (R.A.D.) 12 days after injury. X-ray films revealed a comminuted Salter-Harris 4 fracture of the middle phalanx of the right ring finger exhibiting 2 to 3 mm in diastasis, volar apex angulation, and collapse with loss of height and splay (►Fig. 1A, B). The patient was taken to the operating room and underwent open reduction of the fracture and placement of static multivector external fixation using a pediatric mandibular multivector distractor/fixator (►Fig. 2A–C). Significant traction was applied to distract the fracture and surrounding soft tissues back to preinjury length. Hardware was removed 6 weeks postoperatively, and active range of motion (AROM) of the affected joint was initiated after application of a thermoplast protective splint (►Table 1). At the time, minor skin necrosis was noted along the longitudinal axis between the pins, and a pseudo-mallet deformity has occurred due to the extensive force of distraction required. Eight weeks postoperatively, the patient was advanced to passive range of motion (PROM). Nine weeks postoperatively, a static progressive splint was fashioned, and 1 week later, the patient began strengthening of the digit. The overall treatment course is outlined in ►Fig. 3. ROM in the distal interphalangeal (DIP) and PIP joint of the right ring finger improved, and the authors continued rehabilitation to reach near baseline function (►Table 1). Additionally, at 12 weeks postoperatively, the patient exhibited nearly equal grip strength (right average: 46.6 lb vs. left average: 58.3 lb) as tested with Jamar hand dynamometer (Lafayette, Indiana, United States) at position 2. At 14 months follow-up, radiographic imaging showed the patient to have complete healing and remodeling of the fracture and realignment of the PIP joint (►Fig. 4A, B). Additionally, the patient had no evident deformity or pain in the affected digit and displayed restoration of finger length comparable to the contralateral finger (►Fig. 5A, B).

Discussion

Several methods have been proposed for surgical treatment of pilon fractures; however, no single method has proven definitively superior compared with others.¹⁷ Stern et al conducted a review of 20 patients with pilon fractures treated using static extension blocking splinting, skeletal traction, or open reduction and internal fixation using K-wires. They concluded that optimal outcomes were associated with traction and that suboptimal results were produced with static fixation and open reduction.³ Whereas current literature generally agrees that a dynamic component to treatment is optimal for prevention of posthealing PIP joint stiffness,¹⁸ controversy has remained over the ideal method for treating pilon fractures.^{10,19,20} Allison reported on the application of spring-loaded dynamic traction with a stainless steel device that permitted AROM and PROM across the joint.¹⁵ Allison found

Fig. 1 Severe pilon fracture of the base of the middle phalanx of the ring digit. **(A)** Lateral radiograph depicting a severe comminuted pilon fracture of the base of the middle phalanx. **(B)** Because of the delayed presentation of the fracture, the fracture was reduced under direct visualization.

Fig. 2 Intraoperative application of static pediatric mandibular fixator. **(A)** Immediately postoperatively. **(B)** PA radiograph. **(C)** Lateral radiograph.

that this device was accepted by patients and that outcomes were similar to other devices. Additionally, Allison noted 86% of patients were satisfied with final outcome and that patients who were compliant with hand therapy had superior ROM. Hynes and Giddins outlined the use of two K-wires for dynamic external fixation after closed reduction and highlighted the

simplicity of their technique as well as nearly full return of ROM in all patients as advantages.¹⁰ Suzuki et al developed a popular pins and rubber traction system that ultimately led to nearly full return of ROM in patients with pilon fractures.¹³ Multiple other modifications to and variations on these protocols also exist.^{4,11,14,16,19,21,22} The variety in treatment

Table 1 Ring finger post-op ROM

Post-op week	MP	PIP	DIP	TAM
6	0/75	0/25	-15/30	115
10	0/90	0/85	0/75	250
12	0/90	0/105	0/80	275

Abbreviations: DIP, distal interphalangeal; MP, metacarpophalangeal; PIP, proximal interphalangeal; post-op, postoperative; ROM, range of motion; TAM, total active motion.

approaches is not surprising given how fracture patterns differ depending on the mechanism, direction, and force of injury.¹ Ultimately, however, some variation of dynamic traction is arguably the most accepted therapeutic method for pilon fractures given ligamentotaxis can be achieved while allowing for early motion of the joint.^{20,22,23}

In the pediatric population, orthopedic injuries are generally more concerning in that epiphyseal plates, and therefore normal bone growth, may be affected. Apart from head injuries, the hand is the most commonly injured part of the body in young children and hand fractures are the leading cause of morbidity in children.^{24,25} Literature shows proximal phalanx fractures are the most common type of hand fractures in children.⁸ Furthermore, in a prospective study investigating hand injuries in children, Liu et al found that they more common in males, and that the vast majority of injuries were nonsurgical and associated with athletic activities.²³ Furthermore, pediatric hand fractures have been observed more frequently in the phalanges and tend to occur in a biphasic distribution; they are most common in 1 to 3 year olds and 10 to 12 year olds.²⁶ Mahabir et al reviewed 242

pediatric fractures cases and reported comminution in 12.4% of cases and severe displacement in 12% of cases. Additionally, they noted 31% of fractures had epiphyseal involvement (Salter-Harris fractures), most commonly Salter-Harris type II in which part of the epiphyseal plate is fractured. Given the prevalence of pediatric hand fractures complicated by epiphyseal involvement, attention must be directed toward timely management and careful joint realignment. In more severe cases (types III and IV fractures), this management most often includes surgery to achieve proper alignment and fixation and to reduce the need for excessive closed manipulation that may amplify physeal damage and increase growth plate arrest.²⁷ While there is limited literature regarding the prevalence and incidence of pilon fractures within the pediatric population, given the high incidence of hand fractures and specifically epiphyseal fractures in children, it is reasonable to conclude that pediatric pilon fractures may be more common than previously thought.

Literature regarding the surgical treatment of pilon fractures of the hand in pediatric patients is limited. However, there are a multitude of considerations that must be taken into account when treating operative hand fractures in pediatric patients. The complications of hand surgery (infection, nonunion, loss of ROM) may have greater impact on pediatric patients as any associated postoperative morbidity would have lasting impact on a large proportion of the patient's lifespan. Additionally, the potential for adverse reactions to anesthesia and an increased likelihood of postoperative non-compliance must be factored when deciding whether or not to operate on pediatric patient. On the other hand, certain qualities unique to the pediatric population favor better outcomes following hand surgery. Namely, children are more likely to avoid joint stiffness after healing and generally heal more quickly than adults.⁸ Thus, in the presented patient, 44 days of static traction was applied prior to several weeks of dynamic fixation and rehabilitation to achieve preinjury baseline in terms of finger function. Although the prolonged initial static immobilization period may increase the risk of stiffness when compared with dynamic distraction, static traction benefits from simplified operation and improved patient compliance. In this case, the patient's family was not required to assist with device distraction and care was focused on postoperative hand therapy and rehabilitation. This allowed complete healing of the fracture with good anatomical alignment and restoration of finger length and ROM without stiffness.

No literature to date details the use of a mandibular fixator for the purpose of distracting and externally fixating a pilon fracture of the finger. This novel technique was selected in the presented patient for several reasons. The fixator is easily applied, and the technique is reproducible and relatively inexpensive. In addition, this method allows for wound care and is not overly intrusive to a patient's activities of daily living. Most importantly, this technique is advantageous in scenarios in which a greater degree of traction is necessary due to extensive comminution. As designed to be used on the pediatric mandible, mandibular distractors are robust devices that provide durable, stable constructs over long traction durations. Other previously proposed methods would not

Fig. 3 Treatment timeline. AROM, active range of motion; PROM, passive range of motion.

Fig. 4 Postoperative radiographs. **(A)** A 6-week postoperative radiograph after hardware removal. **(B)** Radiograph at 14 months follow-up showing complete resolution of fracture with good anatomical alignment.

Fig. 5 Clinical images at 14 months after injury. **(A)** Full ROM achieved in flexion of affected digit. **(B)** Full ROM achieved in extension of affected digit. Note the maintenance of length in the affected digit.

have provided sufficient traction force to distract the fractured digit back to anatomical length. In applying this larger distraction force, the authors believe that any joint stiffness was prevented as anatomical elements were allowed more laxity.

Use of the proposed technique is limited in that not all pilon fractures require such extreme distraction, and wound care in this case may have been complicated by hardware. Furthermore, in adult patients, the length of the immobilized phase of treatment may need to be shortened to prevent joint stiffness. Finally, this intervention is obviously surgical and therefore not appropriate in outpatient settings or in emergency rooms. The authors also acknowledge that mandibular

distractors may not be available in all settings; however, regardless of the distraction system used, the treatment methodology outlined herein remains relevant.

Conclusion

In conclusion, comminuted intra-articular fractures involving the PIP joint present a therapeutic dilemma. Commonly, patients experience results that are less than ideal—complications after healing include decreased ROM, lack of articular symmetry, and possibly arthritis. Controversy exists over the optimal methods to be used to achieve these goals.

Furthermore, the treatment of these injuries in the pediatric population presents a new set of considerations and has been rarely described. Dynamic traction is generally considered necessary for avoiding posttraumatic joint stiffness and attaining realignment of comminuted fractures. Applying the ligamentotaxis through traction in combination with AROM and PROM during the healing process affords the best opportunity for avoiding posttreatment morbidity.

The authors have presented a novel method for the treatment of a severe pediatric pilon fracture. Early-stage traction and immobilization with a multivector mandibular fixator/distractor was suitable for this patient in that noncompliance with distraction was avoided and there was a decreased risk for stiffness given the patient's age. Combining this early immobilization with subsequent-staged AROM and PROM plus strengthening resulted in no loss of ROM and maintained articular symmetry between the affected and unaffected digits. Ultimately, the authors feel that this is a useful technique to have in the hand surgeon armamentarium.

Conflict of Interest

None.

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