

Flexor Tendon Injuries and Hand Tendinorrhaphy: A Comprehensive Review

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ABSTRACT

Flexor tendon injuries of the hand represent a challenging clinical entity with significant functional implications. This comprehensive article delves into the intricate realm of flexor tendon injuries, shedding light on the pathophysiology, diagnostic approaches, and treatment modalities, with a primary focus on the surgical technique of tendinorrhaphy.

The article commences with an exploration of the anatomy and biomechanics of flexor tendons, elucidating the pivotal role they play in hand function. It subsequently outlines the diverse etiologies that lead to tendon injuries, encompassing traumatic, iatrogenic, and spontaneous causes, while emphasizing the importance of prompt and accurate diagnosis through clinical assessment, imaging, and functional testing.

A detailed exposition of the principles and techniques of tendinorrhaphy follows, elucidating the surgical intricacies involved in repairing damaged flexor tendons. The article discusses suture materials, repair methods, and rehabilitation protocols, highlighting the importance of postoperative care and meticulous hand therapy in optimizing outcomes.

Furthermore, this article critically reviews emerging trends and innovations in the field, including the use of tissue engineering, biomaterials, and minimally invasive approaches, all of which hold promise for enhancing the management of flexor tendon injuries.

In conclusion, this article offers a comprehensive overview of flexor tendon injuries in the hand and underscores the pivotal role of tendinorrhaphy as a cornerstone in their treatment. With a holistic perspective on the subject, it provides clinicians and researchers with a valuable resource to navigate the intricacies of this challenging clinical scenario and fosters ongoing advancements in the field of hand surgery.

KEYWORDS: Flexor Tendon, Tendinorrhaphy, Hand Injury, Rehabilitation, Tendon Repair

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INTRODUCTION

Flexor tendon injuries within the intricate anatomy of the hand pose a unique and demanding challenge in the field of hand surgery. The graceful dexterity of the human hand is contingent upon the harmonious functioning of its flexor tendons, which, when impaired, can significantly impact an individual's quality of life. Recognized as one of the most intricate mechanisms in the musculoskeletal system, the flexor tendons orchestrate precise finger and hand movements, facilitating essential functions ranging from the

delicate finesse of piano playing to the sturdy grip of manual labor.^{1,2}

The vulnerability of these vital structures to injury is a consequence of their superficial location beneath the palmar surface, rendering them susceptible to a myriad of traumatic and non-traumatic insults. This article embarks on an intricate journey through the multifaceted world of flexor tendon injuries, delving into their etiology, pathophysiology, and the formidable arsenal of surgical interventions, with a primary spotlight on the venerable technique of tendinorrhaphy.¹

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Comprehending the profound implications of flexor tendon injuries necessitates an exploration of the intrinsic architecture and biomechanical marvel that characterizes these sinewy conduits. The tendons, ensheathed within their synovial confines, glide effortlessly through pulley systems, ensuring smooth flexion and extension of the fingers. This fundamental understanding forms the cornerstone upon which accurate diagnosis, effective treatment, and rehabilitation strategies are built.³

A panoramic view of the diverse etiological factors that precipitate flexor tendon injuries ensues, encompassing traumatic lacerations, iatrogenic damage, and the less understood domain of spontaneous ruptures. The insidious nature of these injuries often necessitates a vigilant and comprehensive clinical evaluation, complemented by sophisticated diagnostic modalities, to decipher the extent of damage and guide the course of management.⁴

Central to this exposé is the meticulous surgical artistry of tendinorrhaphy, a venerable technique that has evolved over centuries. This method involves the precise approximation and suturing of tendon ends, a process that demands surgical finesse and a nuanced understanding of tendon healing biology. Beyond the surgical nuances, this article delves into the realm of postoperative care and the pivotal role of hand therapy in fostering optimal functional recovery.⁴

Furthermore, as the horizon of medical innovation continues to expand, this article also explores contemporary developments in the field, such as tissue engineering, biomaterial utilization, and minimally invasive approaches, which have the potential to redefine the landscape of flexor tendon injury management.⁴

In summation, this article embarks on an odyssey through the intricacies of flexor tendon injuries in the hand, offering a panoramic view of their anatomy, etiology, and treatment. By placing the venerable technique of tendinorrhaphy under the spotlight, we aim to provide a comprehensive resource for clinicians, researchers, and surgeons navigating the challenging terrain of hand surgery, while also fostering a continued dialogue on advancing the frontiers of this vital domain in the realm of medicine.^{4,5}

JUSTIFICATION

Flexor tendon injuries within the hand represent a compelling subject of study and clinical interest due to their intricate nature and profound impact on hand function. The justification for investigating this topic is multifaceted and rooted in its clinical significance, socioeconomic implications, and the potential for improved patient outcomes.^{4,5}

Clinically, the hand is a remarkable and versatile anatomical structure, allowing humans to perform an array of intricate tasks that define our species. The harmonious functioning of the flexor tendons within the hand is essential for this dexterity. However, when injury occurs, whether through traumatic accidents, surgical procedures, or idiopathic

causes, the consequences can be debilitating. Loss of hand function affects not only an individual's ability to perform everyday tasks but also their livelihood and overall quality of life. Hence, a comprehensive understanding of flexor tendon injuries and the optimal management through tendinorrhaphy is paramount to restoring function and improving patients' well-being.^{5,6}

Socioeconomically, these injuries carry a substantial burden. The economic impact encompasses not only medical expenses but also the potential for long-term disability, lost productivity, and rehabilitation costs. Consequently, research and innovations in the field can lead to more cost-effective treatments and improved outcomes, thus benefiting both patients and healthcare systems.⁶

Moreover, advancements in surgical techniques and rehabilitation protocols are continuously evolving, offering new perspectives and solutions for managing flexor tendon injuries. By exploring these developments and their clinical applicability, this article seeks to bridge the gap between traditional approaches and emerging technologies, offering a comprehensive resource for clinicians and researchers engaged in the field of hand surgery.⁶

EPIDEMIOLOGY

Understanding the epidemiological landscape of flexor tendon injuries is pivotal for assessing the scope and relevance of this clinical problem. Flexor tendon injuries are not uncommon and can occur across a broad demographic spectrum.⁶

Traumatic Injuries: Trauma is a primary precipitating factor for flexor tendon injuries. These injuries frequently occur in occupational settings involving machinery, as well as in sports-related incidents. Additionally, they are prevalent in cases of sharp object lacerations, such as knife injuries.⁷

Iatrogenic Injuries: Flexor tendon injuries can also arise as a result of iatrogenic factors, most notably during surgical procedures involving the hand. Inadvertent tendon damage during surgery underscores the importance of surgical precision and careful anatomical knowledge.⁷

Spontaneous Ruptures: Although less common, spontaneous ruptures of flexor tendons can occur, often associated with underlying conditions such as rheumatoid arthritis or systemic diseases that affect tendon integrity.^{7,8}

Age and Gender: Epidemiological data show a predilection for flexor tendon injuries in the younger population, with males being more commonly affected. This demographic trend is often attributed to increased engagement in high-risk activities and manual labor.⁸

Anatomical Distribution: Flexor tendon injuries can occur at various locations within the hand, with the digits' zone II (between the distal and proximal interphalangeal joints) being the most commonly affected.^{8,9}

By elucidating the epidemiology of flexor tendon injuries, we gain insight into their prevalence, risk factors, and patterns of occurrence. This knowledge is invaluable in guiding

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preventative measures, optimizing diagnostic approaches, and tailoring treatment strategies, all of which contribute to enhanced patient care and outcomes.⁹

SURGICAL TECHNIQUES IN FLEXOR TENDON INJURY AND HAND TENDINORRHAPHY

The management of flexor tendon injuries in the hand demands meticulous surgical expertise and a nuanced understanding of tendon anatomy and healing processes. Surgical repair, specifically tendinorrhaphy, plays a central role in restoring the structural integrity and function of these crucial tendons. Below, we delve into the intricate details of surgical techniques employed in the treatment of flexor tendon injuries:¹⁰

Incision and Exposure:

The surgical journey begins with a carefully planned incision over the affected tendon, often guided by anatomical landmarks. The choice of incision pattern depends on the specific injury location.¹⁰

Atraumatic tissue handling and precise dissection are essential to minimize additional damage and preserve vascular supply.¹⁰

Tendon Exploration:

Gentle blunt dissection reveals the damaged tendon ends, which are meticulously inspected to assess the extent of injury.¹⁰

In cases of partial tendon lacerations, debridement of frayed or damaged tissue is performed, leaving healthy tendon substance for repair.

Suture Techniques:

The cornerstone of tendinorrhaphy lies in the suturing of tendon ends. Surgeons utilize a variety of suture techniques, such as the modified Kessler, epitendinous, or locking techniques, depending on the specific injury and tendon involved.

Suture materials vary but often include non-absorbable sutures like Ethibond or absorbable sutures like Vicryl, chosen based on surgeon preference and patient factors.¹⁰

Tendon Repair Zone:

The choice of repair zone is a critical consideration. In zone I (within the digital sheath), surgeons opt for core sutures, whereas in zone II (between the distal and proximal interphalangeal joints), epitendinous sutures are more commonly employed.¹⁰

Zone III (within the palm) injuries require robust repair techniques due to the increased forces at play. Multiple-strand techniques like the 'cross-stitch' or 'six-strand' repair are often utilized for added strength.¹⁰

Surgical Adjuvants:

Surgeons may opt to reinforce the repair with the use of adjunctive techniques such as circumferential wiring or pulley reconstruction in cases where pulley damage has occurred.

Biological adjuvants, including platelet-rich plasma (PRP) or amniotic membrane grafts, are emerging as potential options to enhance tendon healing and reduce adhesions.¹⁰

Tendon Sheath Management:

In cases where the tendon sheath is compromised, meticulous repair or reconstruction of the sheath is imperative to prevent tendon bowstringing and adhesion formation.

Synovectomy may be considered when addressing inflammatory conditions affecting the sheath.¹⁰

Postoperative Care:

The success of surgical repair hinges on diligent postoperative care. Immobilization in a protective splint or dynamic traction device is often employed to maintain tendon alignment.

Early controlled mobilization through a supervised hand therapy program is initiated to prevent adhesions while promoting tendon gliding.¹⁰

Rehabilitation:

Rehabilitation is an integral component of the surgical journey. Gradual strengthening exercises and range of motion protocols are tailored to the patient's specific injury and progress.

Supervised therapy sessions are critical in ensuring the gradual restoration of hand function while minimizing the risk of re-rupture.¹⁰

In conclusion, the surgical techniques employed in the treatment of flexor tendon injuries and the utilization of tendinorrhaphy represent a delicate interplay of surgical skill, anatomical knowledge, and postoperative care. This multifaceted approach aims not only to restore the structural integrity of the tendons but also to optimize functional outcomes, ultimately enabling patients to regain the intricate dexterity and hand function that are quintessential to their daily lives.¹⁰

POTENTIAL SEQUELAE FOLLOWING FLEXOR TENDON INJURY AND HAND TENDINORRHAPHY

Flexor tendon injuries, while often successfully treated with tendinorrhaphy, can lead to a spectrum of sequelae that impact hand function and patient outcomes. Understanding these potential complications is crucial for both patients and healthcare providers. Below, we explore the myriad sequelae that may arise following such injuries and their subsequent surgical intervention:^{11,12}

Tendon Adhesions:

One of the most common sequelae is the formation of adhesions, wherein the healing tendon becomes bound to surrounding structures or the tendon sheath.

Adhesions can hinder the gliding of tendons, leading to restricted finger movement and reduced hand function.¹²

Tendon Rupture:

Despite surgical repair, there is a risk of tendon re-rupture, particularly during the early stages of postoperative rehabilitation.¹²

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This complication necessitates revision surgery and may result in compromised function.

Tendon Bowstringing:

Bowstringing occurs when the repaired tendon fails to glide smoothly within its sheath, leading to visible protrusion and reduced finger flexion.¹²

It may require secondary surgical interventions to correct.

Stiffness and Reduced Range of Motion: Postoperative stiffness is a common complaint, often attributed to scarring and adhesions.

Patients may experience difficulty in achieving full finger flexion and extension, impacting their ability to perform everyday tasks.¹²

Joint Contractures: In severe cases, prolonged immobilization or inadequate postoperative therapy may lead to joint contractures.¹²

Contractures can result in permanent joint deformity and further restrict hand function.

Nerve Injury: The proximity of flexor tendons to nerves increases the risk of nerve injury during surgical repair.¹²

Nerve damage may lead to sensory deficits, motor dysfunction, or neuropathic pain.

Vascular Compromise: Inadequate blood supply to the repaired tendon can hinder healing and result in poor functional outcomes. Vascular compromise may necessitate revision surgery or vascular interventions.¹²

Infection: Surgical wounds are susceptible to infection, which, if left untreated, can undermine the healing process and lead to severe complications.

Early detection and intervention are critical in preventing long-term sequelae.

Tendon Graft Failure: When tendon defects are extensive, grafting procedures may be employed. Graft failure can occur due to issues like inadequate vascularity, leading to the need for revision surgery.¹²

Complex Regional Pain Syndrome (CRPS): CRPS is a rare but debilitating complication characterized by severe pain, edema, and changes in skin color and temperature.¹²

Timely diagnosis and comprehensive pain management are essential to mitigate its effects.

Psychological Impact: Living with hand dysfunction and persistent pain can have a profound psychological impact on patients, leading to anxiety, depression, and reduced quality of life.

It is imperative for healthcare providers to educate patients about these potential sequelae and to employ preventive measures and comprehensive rehabilitation strategies to minimize their occurrence. Furthermore, ongoing research and advancements in surgical techniques aim to reduce the incidence of these complications and improve overall patient outcomes in the management of flexor tendon injuries and hand tendinorrhaphy.^{13,14}

CONCLUSION

In the intricate landscape of hand surgery, the management of flexor tendon injuries through tendinorrhaphy stands as a testament to the precision, innovation, and dedication that characterize the field. This comprehensive exploration of flexor tendon injuries and their surgical repair has illuminated the multifaceted nature of these injuries, the complexity of their treatment, and the remarkable potential for restoration of function.

Throughout this journey, we have traversed the labyrinthine anatomy of flexor tendons, appreciating their pivotal role in the orchestration of dexterity within the human hand. We have explored the diverse etiological factors that precipitate these injuries, ranging from traumatic lacerations to the less-understood domain of spontaneous ruptures. We have delved deep into the surgical theater, witnessing the artistry of tendinorrhaphy, where meticulous suturing techniques merge with cutting-edge adjuvants to promote optimal healing.

Yet, with every surgical triumph, we have encountered the shadow of potential complications—tendon adhesions, rupture, bowstringing, stiffness, nerve injury, vascular compromise, infection, graft failure, and the ominous specter of Complex Regional Pain Syndrome. These potential sequela remind us of the delicate balance between surgical intervention and the body's natural healing processes, compelling us to tread cautiously and conscientiously.

In the realm of flexor tendon injuries, prevention, early diagnosis, and comprehensive rehabilitation have emerged as indispensable allies. Educating patients on the importance of adherence to postoperative care and rehabilitation regimens is as vital as the surgical skill employed. A holistic approach that addresses not only the physical but also the psychological well-being of patients is the cornerstone of successful outcomes.

As we conclude this exploration, we recognize that the landscape of hand surgery continues to evolve. Emerging technologies, such as tissue engineering and minimally invasive techniques, hold promise in refining the art of tendinorrhaphy. Research endeavors, both in the laboratory and the clinic, strive to unravel the mysteries of tendon healing biology and improve our understanding of the factors that influence outcomes.

In the grand tapestry of medicine, the intricate symphony of the human hand is a marvel that defines our humanity. It is a testament to our ingenuity that we continue to refine our ability to restore this symphony even when discord strikes in the form of flexor tendon injuries. The journey of understanding, treating, and innovating in this field is far from over, but with each step, we move closer to ensuring that individuals afflicted with such injuries can regain not only the function of their hand but also the essence of their being.

In the pursuit of excellence in hand surgery, the saga of flexor tendon injuries endures, inspiring us to reach further, study deeper, and heal better. This article serves as a testament to our commitment to this endeavor and as an invitation to all

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who share this passion to continue pushing the boundaries of what is possible in the realm of hand tendinorrhaphy.

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