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Phalangeal Fractures Treated by *Tendinotaxis*: A Narrative Review of Principles, Techniques, and Outcomes

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ABSTRACT

Phalangeal fractures are common injuries sustained to the hand which frequently lead to stiffness, malunion, and functional compromise due to the close relationship between bone, tendon, and soft tissues with the digital skeleton. Management strategies vary, from immobilization, to closed reduction and open reduction techniques with the goal to restore bony alignment and eventual range of motion and hand function. It is generally accepted that surgical fixation methods, given the additional disruption of surrounding soft tissues, is associated with increased risk of tendon adhesions and potential reduced range of motion outcomes.

Traction of fracture fragments to restore alignment can be achieved externally through skin traction and use of orthoses, internally via a fixation apparatus, or a combination of the two with skeletal traction. The restoration of bony alignment is achieved through the principle of *tendinotaxis*. *Tendinotaxis* is a principle of fracture reduction that uses tension generated by tendon forces to realign fracture fragments, offering a minimally invasive technique to achieve stable alignment while preserving soft tissue integrity. This narrative review examines the anatomical basis, biomechanics, clinical indications, surgical techniques, and outcomes of *tendinotaxis* in the management of proximal, middle, and distal phalangeal fractures. *Tendinotaxis* techniques have shown favorable outcomes in comminuted, intra-articular, and unstable fractures. Evidence suggests that *tendinotaxis* via traction can effectively restore bony alignment, and minimize surgical soft tissue trauma, restoring normal joint motion. Available literature demonstrates improved range of motion, reduced rates of stiffness, and lower complications as compared with conventional open reduction methods. Further high-quality comparative studies are needed to standardize protocols and define indications. *Tendinotaxis* remains a valuable technique in carefully selected phalangeal fractures where the preservation of soft tissues and early mobilization are essential to functional recovery.

Keywords: *Tendinotaxis*, phalangeal fractures, ligamentotaxis, digital fractures, dynamic external fixation, hand surgery.

Introduction

Phalangeal fractures are among the most common injuries sustained to the hand, and account for approximately 10% of all fractures[1]. Despite their frequency, achieving optimal clinical and functional outcomes remains challenging due to the tight anatomical constraints of the digits and the close proximity of tendons, joints and neurovascular structures. Due to these reasons, there is substantial risk of adhesion formation, joint contracture and tendon imbalance, all of which can compromise digital motion and hand function if not managed optimally[2,3]. Management strategies vary, from immobilization, to closed and open reduction techniques with the goal to restore bony alignment, range of motion and hand function. Although traditional open reduction techniques may achieve anatomical alignment, they do so at the expense of further soft tissue disruption, thereby increasing the likelihood of post-operative adhesions, stiffness and suboptimal functional outcomes[2-6].

In response to these challenges, contemporary management strategies increasingly emphasize approaches that preserve soft tissues while obtaining fracture stability. One such principle is *tendinotaxis,* which exploits the physiological tension generated by intact musculotendinous units to assist in fracture reduction and stabilization. The concept of *tendinotaxis* has its origins in orthopedic literature describing isotonic traction in the management of femoral safe and long bone fractures[6,7]. Within the context of hand fractures, *tendinotaxis* represents a specialized and dynamic form of indirect reduction that differs conceptually and mechanically from *ligamentotaxis*.

Tendinotaxis utilizes tension transmitted through intact flexor and extensor tendons, along with contributions from the interossei and lumbricals, to restore and maintain fracture alignment without the need for extensive surgical exposure[8]. In contrast, *ligamentotaxis,* relies primarily on tensioning static capsuloligamentous structures to achieve fracture reduction. A well-established application of ligamentotaxis is with intra-articular proximal interphalangeal joint fractures, where dynamic traction devices tension the volar plate collateral ligaments, and joint capsule to maintain joint congruity and fracture alignment[9-14]. While the term *tendinotaxis* is frequently applied to extra-articular phalangeal fractures, clear differentiation between these two mechanisms is essential, as they involve distinct anatomical structures, biomechanical forces, and clinical applications.

In extra-articular phalangeal fractures, intact tendons crossing the fracture site exert longitudinal and directional forces that can favorably influence alignment, particularly with respect to angulation, shortening, and rotational deformity[1,15]. When appropriately harnessed through fracture-specific positioning and orthotic design, these forces can provide sufficient stability to permit early controlled mobilization. Therefore, orthotic management plays a critical role in the effective application of *tendinotaxis*, transforming orthoses from a purely immobilization strategy, into an active biomechanical intervention that optimizes tendon tension while fracture the fracture.

The integration of *tendinotaxis* with early controlled rehabilitation offers additional biological and functional advantages. Controlled motion within a mechanically safe range promotes tendon gliding, enhances synovial diffusion, and supports collagen organization along functional stress lines, thereby reducing the risk of adhesions and joint stiffness[16]. Clinical studies have demonstrated that early mobilization protocols, when combines with stable fracture alignment, do not compromise fracture union and are associated with improve range of motion, reduced extensor lag, and earlier return to function[5,16,].

This review outlines the principles, anatomical considerations, indications, techniques, orthotic strategies, and clinical outcomes associated with the application of *tendinotaxis* in the management of phalangeal fractures. By clarifying its distinction

from *ligamentotaxis* and emphasizing its role within a function-oriented treatment paradigm, this manuscript aims to highlight *tendinotaxis* as a key determinant of successful, biologically sound fracture management in the hand.

Anatomical and Biomechanical Basis

The phalanges are encased in a dense fibro-osseous system consisting of: flexor and extensor tendons, collateral ligaments, retinacular structures, as well as the neuro-vascular bundles. In this environment, even minor skeletal displacement may impair full tendon gliding and therefore limit joint motion of both flexion and extension[5]. *Tendinotaxis* relies on these intact structures to apply controlled linear traction forces, pulling fracture fragments into alignment. The flexor digitorum profundus (FDP), flexor digitorum superficialis (FDS), and central slip exert longitudinal tension, while circumferential soft tissue structures provide containment. The biomechanical environment allows traction to create: 1) distraction, reducing fracture displacement and/or angulation, 2) reduce abnormal joint compressive forces, 3) realignment of fractures, particularly of the comminuted fractures, 4) stable yet elastic fixation, supporting early mobilization without compromising integrity of these soft tissues.

Tendinous structures surrounding the skeletal system act as deforming forces on phalangeal fractures. At the level of the proximal phalanx, deforming forces lead to an apex volar angulation with the distal fragment extending due to the central slip and the proximal fragment flexing due to the action of the interossei[1,15,17]. Deforming forces of the middle phalanx is dependent on the location within the bone. With fractures at the distal 1/3, the tension of FDS flexes the proximal fragment, the extensor mechanism extends the distal fragment creating an apex volar angulation (Figure 1). With proximal 1/3 fractures the central slip extends the proximal fragment, FDS flexes the distal fragment leading to an apex dorsal angulation. Middle 1/3 can lead to an apex dorsal or volar. With distal phalanx fractures, the insertions of the FDP and terminal tendon act on fracture fragments near the base[15]. Linear traction, through *tendinotaxis*, can neutralize these deforming forces to restore bony alignment.

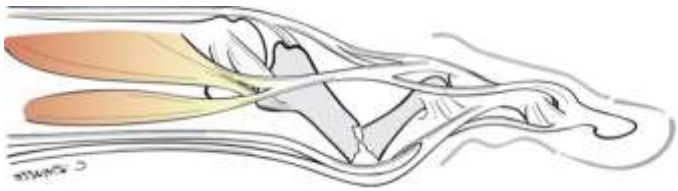


Figure 1: Proximal phalanx fracture with apex volar angulation due to the deforming forces of the FDS tendon and extensor mechanism.

Indications for *Tendinotaxis*

Tendinotaxis can be a successful management strategy for proximal, middle, and distal phalangeal fractures with the following fracture patterns:

- Comminuted diaphyseal fractures
- Intra-articular base fractures of the proximal interphalangeal joint (PIP), and distal interphalangeal joint (DIP)
- Pilon-type fractures
- Unstable spiral or oblique fractures, with minimal loss of length (2-3mm)
- Closed crush injuries with preserved tendon continuity
- Minor malrotation.

Whereas contraindications for its application include:

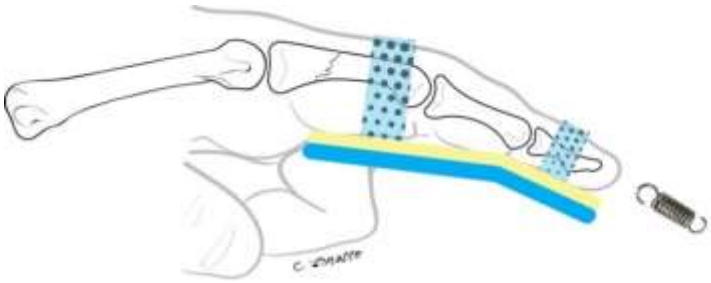
- Complete tendon laceration
- Open injuries with severe soft-tissue loss and exposed bone
- Joint subluxation not correctable by traction
- Poor patient compliance
- Delayed application, after hardening of soft callus
- Significant malrotation.

Tendinotaxis Techniques

Several techniques have been described including manufactured components, or use of K-wires and rubber bands to apply traction. These include the

dynamic external fixation systems e.g. Ligamentotaxator® / Suzuky Frame, Perionychial K-wire, and finger sleeve traction devices and others[18]. The Suzuky frame uses a) K-wires placed proximally and distally connected with elastic bands or hinged rods, b) provides controlled distraction and mobilization and is c) particularly beneficial for comminuted intra-articular PIP fractures[19-21]. The perionychial K-wire utilizes *tendinotaxis* in cases of distal phalanx fractures, this includes a single K-wire passed dorsal to the nail fold, tensioning the terminal extensor tendon to align distal phalanx fragments. As well, the finger sleeve traction device which consists of modern traction sleeves applying axial tension through the fingertip and utilize tendon forces to maintain alignment of proximal and middle phalangeal fractures.

Other conversative approaches have been described through the use of orthoses, casting and other materials to apply traction externally including EAVAST, Southampton, nail traction, as well as others[22-24]. Our conservative approach, the Roth-McFarlane Hand and Upper Limb Centre (HULC) method, includes static linear traction via skin traction maintained with taping and a spring secured within an orthosis[25] (Figure 2 A,B).



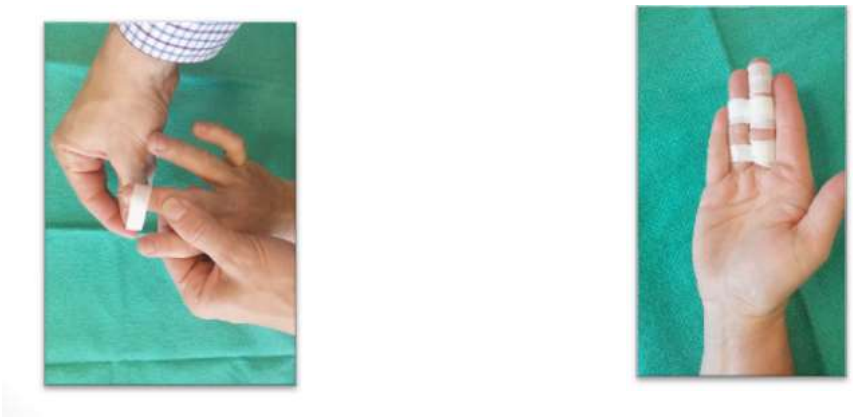
A

B

Figure 2: Application of static linear traction within a custom thermoplastic orthosis, utilizing the HULC method, schematic (A), and patient application (B).

Derotational taping can also be applied with minor malrotation to correct potential scissoring prior to traction application (Figure 3A, B). Weekly radiologic and/or fluoroscopic evaluation is recommended to monitor fracture healing. This can be applied with both proximal and middle

phalangeal fractures. The following are case studies demonstrate the application of this technique, including radiographic changes and range of motion outcomes.



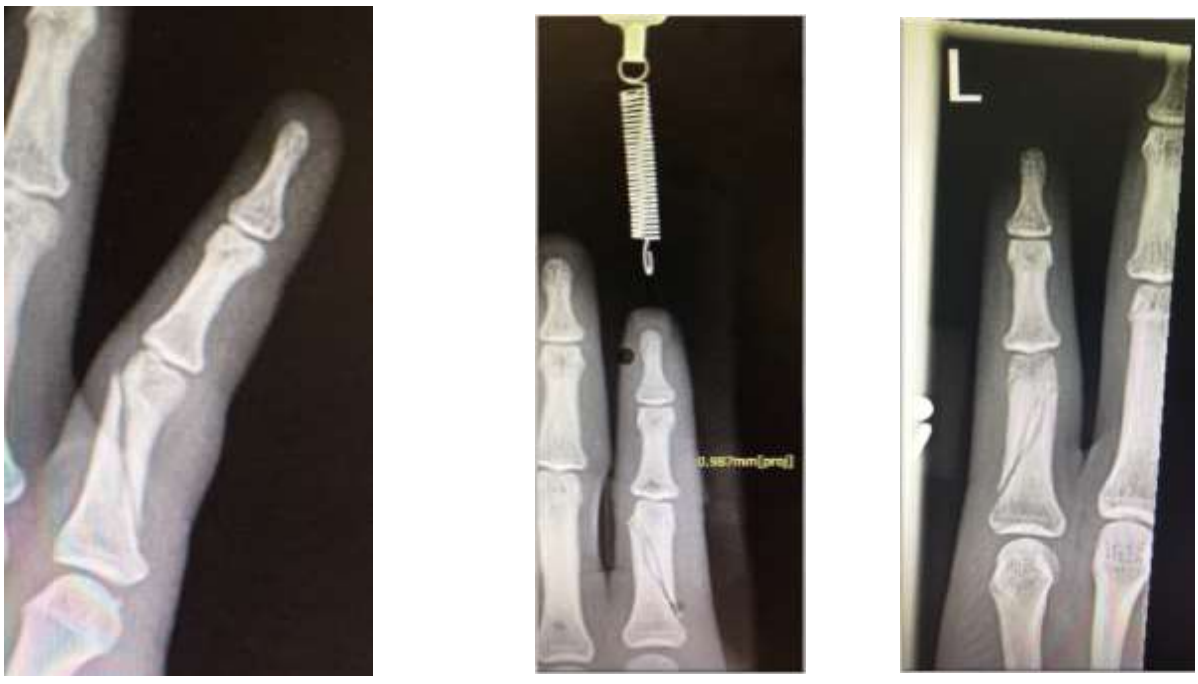
A B

Figure 3: A, B. Derotational taping technique to correct mild malrotation

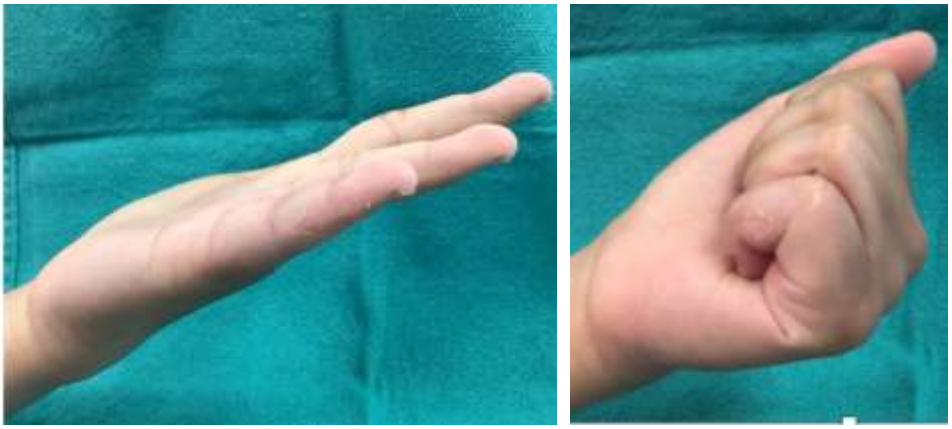
Illustrative Cases

The following illustrative cases demonstrate the application of linear traction for various fracture patterns in proximal and middle phalangeal fractures, with restoration of anatomic fracture alignment illustrating the *tendinotaxis* principles.

Case 1: Small finger spiral proximal phalanx fracture managed with static linear traction with the HULC technique described above. The fracture is demonstrated before traction application, with traction, fracture healing post traction as well as final range of motion outcomes (Figure 4 A,B,C,D,E).



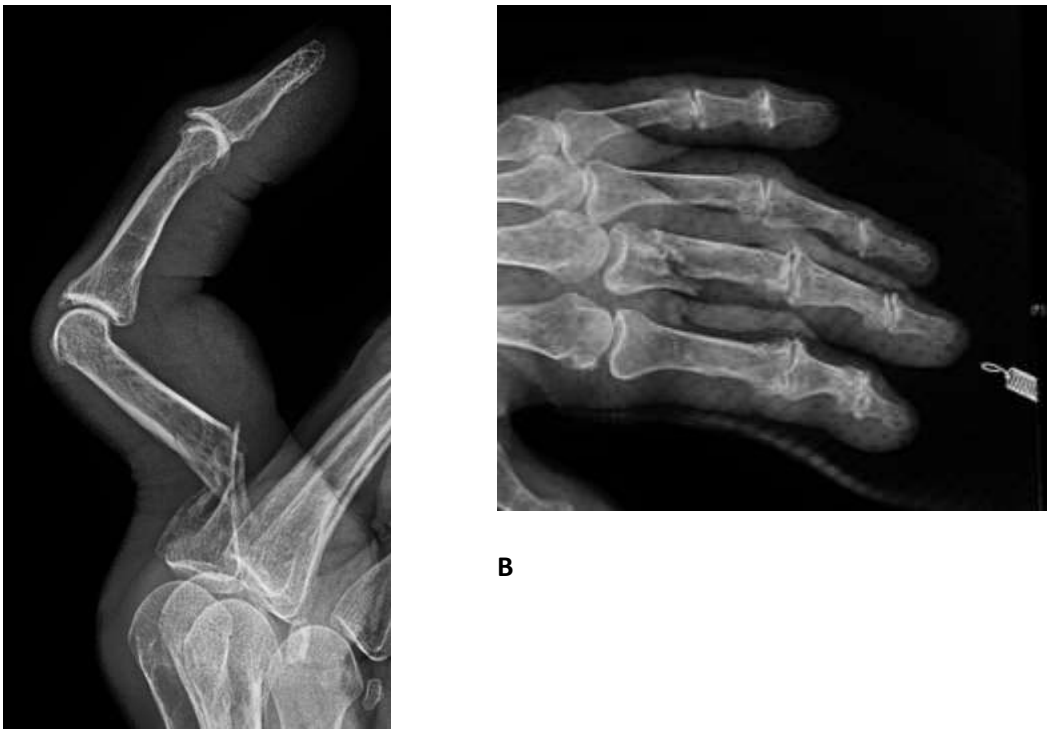
A B C



D E

Figure 4: Left small proximal phalanx fracture pre-traction application (A), with traction application (B), fracture healing post traction (C), range of motion in extension (D), and flexion (E).

Case 2: Left middle finger proximal phalanx fracture with significant angulation, managed with HULC method linear traction. Radiographs depicting initial injury, within the traction orthosis, fracture healing, and figures for final range of motion outcomes (Figure 5A,B,C,D,E,F)



B

A

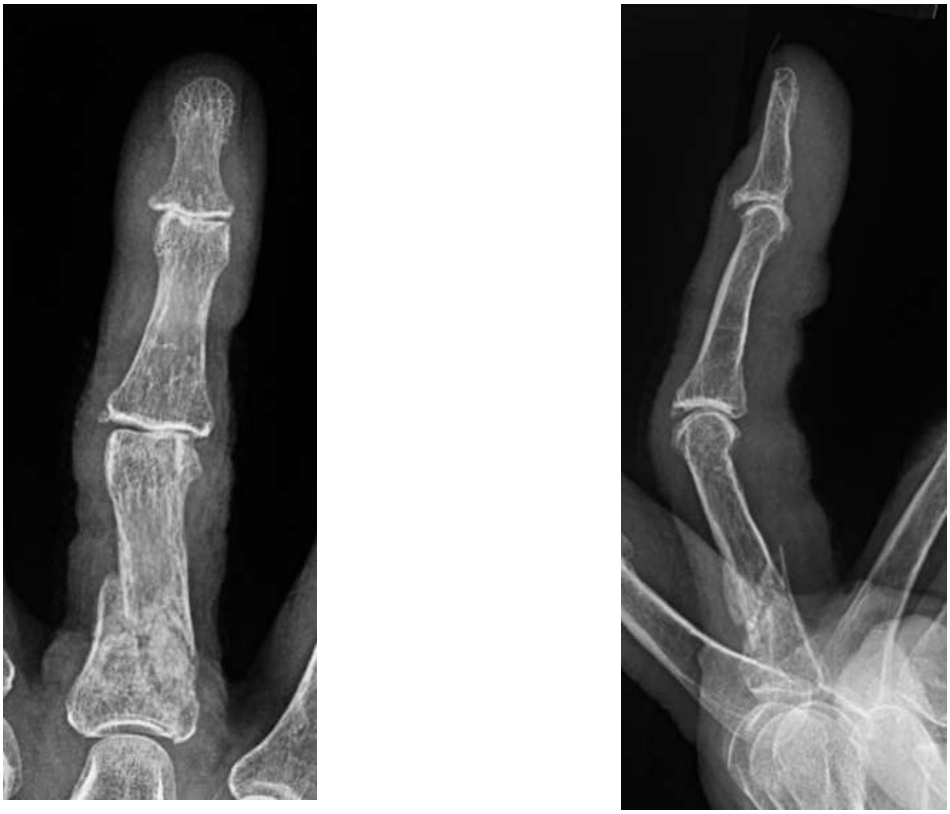
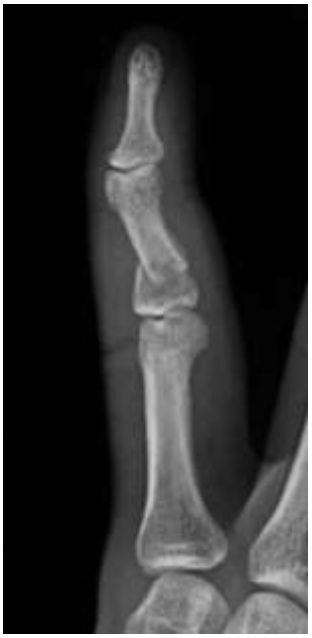


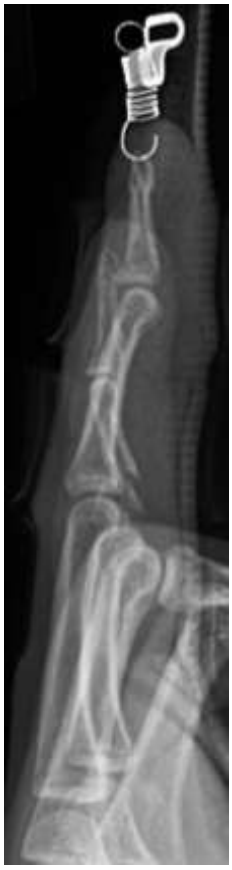
Figure 5: Left middle finger proximal phalanx fracture pre-traction application (A), with traction application (B), fracture healing post traction (C,D), and range of motion in extension (E), and flexion (F).

Case 3: Left small finger base of middle phalanx fracture with apex volar angulation, and failed attempts at closed reduction. The case was managed with the HULC technique for static linear traction. Figures depict images demonstrate fracture, with static traction proximal phalanx fracture with significant angulation, managed with HULC method linear traction. Radiographs depicting initial injury, within the traction orthosis, fracture healing, and final range of motion outcomes (Figure 6A,B,C,D,E,F,G,H)

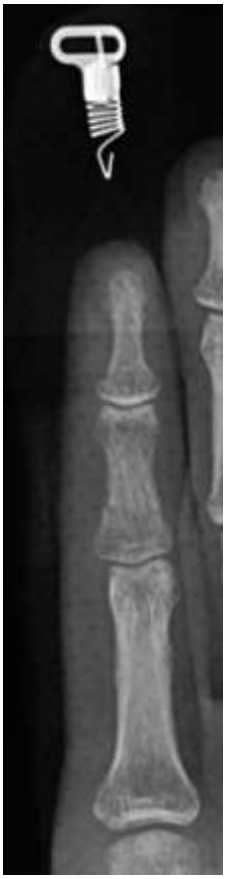
A



B



C



D

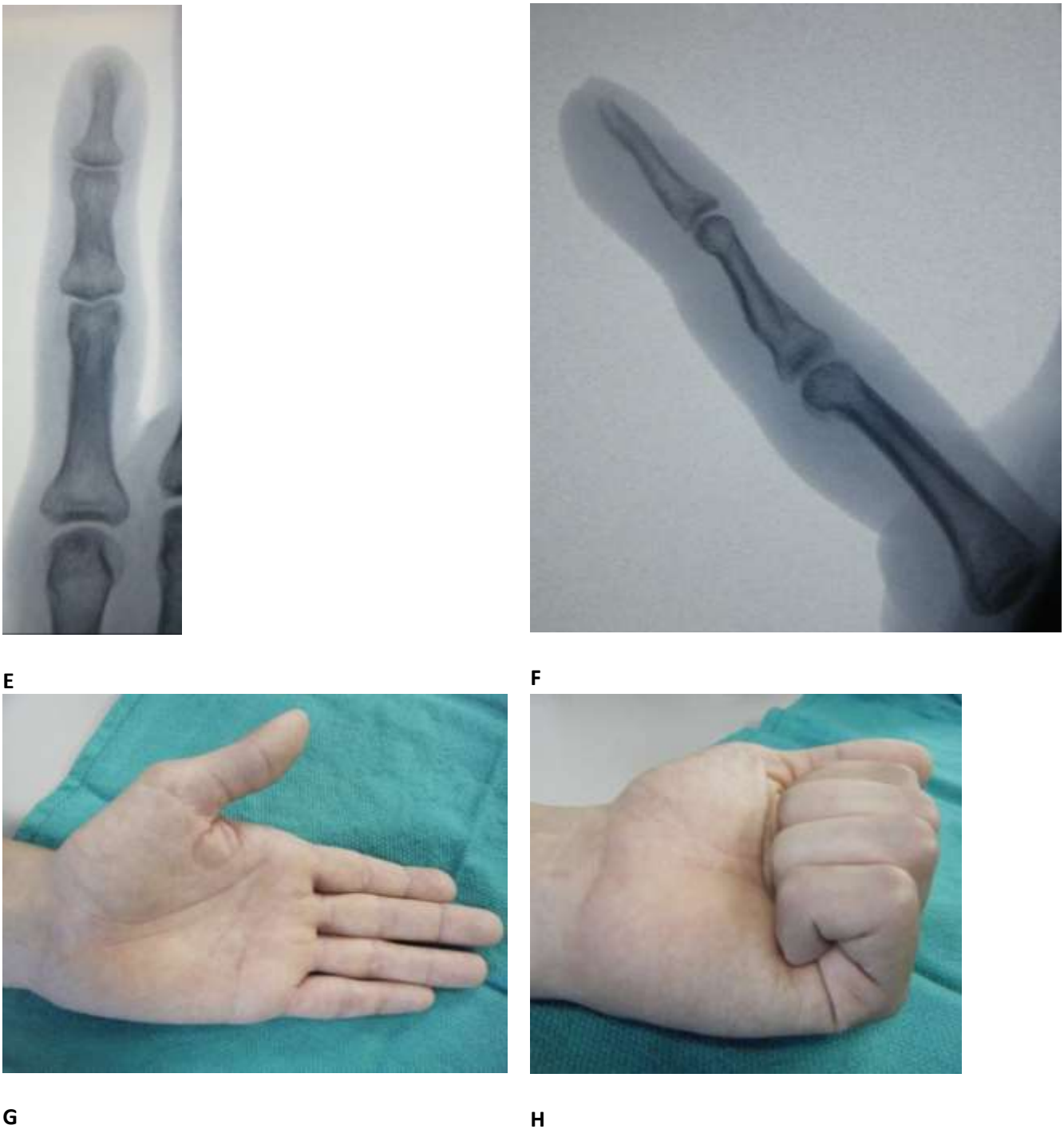


Figure 6: Left small finger base of middle phalanx fracture pre-traction application (A,B), with traction application (C,D), fracture healing post traction (E,F), and range of motion in extension (G), and flexion (H)

Rehabilitation Considerations

Early controlled mobilization remains essential upon radiologic confirmation of fracture healing. *Tendinotaxis* provides stable yet dynamic fixation, permitting edema control, prevention of adhesions, allowing tendon gliding and restoration of motion and strength[12]. Custom orthoses may complement traction techniques.

Outcomes

Studies have reported outcomes with the use of dynamic traction in the management of PIPJ fracture dislocations as being a mean PIPJ arc of motion as -5 extension and 89.4 +/- 9.79 degrees of flexion, no infection rate, and complete fracture union rate, and 20% with slight joint narrowing, and 10% uneven articular surface[26]. Lo et al also report similar ROM outcomes with the application of the Suzuki frame[27]. Studies implementing the use of

traction via dynamic external fixators with proximal phalangeal fractures reported outcomes of an average of 258.61 degrees of TAM, 72% in the excellent range of motion category, and no cases of infection or non-union[12]. Similarly, the application of static linear traction in the management of phalangeal fractures is demonstrated to yield good results. Jehan et al case series with 43 patients, outcomes as 81% achieving good TAM (210° or more) and 77% good (less than 10° angulation on radiograph) reduction, and 4.7% with poor TAM and fracture alignment[24].

Complications

Although uncommon, potential complications include: over distraction, PIP extensor lag, and skin irritation. Over distraction, if identified radiologically or fluoroscopically, can be corrected with the linear traction force reduced to maintain 1-2 mm of joint space. An extensor lag could also be managed by relative motion metacarpophalangeal joint (MCP) flexion splinting and a tendon acceleration program. Skin irritation, if identified, can be addressed by replacing with a hypoallergenic tape. Proper technique, frequent follow-up, and timely device removal reduce these possible risks.

Discussion

Tendinotaxis exploits the inherent biomechanical forces generated by intact flexor and extensor tendons, together with the intrinsic musculature, to achieve fracture reduction that is both stable and dynamically responsive. In phalangeal fractures, this principle allows fracture alignment to be influenced by physiological tendon tension rather than rigid mechanical constraint, thereby maintaining alignment while preserving the surrounding soft-tissue envelope essential for functional recovery[2,3,8,12].

Compared with open reduction and internal fixation, *tendinotaxis*-based strategies minimize iatrogenic soft-tissue trauma and disruption of periosteal and vascular structures. Although open techniques may provide precise anatomical reduction, they are frequently associated with tendon adhesions, joint stiffness, and delayed return of function, particularly within the confined anatomical environment of the digits [2,4,17,28]. In contrast, indirect reduction through *tendinotaxis*, via various traction approaches, supports biological fracture healing while facilitating early controlled mobilization, a cornerstone of contemporary hand fracture management[7].

Clinical evidence suggests that traction-based and *tendinotaxis*-driven techniques are particularly effective in comminuted extra-articular phalangeal fractures, fractures associated with joint depression, and injuries in which avoidance of open dissection is desirable[12]. In such fractures, intact tendons spanning the fracture site exert longitudinal and corrective forces that help restore alignment, maintain length, and neutralize deforming forces. This dynamic stability is especially advantageous in fracture patterns prone to collapse or stiffness treated with static immobilization alone, such as proximal and middle phalangeal fractures[8,10].

Orthotic design and application are key to the successful implementation of *tendinotaxis*. Dynamic and static-progressive orthoses allow precise joint positioning to optimize tendon tension while protecting the fracture site [8,10]. Advances in orthosis materials and modular traction systems have improved reproducibility, adjustability, and patient comfort, thereby enhancing compliance and enabling earlier initiation of rehabilitation[12,14]. In combination with guided, phase-appropriate progression of mobilization protocols, these strategies promote tendon glide, reduce adhesion formation, and facilitate earlier and more complete restoration of functional hand use[10].

Despite its advantages, *tendinotaxis* is not universally applicable and requires careful patient selection. Its effectiveness depends on fracture pattern, the integrity of the musculotendinous

units, and the ability to maintain alignment through orthotic means. Fractures with unstable rotational deformity, significant articular incongruity, or associated tendon injury may require alternative or adjunctive fixation strategies[13,28]. Furthermore, outcomes are closely linked to the quality of orthotic fabrication, patient adherence, and coordinated hand therapy, emphasizing the importance of a multidisciplinary approach[8,10].

Limitations and Future Directions

The application of *tendinotaxis* with phalangeal fracture management has several important limitations. Its success is contingent on intact tendon systems and fracture patterns amenable to reduction through traction. Injuries with extensive articular involvement, severe instability, or compromised tendons may not be suitable for *tendinotaxis* as a standalone intervention and often necessitate open reduction or supplemental fixation[13,28]. In addition, treatment outcomes are influenced by patient compliance, access to specialized hand therapy services, and clinician expertise in orthotic design and rehabilitation progression[8,10].

From an evidence standpoint, much of the current literature supporting *tendinotaxis* consists of retrospective series, technical descriptions, and small cohort studies, with limited high-level comparative data[12,14]. Future research is suggested to focus on prospective and randomized studies comparing *tendinotaxis*-based protocols with rigid internal fixation and prolonged immobilization, using standardized functional and patient-reported outcome measures. Further investigation into fracture-specific orthotic designs, optimal timing and dosage of early controlled motion, and long-term functional outcomes is essential to refine indications and establish evidence-based clinical guidelines for *tendinotaxis* in phalangeal fracture care.

Conclusion

Tendinotaxis represents a biologically sound and function-oriented strategy in the management of selected phalangeal fractures. By utilizing physiological tension generated by intact flexor and extensor tendons, this approach enables indirect fracture reduction while preserving the surrounding soft-tissue envelope essential for optimal functional recovery[6-8]. When applied through appropriately designed orthoses and combined with controlled mobilization, *tendinotaxis* supports fracture union, minimizes adhesion formation, and facilitates restoration of coordinated digital motion[10.12].

Compared with rigid fixation or prolonged immobilization, *tendinotaxis*-based protocols align with contemporary principles of biological fixation and rehabilitation-driven fracture care, emphasizing soft-tissue preservation and early function, rather than purely radiographic outcomes[2,4,28]. When applied to appropriate fracture patterns and supported by coordinated hand therapy, *tendinotaxis* offers a reliable alternative to more invasive techniques, reinforcing its continued relevance in modern phalangeal fracture management.

Conflict of Interest:

The authors have no conflicts of interest to declare.

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