CLINICAL FEATURES OF DIGITAL FLEXOR TENDON SHEATH: AN ANATOMIC STUDY

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Abstract

Objectives: To study clinical features of digital flexor sheath. ***Methods:*** An observational anatomic study on 26 cadaver hands which were dissected and studied to conclude several anatomic features of the digital flexor sheath contributing to the management of the flexor sheath injuries in clinical practice. ***Results:*** The average length of A1, A2, A4 pulleys in the long fingers were 7.11mm, 16.12mm, and 5.94mm, respectively. The average width and thickness of A2, A4 pulleys in the long fingers were 6.25mm x 3.68mm and 4.98mm x 2.90mm, respectively. The distances from the MCP joint to the proximal border of A2, A4 pulleys on the same digitorium were 6.35mm and 7.96mm, respectively. ***Conclusion*:** A2 has the longest length and biggest cast thickness and width.

Keywords: Anatomy of the digital sheaths; A2; A4 pulley.

INTRODUCTION

It is widely known that the anatomy and function of the pulley system in the digital sheath are relatively complex. The pulley system fundamentally facilitates the conversion from reciprocating motion of flexor tendons into angular motions via interphalangeal joints resulting in the flexion of the PIP and DIP joints. Moreover, the pulley system ensures a tight relationship between flexor tendons and phalanges. The axial motion of the joints prevents "bowstringing" of flexor tendons [1]. A thorough understanding of the anatomy and function of the digital flexor sheath helps surgeons treat injuries of the flexor tendons and the pulley system more effectively. The purpose of this study was: *To describe several anatomic features of adult digital sheaths contributing to surgery of flexor tendon injuries in case of early or late admissions.*

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MATERIALS AND METHODS

1. Materials

26 cadaver hands or amputated hands of adults.

This study was undertaken at the Department of Pathology, Viet Duc University Hospital, and the Department of Anatomy, Ho Chi Minh Medical and Pharmacological University.

2. Methods

* *Study design:* An observational anatomic study was conducted.

To measure the pulley length: A Loup magnifier was used to dissect the proximal and distal ends of A1, A2, and A4 pulleys, thumb cruciate pulleys (C pulleys), and a digital caliper with high precision 0.01 was used to measure. The MCP, PIP, and DIP joints were at 0 degree.

To measure the distance from the MCP joints and proximal interphalangeal joints to the proximal border of the pulley: Pin the joint with tiny pins and measure the distance from the pin to the proximal ends of A2, A4 pulleys and the lowest point of the cruciate pulleys.

To measure the pulley thickness and width: Dissect to remove all the flexor digitorum superficialis, profundus tendons of the long finger and flexor pollicis longus tendon of the thumb, make a plaster cast in each digital sheath, determine the cast diameter by measuring the cast thickness and width.

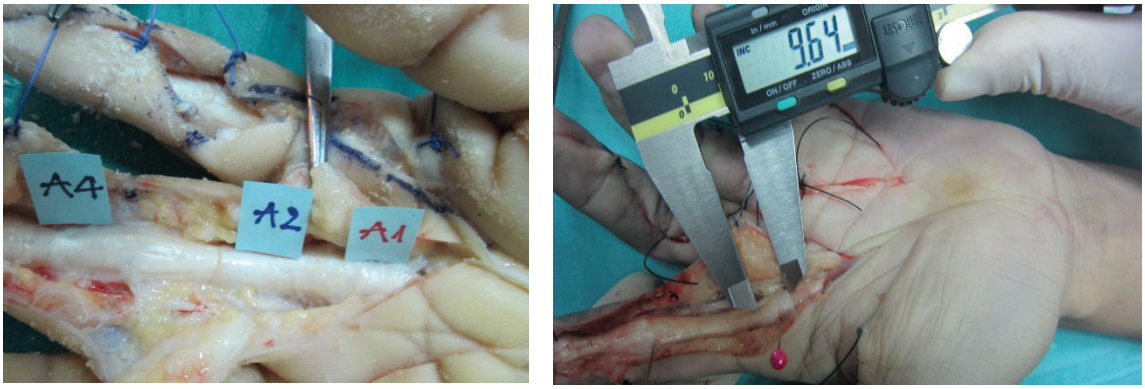

Figure 1. Measure the pulley's length.

* *Data analysis:*

The statistical analysis of the data was done using SPSS Software, version 16.0 (SPSS Inc., Released 2007. SPSS for Windows, version 16.0. Chicago. SPSS Inc.)

RESULTS

1. The pulley length of the thumb and long finger

Table 1. The A1 and C pulley length of the thumb.

Pulley length of the thumb (mm) (n = 26)	A1	C
$\bar{X}$ ± SD	5.45 ± 1.05	14.09 ± 3.00
Min	3.70	8
Max	7.65	21

The average length of the A1 pulley was 5.45mm (3.70 - 7.65mm). The oblique pulley measured from its highest point to its lowest point had an average length of 14.09mm.

Table 2. The A1, A2, and A4 pulley length of the long finger.

Pulley length of the long finger (n = 26)	$\bar{X}$ ± SD (min - max) (mm)		
	A1	A2	A4
The index finger	7.78 ± 1.38 (5.50 - 12.15)	15.72 ± 2.81 (11.60 - 20.98)	6.20 ± 1.23 (5.04 - 10.20)
The middle finger	7.79 ± 1.50 (5.31 - 11.12)	18.95 ± 3.46 (11.10 - 24.53)	6.59 ± 1.22 (5.01 - 11.00)
The ring finger	7.24 ± 1.25 (5.30 - 9.92)	17.28 ± 2.38 (11.40 - 21.25)	6.02 ± 0.91 (5.01 - 8.76)
The little finger	5.66 ± 1.38 (3.40 - 10.36)	12.55 ± 2.56 (6.44 - 16.76)	4.95 ± 0.87 (3.50 - 6.60)
Overall	7.11 ± 1.19 (5.48 - 10.23)	16.12 ± 2.43 (11.53 - 20.7)	5.94 ± 0.86 (4.96 - 8.20)

The longest pulley was A2 (18.95mm in the middle fingers); the shortest pulley recorded was A4 (6.59mm in the middle fingers; 6.2mm in the index fingers). The average A1, A2, and A4 pulley lengths of the long fingers were 7.11mm, 16.12mm, and 5.94mm, respectively.

2. The digital sheath width and thickness

Table 3. The digital sheath width and thickness of the thumb at C pulley.

Digital sheath at C pulley (mm); (n = 26)	Thickness	Width
$\overline{X}$ ± SD	3.57 ± 0.58	5.08 ± 0.69
Min	2.60	3.6
Max	4.73	6.22

Table 4. The digital sheath thickness at A2 and A4 pulleys.

The digital sheath thickness (mm); (n = 26)	A2 $\overline{X}$ ± SD (min - max)	A4 $\overline{X}$ ± SD (min-max)
The index finger	3.55 ± 0.49 (2.50 - 4.47)	2.92 ± 0.42 (2.21 - 4.06)
The middle finger	4.20 ± 0.46 (3.16 - 5.22)	3.18 ± 0.56 (2.18 - 4.56)
The ring finger	3.85 ± 0.41 (3.00 - 4.61)	2.99 ± 0.37 (2.06 - 3.56)
The little finger	3.11 ± 0.41 (2.36 - 4.23)	2.52 ± 0.37 (1.75 - 3.19)
Overall	3.68 ± 0.35 (2.97 - 4.52)	2.90 ± 0.27 (2.37 - 3.39)

Table 5. The digital sheath width at A2 and A4 pulleys.

The annular pulley width (mm)	A2 $\overline{X}$ ± SD (min - max)	A4 $\overline{X}$ ± SD (min - max)
The index finger	6.17 ± 0.74 4.96 - 7.48	5.14 ± 0.58 3.67 - 6.12
The middle finger	6.91 ± 1.18 2.26 - 8.09	5.42 ± 0.63 4.32 - 6.55
The ring finger	6.49 ± 0.66 5 - 7.61	5.12 ± 0.59 4.14 - 6.24
The little finger	5.43 ± 0.79 3.74 - 6.62	4.26 ± 0.55 2.78 - 5.21
Overall	6.25 ± 0.60 (5.15 -7.13)	4.98 ± 0.38 (4.24 - 5.61)

The width and thickness of long fingers: At the A2 pulley was 6.25mm x 3.68 mm; at the A4 pulley was 4.98mm x 2.90mm. The widest and thickest portion was located in the middle finger: At A2 pulley: 6.91mm x 4.20mm; at A4 pulley: 5.42mm x 3.18mm. The most narrow and thinnest portion was in the little finger: At A2: 5.43mm x 3.11mm, at A4: 4.26mm x 2.52mm. The average width and thickness of long fingers were 6.25mm x 3.68mm.

The average distance from the MCP joint to the most proximal part of the C pulley of the thumb was 4.67mm.

The distance from the MCP and PIP joints to the distal ends of A2, and A4 pulleys on the same long fingers were 6.35mm and 7.96mm, respectively. At A2 and A4 pulleys (mm) in the index finger: 7.16mm and 7.89mm; in the middle finger: 6.61mm and 8.85mm; in the ring finger: 6.08mm and 8.0mm; in the little finger 5.56mm and 7.08mm.

DISCUSSION

1. The pulleys of the thumb

In 1977, Doyle and Blythe [2] studied the pulley system of the thumb and showed only one oblique pulley running from the radial side to the ulnar side of the thumb and 2 cruciate pulleys A1 annular pulley whose length is 7 - 9mm overlies the MCP joint; similarly, A2 annular pulley (average length 8 - 10mm) overlies the PIP joint; lastly oblique pulley (average length 9 - 11mm) runs from the extended ulnar side of the adductor pollicis tendon to its radial portion between A1 and A2 pulleys. According to Doyle et al., the oblique pulley has the most important role in the thumb, which ensures appropriate gliding of the flexor pollicis longus tendon against the “bowstringing effect”. In 1994. Zissimos et al. [3] affirmed that: If the A1 and C pulleys of the thumb are cut, considerable bowstringing can be observed simultaneously with decreased angular ROM of interphalangeal joints. Besides, the A2 pulley is the least to contribute to the arc motion of the thumb. Therefore, the authors emphasized that C pulley reconstruction could restore normal ROM of the thumb.

Bayat A [4] studied 14 cadaver hands and indicated that A1 pulleys are entirely transverse retinacular pulleys. Its proximal two-thirds were at the level of the volar plate at the MCP joint, with the distal one-third overlying the base of the proximal phalanx. The average length is 6mm (4 - 8mm). The

oblique pulley originating from the ulnar side of the proximal half of the proximal phalanx and connecting to the radial side of the base of the distal phalanx has an average width of 4.1mm (3 - 5mm). The A2 pulley is thinner, its proximal two-thirds covered the head of the proximal phalanx and the volar plate of the interphalangeal joint, while the distal third overlying the base of the distal phalanx of the thumb. Its average length is 8mm (5 - 10mm). The authors showed 4 types of pulleys of the thumb, while we have not studied and dissected them to research further yet.

Dissection of 26 cadaver thumbs, we recognized the appearance of all pulleys. The average length of the A1 pulley is 5.45mm (3.70 - 7.65mm), which is insignificantly shorter than the A1 pulley length from the previous international studies. The oblique pulley measured from its highest point to its lowest point has an average length of 14.09mm. The average distance from the MCP joint pin to the distal end of the oblique pulley is 4.67mm, which serves as an anatomic landmark for surgeons in oblique pulley reconstruction, more importantly, in 2-stage tendon reconstruction.

2. The pulleys of the long fingers

Although pulley construction was described in 1933, until 1975, Doyle et al. informed anatomic as well as physiological knowledge of pulleys. The very first description was about 4 annular pulleys and 3 cruciate pulleys, then Hunter complemented that the 5th annular pulley attaches the volar plate of the DIP joint. The pulleys are fibrous bands in ring-shaped or cruciform configurations. A1, A3, and A5 pulleys attach the volar plates and insert them onto the adjacent bony surface of MCP, PIP, and DIP joints. A2 and A4 pulleys just attach the respective proximal and middle phalanges. The thickest portion of the A2 pulley (0.75mm) localizing at the distal part is described as a long, large pulley and less likely to be restricted during finger flexion compared to other pulleys, which functionally hold the flexor tendons close to the axis of motion of the joints [2]. The pulley length is 7.9mm (A1), 16.8mm (A2), 2.8mm (A3), 6.7mm (A4), and 4.1mm (A5) [5]. Dissection of 26 cadaver hands comprising 104 long fingers, we observed that the longest pulley was A2 (18.95mm in the middle fingers; 17.28mm in the ring fingers), and the second longest pulley was A1 (7.79mm in the middle fingers,

7.78mm in the index fingers). The shortest pulley recorded was A4 (6.59mm in the middle fingers; 6.2mm in the index fingers). The average A1, A2, and A4 pulley lengths of the long fingers are 7.11mm, 16.12mm, and 5.94mm, respectively.

Pulley reconstruction is a vital procedure after the flexor tendon injury which is less common in an intact pulley disruption. Surgery, to be more specific - pulley reconstruction, is indicated in the "bowstringing tendon" to restore the normal kinematics of the flexor tendon system. The biomechanical studies showed that A2 and A4 pulleys play the most decisive role in bowstringing flexor tendon resistance. The whole function of the fingers was ensured. A1 and A5 pulleys are the least likely to affect finger motions during work [5, 6].

Chow JC (2014) [7] and Christopher J Dy (2013) [8] showed the importance of the proximal part of A2 and A4 pulleys in normal kinematics of the fingers, especially the PIP joints serve the most important in normal ROM of the fingers. The changes in the proximal part of A2 and A4 could affect the flexion ROM of the fingers. "Bowstringing tendons" are observed when the pulleys are unavailable or cut, reducing the angles of rotation, which enhances the axial motion at the respective joint. The proximal parts of A2 and A4 are the anatomic structures close to the MCP and PIP joints, which are the most important factors to prevent the "bowstringing tendons" of these joints. The authors support the opinion of cutting the distal parts of A2 and A4 in several specific case scenarios. In our studies, the distance from the most proximal part of the A2 to the MCP joint pin is 6.35mm, and the distance from the PIP joint pin to the distal end of the A4 pulley is 7.96mm. In clinical practice, we need to follow the original anatomic structures to restore normal functions.

The width and thickness of long fingers: At the A2 pulley is 6.25mm x 3.68 mm; at the A4 pulley is 4.98mm x 2.90mm. The widest and thickest portion is located in the middle finger: At A2 pulley: 6.91mm x 4.20mm; at A4 pulley: 5.42mm x 3.18mm. The narrowest and thinnest portion is in the little finger: At A2: 5.43mm x 3.11mm; at A4: 4.26mm x 2.52mm. The average width and thickness of long fingers are 6.25mm x 3.68mm. From these results, the orthopedic surgeons can choose the size of the available equipment for 2-stage tendon gliding tunnel reconstruction from the first stage.

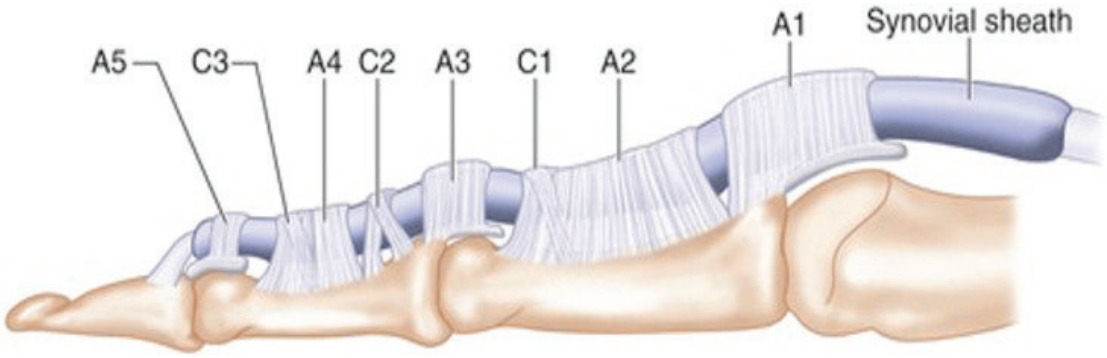

Figure 2. Pulley system of flexor tendons of the hand: The pulley system consist of five annular (A1 through A5) and three curciate (C1 through C3) pulleys that fix the tendons to the phalangeal bones [9].

CONCLUSION

From our anatomic study on clinical features of the digital shealths in 26 adult cadaver hands, we conclude that the A2 pulley has the maximal length at the middle finger (18.95mm); and the minimal length at the ring finger (4.95mm). In terms of the A4 pulley, the maximal and minimal lengths are at the middle finger (6.59mm) and the little finger (4.95mm), respectively. The average pulley lengths of the long fingers at A1, A2, and A4 pulleys are 7.11mm, 16.12mm, and 5.94mm, respectively. About the thumb, the width of the oblique pulley and A1 pulley is 14.09mm and 5.45mm, respectively. The width and thickness of the digital sheaths of long fingers at A2, and A4 pulleys are 6.25mm x 3.68mm and 4.98mm x 2.90mm, respectively. The distance from the MCP and PIP joints to the distal ends of A2, and A4 pulleys on the same long fingers are 6.35mm and 7.96mm, respectively. The average distance from the MCP joint to the most proximal part of the C pulley of the thumb is 4.67mm.

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