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Acute Flexor Tendon Injuries in the Palm and Hand: A Review of Surgical Repair Techniques and Rehabilitation Outcomes

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Abstract

Background: Flexor tendon injuries of the hand are clinically important traumatic injuries because they may impair finger flexion, grip strength, and daily hand function. Successful management requires proper understanding of tendon anatomy, nutrition, healing, injury zones, repair techniques, suture materials, rehabilitation protocols, and postoperative complications. This review aims to summarize the relevant surgical anatomy, biological basis of tendon healing, clinical assessment, principles of flexor tendon repair, commonly used repair techniques, suture materials, postoperative rehabilitation, and complications of flexor tendon injuries of the hand.

Conclusion: Optimal management of flexor tendon injuries depends on accurate diagnosis, early appropriate repair, sufficient repair strength, preservation of tendon gliding, and structured postoperative rehabilitation. Four-strand repair techniques provide improved strength and may allow early controlled mobilization; however, adhesions and stiffness remain important challenges.

Keywords: Flexor tendon injury; Hand surgery; Modified Kessler technique; Tendon healing; Adhesions; Rehabilitation.

Introduction

The hand is involved in most daily activities and is therefore highly exposed to trauma, particularly in domestic, industrial, agricultural, and road traffic settings. Flexor tendon injuries are among the most significant hand injuries because they directly affect active finger flexion and hand function (Samant et al., 2019; de Jong et al., 2014).

Acute flexor tendon injury is commonly managed by primary end-to-end repair, preferably early after trauma. The ideal repair should provide adequate tensile strength, maintain tendon gliding, and allow early controlled postoperative motion to reduce stiffness and adhesion formation (Plastic Surgery - Principles and Practice, 2022; Wichelhaus et al., 2016).

Relevant Surgical Anatomy

The anatomy of the hand is complex and essential for daily functional activity. The hand contains bones, joints, intrinsic muscles, extrinsic tendons, nerves, vessels, and specialized tendon sheaths. Understanding this anatomy is necessary for accurate diagnosis and surgical repair of flexor tendon injuries (Bazira, 2022; Moore, 2009).

The flexor mechanism of the hand depends mainly on the extrinsic flexor tendons, including the flexor digitorum superficialis, flexor digitorum profundus, and flexor pollicis longus. The anatomical arrangement of these muscles and tendons is demonstrated in Figure 1 and Figure 2 (Schünke et al., 2024; Lung & Burns, 2026).

The forearm flexor muscles are divided into superficial and deep groups. The superficial group includes pronator teres, flexor digitorum superficialis, flexor carpi radialis, palmaris longus, and flexor carpi ulnaris, while the deep group includes flexor digitorum profundus, flexor pollicis longus, and pronator quadratus. This arrangement is shown in Figure 3 (Schünke et al., 2024).

The flexor digitorum profundus tendon is a key component of finger flexion because it flexes the distal interphalangeal joint and contributes significantly to full finger flexion and grip strength (Lapegue et al., 2020; Lung & Burns, 2026).

The flexor tendons pass through the carpal tunnel and the digital fibro-osseous sheath. The relationship of the tendons inside the carpal tunnel and at different levels of the hand is illustrated in Figure 4 and Figure 5 (Schünke et al., 2024; Presazzi et al., 2011).

The pulley system is important for maintaining the flexor tendons close to the phalanges and preventing bowstringing during finger flexion. The annular and cruciate pulleys are shown in Figure 7, while Camper's chiasm formation is shown in Figure 6 (Campbell & Goyal, 2017; Schmidt et al., 1994).

Flexor tendon injuries are classified according to Verdan's zones. This classification is important because the anatomical level of injury affects surgical exposure, tendon gliding, risk of adhesion, and functional outcome. Verdan's classification is shown in Figure 8 (Campbell & Goyal, 2017; Ahmad et al., 2019).

Normal range of motion of the finger joints is essential for evaluating postoperative recovery. The normal motion of the DIP, PIP, and MCP joints is illustrated in Figure 9 (Wilson, 1990).

Flexor Tendon Nutrition and Healing

Flexor tendons are composed mainly of collagen fibers and tendon cells, including tenoblasts and tenocytes. Type I collagen forms the major component of tendon dry mass and provides mechanical strength. The histological structure of the flexor tendon is shown in Figure 10 (Bordoni et al., 2026; James et al., 2008).

Flexor tendon nutrition depends on intrinsic tendon vascularity and synovial diffusion. Within the synovial sheath, vascularity is supported by vincular vessels, while synovial diffusion contributes to nutrition during tendon gliding. The relationship of the vincula to the tendons is illustrated in Figure 11 (Tempfer & Traweger, 2015; Fenwick et al., 2002).

The ability of intrasynovial flexor tendons to heal intrinsically supports the concept of early postoperative mobilization after repair. Intrinsic healing improves tendon structure and gliding, whereas extrinsic healing may increase scar formation and adhesions (Klifto et al., 2018; Wang, 2006).

Tendon healing occurs through inflammatory, proliferative, and remodeling phases. These phases include inflammatory cell migration, fibroblast proliferation, collagen synthesis, and later collagen remodeling and alignment along the tendon axis. The overview of tendon healing is shown in Figure 12 (Sharma & Maffulli, 2005; Shen et al., 2016; Chen et al., 2011).

Flexor Tendon Injury and Clinical Assessment

Flexor tendon injuries commonly occur after sharp lacerations to the volar aspect of the hand or fingers. These injuries may be associated with manual work, domestic trauma, sports injuries, or road traffic accidents (Huynh et al., 2022; Spark et al., 2019).

Clinical assessment should include wound site, wound size, contamination, vascularity, sensation, and active finger motion. Examination of FDS and FDP tendons is essential to identify the injured tendon. The clinical examination of FDS and FDP is demonstrated in Figure 14 (Goldfarb et al., 2016; Wolfe et al., 2022).

The normal cascade of the fingers during flexion helps in detecting flexor tendon disruption. Loss of the normal cascade or abnormal tenodesis effect may indicate tendon injury. The normal finger cascade is shown in Figure 15 (Wolfe et al., 2022).

Radiological assessment is useful to exclude associated fractures or retained foreign bodies. Associated neurovascular injuries should also be assessed because they may affect timing of repair, surgical planning, rehabilitation, and prognosis (Goldfarb et al., 2016; Ramirez & Hoyt, 2016).

Principles of Flexor Tendon Repair

Primary repair is preferred in clean acute flexor tendon lacerations because it allows easier tendon retrieval, reduces scarring, and improves the chance of functional recovery. Surgical exposure should provide adequate visualization while protecting the neurovascular bundles and preserving skin flap viability (de Jong et al., 2014; Wolfe et al., 2022).

Bruner's incision provides wide exposure of the volar aspect of the finger while crossing flexion creases in a zigzag manner to reduce the risk of scar contracture. This incision is shown in Figure 16 (Wolfe et al., 2022; Allan, 2005).

The strength of flexor tendon repair depends on the number of core suture strands, suture purchase length, anchoring technique, locking configuration, suture material, and repair method. Increasing the number of strands improves tensile strength and gap resistance (Miller et al., 2007; Benameur et al., 2022; Nassar et al., 2023).

Methods of Flexor Tendon Repair

Different flexor tendon repair techniques have been described, including two-strand, four-strand, and six-strand techniques. Examples of two-strand repair techniques are shown in Figure 17, while examples of four- and six-strand techniques are shown in Figure 18 (Goggins et al., 2014; Viinikainen et al., 2008).

The modified Kessler technique is commonly used because it is simple, reproducible, and provides acceptable repair strength. The modified Kessler suture technique is shown in Figure 19 (Sharma, 2004; Neligan & Chang, 2013).

Four-strand modified Kessler repair increases the number of strands crossing the repair site, which improves repair strength and allows safer early controlled mobilization. The steps of the 4-strand modified Kessler technique are shown in Figure 20 (Miller et al., 2007; Benameur et al., 2022).

The cross-sectional appearance of flexor tendon repair using different core suture techniques is demonstrated in Figure 21. This is important because increased repair bulk may impair tendon gliding, especially within narrow pulley zones (Miller et al., 2007; Nassar et al., 2023).

The epitendinous suture adds strength to the repair, improves tendon contour, and reduces catching during tendon gliding. The epitendinous suture is shown in Figure 22 (Wolfe et al., 2022; Tang et al., 2012).

Closure of the tendon sheath is not always essential. Avoiding constriction of the edematous repaired tendon is important, and preservation or reconstruction of A2 and A4 pulleys is recommended to prevent bowstringing (Wolfe et al., 2022; Lahiri, 2019).

Suture Materials

Non-absorbable synthetic sutures are commonly used in flexor tendon repair because they maintain strength during the early healing period. Coated braided polyester, monofilament nylon, and monofilament polypropylene are commonly used materials (Nassar et al., 2023; Viinikainen et al., 2008).

Coated braided polyester is frequently used for core repair because of its tensile strength, while polypropylene is commonly used for peripheral sutures. Locking sutures provide stronger repair than grasping sutures, and at least a four-strand repair is recommended when early active motion protocols are planned (Hatanaka & Manske, 2000; Nassar et al., 2023).

Bioabsorbable sutures are less commonly used in flexor tendon repair because of concerns regarding early loss of tensile strength, tissue reaction, and possible adhesion formation (Wada et al., 2001; Chen et al., 2011).

Postoperative Rehabilitation

Postoperative rehabilitation is a critical factor in the final outcome after flexor tendon repair. Controlled mobilization promotes healing by enhancing fibroblast proliferation, collagen alignment, and tendon gliding (Wang, 2006; Pettengill & Van Strien, 2012).

Immobilization may be used in selected cases, but prolonged immobilization increases the risk of adhesions and stiffness. The posterior slab and protective dressing used for immobilization are shown in Figure 23 (Pettengill & Van Strien, 2012; Thien et al., 2004).

Passive mobilization protocols aim to provide tendon excursion with minimal stress on the repair site. Kleinert and Duran protocols are examples of controlled postoperative motion programs, as shown in Figure 24 (Neligan & Chang, 2013; Kitis et al., 2009).

Controlled active motion protocols are used after strong multistrand repair because they may improve tendon excursion and functional recovery. A thermoplastic splint used in early active mobilization protocols is shown in Figure 25 (Pettengill & Van Strien, 2012; Frueh et al., 2014).

Controlled active motion following flexor tendon repair is demonstrated in Figure 26. This protocol usually combines dorsal blocking splint protection with controlled tendon gliding exercises to reduce adhesions and protect the repair (Strickland, 2005; Pettengill & Van Strien, 2012).

Complications of Flexor Tendon Repair

Tendon rupture is one of the serious complications after flexor tendon repair and may result from weak repair, excessive early loading, poor compliance, or technical failure. Strong multistrand repair and protected rehabilitation reduce this risk (Wongsiri & Liawrungrueang, 2021; Miller et al., 2007).

Adhesion formation is one of the most common complications and may limit tendon gliding and total active motion. Adhesions are influenced by injury severity, zone of injury, tissue handling, repair bulk, postoperative edema, and rehabilitation compliance (Neligan & Chang, 2013; Hatanaka & Manske, 2000).

Triggering may occur when the repair site catches on the pulley or tendon sheath. Bulky repair or tight sheath closure may contribute to triggering, so intraoperative assessment of tendon gliding is important (Lilly & Messer, 2006; Wolfe et al., 2022).

Pulley failure may lead to bowstringing, especially when A2 or A4 pulleys are damaged. Bowstringing reduces tendon efficiency, finger strength, and tendon excursion; therefore, preservation or reconstruction of key pulleys is important (Lilly & Messer, 2006; Lahiri, 2019).

Quadriga is the inability of uninjured fingers to obtain full flexion due to functional shortening or tethering of the FDP tendon. Proper tendon tensioning during repair helps prevent this complication (Wolfe et al., 2022).

The prognosis after flexor tendon repair depends on mechanism and extent of injury, patient factors, timing of repair, repair technique, associated injuries, and compliance with rehabilitation. Good outcomes require strong repair, preserved tendon gliding, and structured postoperative therapy (Wolfe et al., 2022; Spark et al., 2019).

Conclusion

Flexor tendon injuries require accurate anatomical knowledge, proper surgical technique, suitable suture material, and structured postoperative rehabilitation. Four-strand repair techniques improve repair strength and allow early controlled mobilization, but the repair should remain smooth enough to preserve tendon gliding (Miller et al., 2007; Benameur et al., 2022; Nassar et al., 2023).

Adhesions, stiffness, rupture, triggering, bowstringing, and quadriga remain important complications after flexor tendon repair. Optimal outcomes depend on early diagnosis, primary repair when suitable, preservation of the pulley system, controlled rehabilitation, and close follow-up (Wolfe et al., 2022; Pettengill & Van Strien, 2012; Lahiri, 2019).

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