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Redefining Zone II: Anatomy of the Flexor Digitorum Superficialis Insertion

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Abstract

Background: Flexor zone II is defined as the region spanning the proximal aspect of the A1 pulley to the insertion of the flexor digitorum superficialis (FDS) tendon. Descriptions of the FDS insertion are inconsistent in the literature, but zones of injury are frequently determined with reference to superficial landmarks. The purpose of this study was to describe the footprint of the FDS insertion and define its relationship to the proximal interphalangeal (PIP) skin crease. **Methods:** The FDS insertion on the index, middle, ring, and small fingers was dissected in 6 matched pairs of fresh-frozen cadaveric hands. A Kirschner wire was used to mark the level of the PIP skin crease on bone before measurements of the FDS footprint and its position relative to the PIP skin crease were made using digital calipers. **Results:** The radial and ulnar FDS slips inserted a mean distance of 3.22 mm from the distal aspect of the PIP skin crease and varied by digit. The mean distal extent of the FDS insertion was 8.29 mm. The mean length of the insertion of each FDS slip was 5.15 mm and the mean width was 1.9 mm. **Conclusions:** The radial and ulnar FDS slips insert on average 3.22 mm distal to the PIP skin crease and vary by digit. Knowledge of the FDS insertion is clinically relevant when differentiating between flexor zone I and zone II injuries, planning surgical approaches to the finger, and in guiding patient expectations for surgery given the variability in outcome based on zone of injury.

Keywords: flexor zone, flexor digitorum superficialis, flexor tendon, insertion, zone II

Introduction

Few topics in hand surgery have generated as much interest and controversy as the management of flexor zone II lacerations. Known as "No Man's Land" because of its historically poor results of treatment, zone II was responsible for 8.4% of all presentations at the American Society for Surgery of the Hand (ASSH) annual meetings between 1947 and 1993 and 6.8% of all scientific manuscripts published in the *Journal of Hand Surgery* between 1976 and 1994.[6] Iterations of repair techniques, beginning with Verdan and Kleinert's techniques in the 1950s, have given rise to the current repair strategies of flexor zone II lacerations.[4] Given the historical significance and clinical importance of zone II, it is of interest that the distal extent of the zone, the insertion of the flexor digitorum superficialis (FDS), has not been formally described anatomically.

Despite the lack of a formal description of zone II, differentiation between zone I and II injuries is made routinely solely based on superficial landmarks. In fact, the original description of the distal extent of the zone is attributed to Sterling Bunnell and defined as "the middle crease of the finger,"[6] which most would agree does not extend far enough to incorporate the insertion of FDS. In the setting of zone I or II laceration, while the decision to perform an operation is made based on clinical examination, surgical approach and patient counseling may vary depending on the zone of flexor tendon injury. In addition, outcomes of zone I versus zone II injuries have been shown to differ, and FDS involvement in zone II injuries has been shown to portend a worse prognosis.[2,8] For these reasons, understanding the insertion of the FDS relative to superficial landmarks holds clinical value. The purpose of this study was to describe the insertion of FDS on the middle phalanx and define its relationship to the proximal interphalangeal (PIP) skin crease.

Materials and Methods

Measurements of surface landmarks of the index, middle, ring, and small fingers were recorded using digital calipers

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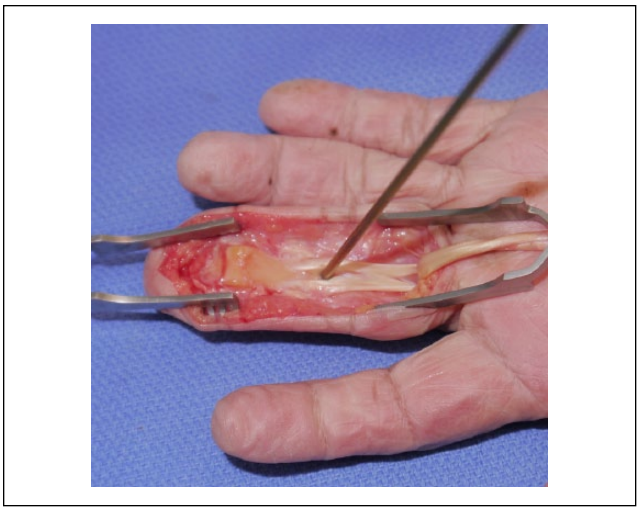

Figure 1. Kirchner wire placement at the apex of the distal aspect of the proximal interphalangeal skin crease.

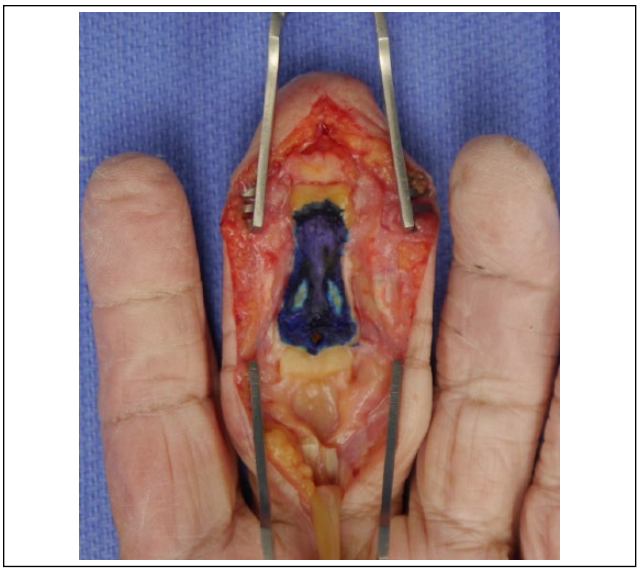

Figure 2. Transected flexor digitorum superficialis insertion after methylene blue staining.

(TruePower 04-0447 Stainless Steel 6-Inch Digital Calipers, Gino Development, Simi Valley, California) for 6 matched pairs of fresh-frozen cadaveric hands, for a total of 48 digits. With the finger held in extension, a 1.6-mm Kirschner wire was placed perpendicularly into bone through the apex of the distal of the 2 creases overlying the PIP joint to mark the distal-most aspect of the crease, and subsequently removed (Figure 1). For ease of description, this position is subsequently referred to as the PIP skin crease. The extended position was chosen to allow reproducible perpendicular placement of the Kirschner wire. Multiple positions of flexion were not analyzed because tendon excursion occurs across a joint, while its insertion remains constant relative to a fixed superficial point distal to the joint. A full-length longitudinal midline incision was made over the volar surface of each digit and the flexor tendon sheath was incised longitudinally to expose the flexor digitorum profundus (FDP), which was transected at the level of the proximal phalanx to remove it from view. All soft tissues adjacent to the FDS insertion were then removed, including the middle phalanx periosteum and the A4 pulley, which was intimately connected to the FDS slips in all specimens. The volar plate was then sharply elevated to expose the PIP joint and the proximal articular surface of the middle phalanx. The middle phalanx was then painted with methylene blue in a method described by Chepla et al.[1] Once the methylene blue was dry, the radial and ulnar slips of the FDS tendon were sharply transected from bone, leaving behind 2 precise FDS footprints (Figure 2). Digital calipers were used to record measurements of the footprint dimensions, the footprint distance from the center of the Kirschner wire hole, and the footprint distance from the proximal middle phalanx articular surface.

Results

The radial and ulnar FDS slips inserted a mean distance of 3.22 mm from the PIP skin crease and varied by digit (Table 1). The FDS insertion in relationship to the proximal and distal extents of the middle phalanx (P2) is shown in Figure 3. The radial slip inserted on average 3.17 mm distal to the PIP skin crease, and the ulnar slip inserted on average 3.26 mm distal to the PIP skin crease ($P = .44$). There was no significant variation between left and right hands for any digit ($P > .05$). The mean distal extent of the FDS insertion was 8.29 mm. The radial slip inserted on average 8.32 mm distal to the PIP skin crease, and the ulnar slip inserted on average 8.26 mm distal to the PIP skin crease. The mean length of the insertion of each FDS slip was 5.15 mm and the mean width was 1.9mm, with slight variation by digit (Table 2). The mean distance from the proximal middle phalanx articular surface to the FDS insertion was 5.94mm and varied by digit (Table 3).

Discussion

The first reference to flexor zone II as "No Man's Land" is attributed to a figure legend in Sterling Bunnell's second edition of *Surgery of the Hand*, which defined it as the zone "between the distal crease of the palm and the middle crease of the finger."[6] Now more commonly defined as the zone spanning the proximal extent of the A1 pulley to the insertion of the FDS tendon, flexor zone II has been a topic of interest since repair was first determined to be possible. Modern repair techniques for flexor zone II lacerations of the hand date to the 1950s and 1960s when Verdan and Kleinert published results previously thought

Table 1. Location of the FDS Insertion Relative to the PIP Skin Crease.

	FDS footprint (proximal)[a]		FDS footprint (distal)[b]	
	Mean (mm), SD	Proportion of P2[c] (%)	Mean (mm), SD	Proportion of P2[c] (%)
Index finger	4.48 (2.66)	25	9.98 (3.27)	56
Middle finger	2.79 (2.52)	13	8.30 (3.29)	39
Ring finger	1.70 (2.40)	09	7.31 (2.97)	39
Small finger	1.76 (2.41)	13	5.83 (3.28)	42

Note. FDS = flexor digitorum superficialis; PIP = proximal interphalangeal.
[a]Distance from distal-most aspect of volar PIP crease to proximal aspect of FDS insertion.
[b]Distance from distal-most aspect of volar PIP crease to distal aspect of FDS insertion.
[c]*P2*, distance between distal-most aspect of volar PIP crease and proximal-most aspect of volar distal interphalangeal crease.

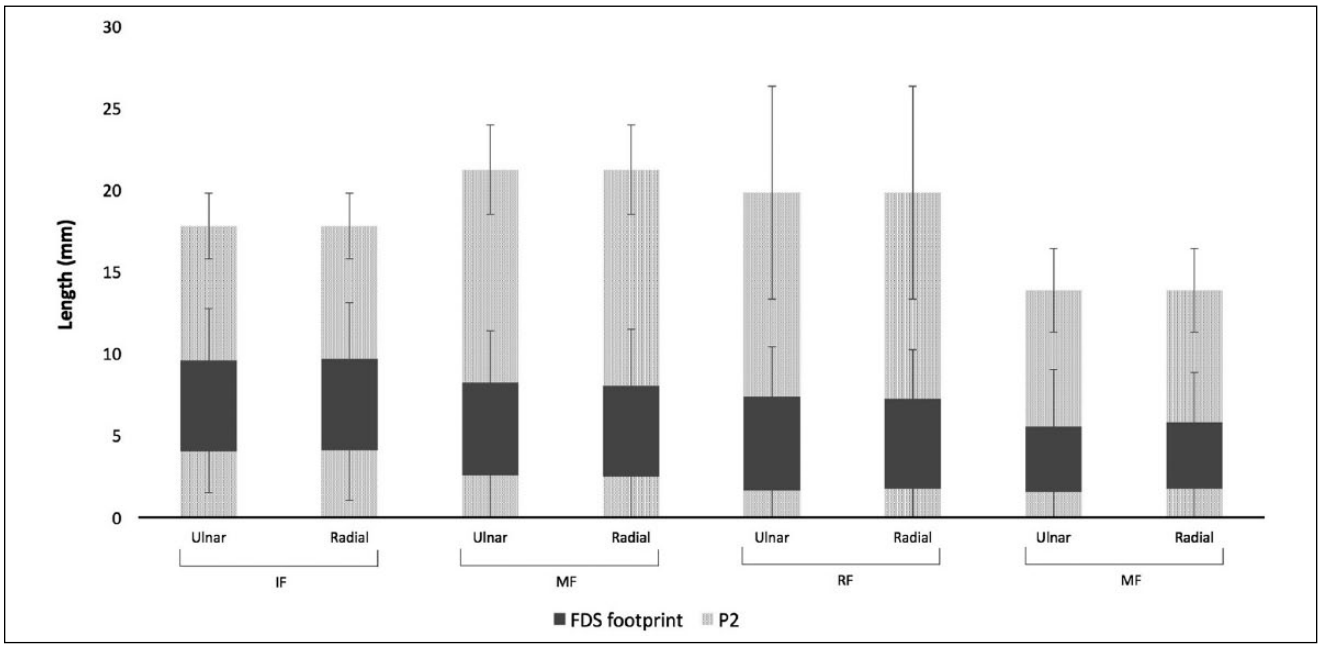

Figure 3. Flexor digitorum superficialis (FDS) insertion on middle phalanx relative to proximal interphalangeal (PIP) skin crease. The light gray area marks the distance from the distal aspect of the PIP skin crease to the proximal aspect of the distal interphalangeal skin crease. The dark gray area represents the FDS insertion on middle phalanx.

unobtainable by primary repair. What Bunnell described as "No Man's Land" was subsequently dubbed "Some Man's Land" and continues to generate much interest and debate among hand surgeons today. Contemporary repair techniques necessitate careful clinical evaluation to guide surgical planning.

Gordon et al were the first to attempt a description of anatomic structures in the finger with reference to superficial landmarks in a study designed to provide a guide to the surgeon performing minimally invasive surgery. In the study, finger creases were used to divide digits into 4 zones, and pulley locations and tendon insertions were described relative to these zones. In the study, the FDS insertion was described as being deep to the A4 pulley, which was located in the middle third of the zone between the proximal and distal interphalangeal creases; however, a precise description of the insertion was not provided.[3]

Injury location and tendon involvement are important predictors of functional outcome. Multiple studies demonstrate improved functional outcomes in zone I injuries relative to zone II injuries, as well as in isolated FDP injuries within zone II.[2,8] In a retrospective analysis of 291 patients with flexor tendon lacerations, Rigo and Røkkum[8] found that in zone II lacerations, injury to FDS in addition to FDP was associated with a significant decrease in active range of motion at 8 weeks. Likewise, at the distal extent of zone II, injuries located between the A2 and A4 pulleys lost 22° of motion more than injuries in zones I and II, presumably because of the involvement of FDS and the proximity of repairs to the A2 and A4 pulleys. By understanding which flexor tendons are likely to be involved preoperatively, surgical approaches can be chosen that optimize FDS repair. Likewise, patient expectations and postoperative protocols can be more appropriately defined preoperatively.

Table 2. Dimensions of the FDS Insertion.

	Radial footprint		Ulnar footprint		Composite FDS insertion	
	Length	Width	Length	Width	Length	Width
Index finger	5.49 (1.17)	1.96 (0.51)	5.52 (1.60)	2.02 (0.64)	5.50 (1.38)	1.99 (0.57)
Middle finger	5.50 (1.32)	2.34 (0.45)	5.86 (1.20)	2.14 (0.42)	5.68 (1.25)	2.24 (0.44)
Ring finger	5.49 (1.62)	2.07 (0.44)	5.73 (1.30)	1.90 (0.62)	5.61 (1.45)	1.98 (0.54)
Small finger	4.24 (1.55)	1.59 (0.63)	4.03 (1.59)	1.46 (0.65)	4.14 (1.55)	1.53 (0.64)

Note. Length and width presented as mean (±SD) in millimeters. FDS = flexor digitorum superficialis.

Table 3. Location of the FDS Insertion Relative to the Proximal Middle Phalanx Articular Surface.

	Radial footprint	Ulnar footprint	Composite FDS insertion
Index finger	5.92 (1.31)	5.97 (2.04)	5.94 (1.59)
Middle finger	6.65 (1.73)	6.30 (1.54)	6.47 (1.53)
Ring finger	6.55 (1.76)	6.65 (1.78)	6.60 (1.64)
Small finger	4.95 (1.94)	4.61 (1.74)	4.78 (1.72)

Note. Distances presented as mean (±SD) in millimeters. FDS = flexor digitorum superficialis.

Because of the tight fibro-osseous sheath within zone II, repair of tendon lacerations requires careful attention to tendon gliding, particularly in the region of the A2 and A4 pulleys. Management of lacerations to the FDS slips is controversial, although several publications note improved tendon gliding and functional outcome with FDS repair.[5,7,8] In a retrospective study of 101 patients managed for flexor tendon laceration, Moriya et al report total active motion of 231° after FDS repair and 205° after FDS excision. Pike and Gelberman[7] describe their surgical technique for FDS repair outside of the A2 pulley and note that restoration of FDS tendon function allows for independent PIP joint flexion and provides a smooth gliding surface for the FDP tendon.

Weaknesses of this study include the limited number of subjects and resulting wide standard deviations, particularly in the smaller digits, which is somewhat expected given the proximity of the FDS insertion to the PIP skin crease. However, the overall pattern of insertion is consistent with digit length, suggesting accurate mean measurements. Furthermore, the use of matched pairs, performed to confirm consistency within individuals, reduces the overall variability of the results.

In this report, we have shown that Bunnell's original description of the distal extent of flexor zone II as the PIP crease does not extend far enough to incorporate the insertion of the FDS tendon, which inserts on average 3.22 mm distal to the distal aspect of the PIP crease and extends another 8.29 mm distal to the PIP skin crease. Understanding the distal extent of zone II can aid in predicting tendon involvement during flexor tendon exploration, planning surgical approaches, and optimizing patient counseling in the setting of flexor tendon lacerations.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

This article does not contain any studies with live human or animal subjects.

Statement of Informed Consent

This article does not contain any studies with live human subjects.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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