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# The effect of releasing critical pulleys of the fibrous sheath during flexor tendons repair in Kleinert–Verdan Zone II: a review

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**ABSTRACT**
The fibrous flexor tendon sheath is a relatively thick structure surrounding both flexor tendons (superficial and profundus) along the finger and distal part of the metacarpus. It consists of circumferentially and obliquely passing bands, so-called 'pulleys'. The flexor tendon fibrous sheath with its pulley system plays an important role in the proper gliding of the tendons by maintaining them close to the bone of phalanges during full finger flexion, and its major defects manifest by impaired flexion of the finger because the tendon bowstringing. There is no commonly accepted opinion about the range of pulley release which is safe and would not cause bowstringing. The article presents current recommendations about the safe range of release of pulleys during repair of the flexor tendons which essentially allows longer incisions than was suggested previously. The priority is the undisturbed gliding of repaired tendon along the finger and avoiding catching the repair at edge of the pulley, which would result in a reduction of the finger's range of motion.
**Keywords**: fibrous flexor tendon sheath; flexor pulley system; venting of the fibrous sheath; bowstringing of the tendon.

## INTRODUCTION

The fibrous flexor tendon sheath is a relatively thick structure surrounding both flexor tendons (superficial and profundus) along the finger and distal part of the metacarpus. Looking with the naked eye, it has an apparently uniform texture; however, anatomical investigations show that it is composed of circumferentially and obliquely passing bands, so-called 'pulleys' (Fig. 1, 2). The flexor tendon fibrous sheath with its pulley system plays an important role in the proper gliding of the tendons by maintaining them close to the bone of phalanges during full finger flexion. Major defects of the fibrous sheath hamper normal finger motion, because the 'naked' tendons tend to 'bowstring', which makes it difficult to complete the flexion of the finger (Fig. 3).

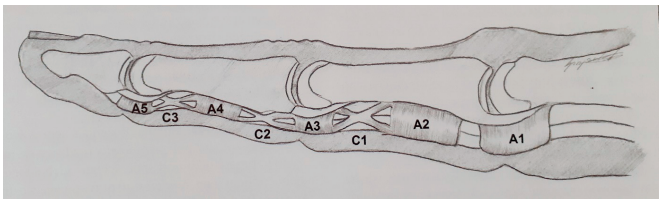


**FIGURE 1.** System of pulleys in the fibrous flexor tendon sheath

However, to expose the lacerated tendon in Zone II and carry out surgical repair, an adequate portion of the fibrous sheath (usually one pulley), needs to be opened (it is called venting of the pulley) [1]. Earlier rules recommended repair of the released pulley, to avoid bowstringing of the tendon [2]. However, current techniques of tendon suturing use 4- or 6-strand repair, which makes the site of the repair bulkier. This can cause tendon repair attachment at the reconstructed pulley and block tendon gliding. To prevent it, suturing of incised pulleys was abandoned and, instead, more courageous venting of pulleys was recommended. There is no commonly accepted what range of pulley venting would be safe for tendon gliding and not cause bowstringing.

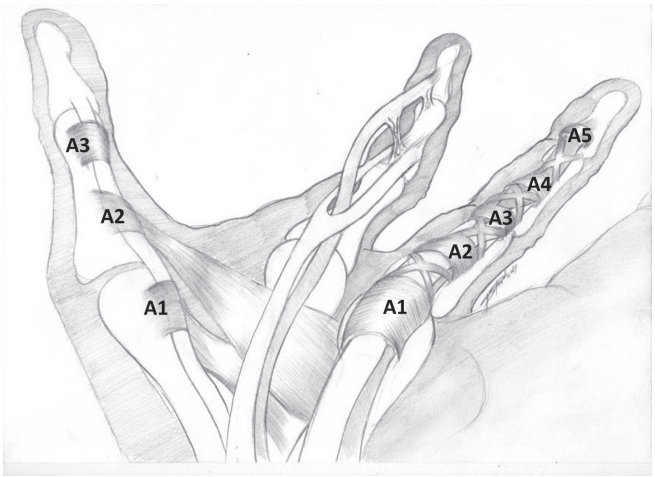


**FIGURE 2.** Annular and cruciate pulleys in the finger and thumb

The objective of this article was to review the literature concerning the current recommendations about the safe range of release of pulleys in the fibrous sheath during the repair of flexor tendons.

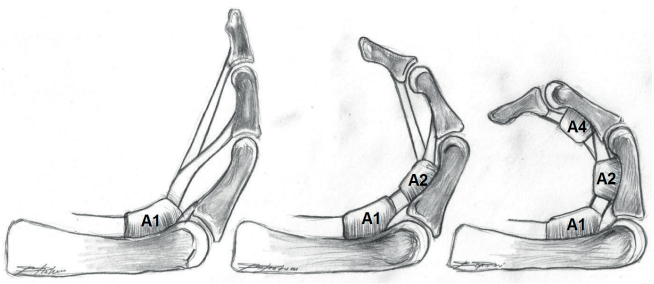


**FIGURE 3.** Illustration of the 'bowstringing' of the tendon following release of the A4 and A2 pulley. Note a significant reduction in finger flexion after the release of the A2 and A4 pulleys

## ZONES OF THE FLEXOR TENDONS

In 1983, Harold Kleinert and Claude Verdan introduced the division of flexor tendons into 5 zones (Fig. 4). The classification was created for several reasons, mostly practical:

- the course of the tendons in various anatomical areas of the hand and forearm, i.e. fingers, metacarpus, wrist,
- the proximity of other structures, i.e. lumbrical muscles, other tendons, carpal tunnel,
- existence of fibrous tendon sheath around tendons.

The practical aspect of this classification is associated with somewhat different methods of tendon repair in particular zones and with prognosis of recovery after injury and repair. Anatomical details of division flexor tendons in 5 zones are provided in Table 1. Also due to practical reasons, Zone II was divided into 4 sub-zones, marked with the first letters of the alphabet. Figure 5 and Table 2 provide anatomical details of this division. This partition of Zone II into 4 sub-zones plays an important role in investigating the effect of venting particular pulleys on the gliding characteristics of the repaired tendon.

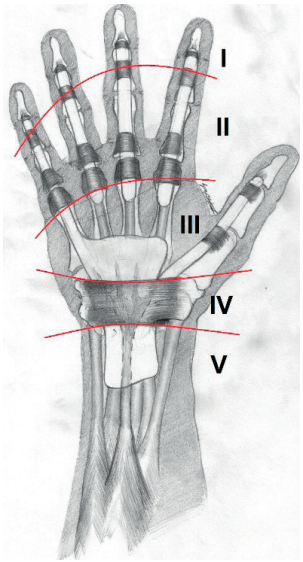


**FIGURE 4.** Division of flexor tendons in the hand and forearm into 5 zones (see also Tab. 1)

**TABLE 1. Details of the division of flexor tendons into 5 zones (see also Fig. 3)**

| Zone | Anatomical description |
|---|---|
| I<br>Ia<br>Ib | The part from the distal attachment of the FDS tendon in the middle phalanx to distal attachment of the FDP tendon in the distal phalanx. Zone I is divided into 2 subzones:<br>the part from the DIP joint to distal attachment of the FDP tendon in the distal phalanx,<br>the part from the distal attachment of the FDS tendon in the middle phalanx to the DIP joint. |
| II | The part in which the FDS and FDP tendons are surrounded by the fibrous sheath. Topographically, it is from the distal palmar crease in the metacarpus to the distal attachment of the FDS tendon in the middle phalanx. |
| III | The part in which both flexor tendons pass in the metacarpus, from the distal edge of the flexor retinaculum to the distal palmar crease. In this part, the lumbrical muscles have their attachments to the FDP tendons of II–V fingers. |
| IV | The part in which flexor tendons pass through the carpal tunnel. |
| V | The part in which flexor tendons pass in the forearm, proximally to the proximal edge of the flexor retinaculum. |

FDS – flexor digitorum superficialis; FDP – flexor digitorum profundus; DIP – distal interphalangeal

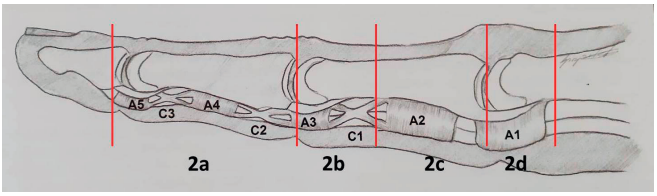


**FIGURE 5.** Division of Zone II into 4 sub-zones (see also Tab. 2)

**TABLE 2. Subzones of Zone II of flexor tendons (see also Fig. 4)**

| Subzone | Anatomical description |
|---|---|
| IIa | The part of the fibrous sheath from the PIP joint to its distal end.<br>This part includes the A4 and A5 pulleys and crucial ligaments C2 and C3. |
| IIb | The part of the fibrous sheath from the FDS tendon bifurcation to the PIP joint.<br>This part includes the A3 pulley and crucial ligament C1. |
| IIc | The part of the fibrous sheath from the MCP joint to the FDS tendon bifurcation.<br>This part includes the A2 pulley. |
| IId | The part of the fibrous sheath from its proximal edge at the metacarpus to the MCP joint.<br>It includes the A1 pulley. |

PIP – proximal interphalangeal; FDS – flexor digitorum superficialis; MCP – metacarpophalangeal

## CURRENT RECOMMENDATIONS FOR VENTING CRITICAL PULLEYS DURING REPAIR OF FLEXOR TENDONS OF THE FINGERS IN ZONE II

As it was already mentioned, to expose the lacerated tendon in Zone II and to repair it, an adequate venting of at least 1 fibrous tendon sheath pulley is necessary. Former recommendations

suggested the total length of incision of the fibrous sheath should not exceed 2 cm, because longer defects might result in bowstringing of the tendon. Incisions of a part of the A2 pulley and the whole A4 pulley were suggested depending on the site of the tendon laceration. The A1 pulley should be preserved in a greater part [2]. However, results of recent investigations showed that such cautious treatment of pulleys was not necessary, because their longer venting did not impair the function of the repaired tendon and motion of the involved finger [3, 4, 5]. The reason for preserving the A2 and A4 pulleys is to avoid bowstringing. However, these 2 pulleys are too narrow to permit undisturbed gliding of the repaired tendon inside them. Inadequate venting leads therefore to a situation when the site of tendon suture catches at those pulleys first, and eventually gets stuck at them. This results in solid adhesions along the tendon, followed by a reduction of movement and deterioration of the function of the involved finger. To correct it, a second operation is necessary for tenolysis and pulley venting to allow the tendon to glide. To avoid this situation, adequate venting of the A2 or A4 pulley immediately after the repair is recommended. Opening the pulley over the bulky 4- or 6-strand repair permits it to glide and allows for maintaining a full range of motion of the involved finger [1]. Results of some studies showed that clinically significant bowstringing did not occur following the moderate opening of the A2 or A4 pulleys [4, 5, 6, 7]. Therefore, current rules say that the sheath venting can include a part of the A2 pulley or the entire A4 pulley, as judged by the level of tendon injury. This means the following localizations of the tendon injury [5, 6, 7]:

- if the injury is located close to the A4 pulley, then the entire A4 (or combined with the A3) can be released [6],
- if the laceration is located close, or distal to the A2 pulley, a ½ or ⅔ of A2 can be released [7],
- occasionally, venting of the entire A2 pulley may be necessary to allow tendon gliding, but in most cases at least part of A2 can be preserved [7].

Incision of the pulley can be along the midline of the sheath, or laterally. In delayed repairs, the sheath or pulleys may be fibrotic and the excision of a part of the sheath may be necessary. Longer incisions of individual pulleys, or a combined release of 2 pulleys simultaneously, can result in some bowstringing. However, a small degree of bowstringing does notsignificantly impair hand function, as was previously thought [1]. Reduction of motion of the injured finger or entrapment of the repaired tendon by adhesions as a result of preservation of A2 or A4 pulleys is much more troublesome than slight-to-moderate bowstringing.

## CURRENT RECOMMENDATIONS FOR VENTING CRITICAL PULLEYS DURING REPAIR OF THE FLEXOR POLLICIS LONGUS TENDON IN ZONE II

The repair of lacerated flexor pollicis longus (FPL) tendon is more difficult than repair of flexor tendons in fingers because of the particular anatomy of this tendon:

- oblique orientation towards the long axis of the hand,
- proximal portion of the fibrous sheath (the A1 pulley) is partly surrounded by thenar muscles,
- proximal stump of the FPL is frequently pulled by the muscle as far as the carpal tunnel which hinders its retrieval to the wound and approximate to the distal stump.

Due to these reasons, results of the FPL repairs are usually worse (higher rate of ruptures, lower range of motion) than for tendons of the fingers. To repair the FPL tendon in Zone II, a release of the whole A1 or A2 pulley may be necessary, as well as a release of the adjacent C1 oblique pulley (Fig. 6). Current recommendations allow the venting of 2 pulleys and preserving only 1. It was confirmed by results of recent studies which showed that 1 oblique and 1 annular pulley maintain the repaired tendon sufficiently close to the bone to perform undisturbed thumb movement (Fig. 7) [1, 3, 8]. Thus, the venting of the fibrous sheath of the FPL should be adequately long to warrant undisturbed gliding of the tendon without catching the repaired site by the edge of the pulley.

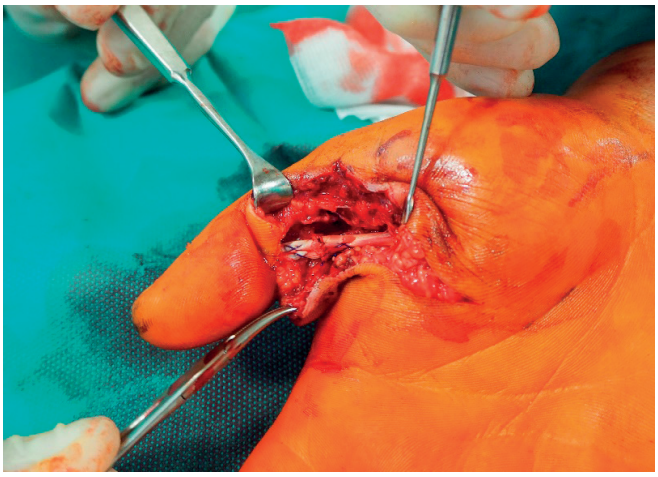

**FIGURE 6.** View of the flexor pollicis longus tendon repaired with 4-strand Adelaide suture. Note the release of the entire A2 pulley

**FIGURE 7.** Full thumb flexion after the entire A2 pulley venting

## WIDE AWAKE ANAESTHESIA IN FLEXOR TENDON REPAIR

In recent years, a method of anaesthesia, referred to as wide awake local anaesthesia no tourniquet (WALANT), has been gaining in popularity [9, 10, 11]. An important aspect of this technique is to obtain, apart from anaesthesia, also the ischaemia of the operated field which permits a surgery without a tourniquet [9, 10, 11]. This is achieved by injecting more than the standard volume of the solution of lidocaine and adrenaline into the tissues. Adrenaline is a vasoconstrictive agent which reduces the bleeding sufficiently enough to allow visualization of most of the small structures such as digital nerves and vessels. Moreover, as the patient is fully conscious during the operation, he can move his fingers freely, also on the request of the surgeon. Wide awake anaesthesia can be used in the fixation of finger fractures and repair of lacerated tendons. In the latter case, it is possible to check intraoperatively how the repaired tendon moves and whether, e.g., it does not interfere with the fibrous sheath during finger flexion or extension (Fig. 8).

**FIGURE 8.** Wide-awake local anaesthesia: the patient can observe the thumb movement after the flexor pollicis longus tendon repair

## PRACTICAL ASPECTS OF TREATING PULLEYS DURING THE WIDE AWAKE SURGERY

When performing repair of the lacerated flexor tendon, it is important to examine bowstringing intraoperatively, to notice if it is clinically significant or not (Fig. 6, 7). If, after the adequate release of pulleys, the repaired tendon forms little visible bowstringing, but without reduction of active flexion and extension of the finger, then the bowstringing is clinically insignificant. It is easier to notice by the awake patient and therefore this technique of anaesthesia is recommended for the repair of lacerations of flexor tendons. Wide awake flexor tendon repair clearly shows that total releasing of the A2 or A4 pulleys does not produce clinically meaningful bowstringing both intraoperatively and after the surgery. Therefore, current recommendations advocate repairing the tendon firmly with an even slightly bulky 6-strand suture followed by a continuous or sparse epitenon suture [1]. Next, an adequate release of A2 or A4 pulleys is performed to allow unrestricted tendon gliding in a full range of motion. Venting pulley is done as much as necessary, usually no more than a total of 2–2.5 cm.

## REFERENCES


1. Tang JB, Lalonde D, Harhaus L, Sadek AF, Moriya K, Pan ZJ. Flexor tendon repair: recent changes and current methods. J Hand Surg Eur 2022;47(1):31-9.
2. Tang JB. Indications, methods, postoperative motion and outcome evaluation of primary flexor tendon repairs in Zone 2. J Hand Surg Eur 2007;32(2):118-29.
3. Elliot D, Giesen T. Primary flexor tendon surgery: the search for a perfect result. Hand Clin 2013;29(2):191-206.
4. Tang JB, Zhou X, Pan ZJ, Qing J, Gong KT, Chen J. Strong digital flexor tendon repair, extension-flexion test, and early active flexion: experience in 300 tendons. Hand Clin 2017;33(3):455-63.
5. Tang JB. New developments are improving flexor tendon repair. Plast Reconstr Surg 2018;141(6):1427-37.
6. Moriya K, Yoshizu T, Tsubokawa N, Narisawa H, Hara K, Maki Y. Clinical results of releasing the entire A2 pulley after flexor tendon repair in zone 2c. J Hand Surg Eur 2016;41(8):822-8.
7. Moriya K, Yoshizu T, Tsubokawa N, Narisawa H, Hara K, Maki Y. Outcomes of release of the entire A4 pulley after flexor tendon repairs in zone 2A followed by early active mobilization. J Hand Surg Eur 2016;41(4):400-5.
8. Pan ZJ, Qin J, Zhou X, Chen J. Robust thumb flexor tendon repairs with a six-strand M-Tang method, pulley venting, and early active motion. J Hand Surg Eur 2017;42(9):909-14.
9. Lalonde D, Martin A. Epinephrine in local anesthesia in finger and hand surgery: the case for wide-awake anesthesia. J Am Acad Orthop Surg 2013;21(8):443-7.
10. Lalonde D. Wide awake local anaesthesia no tourniquet technique (WALANT). BMC Proceedings 2015;Suppl 3:A81.
11. Żyluk A, Szlosser Z. Flexor tendon repair in local infiltration anaesthesia and a bloodless field – a case report. Pol Orthop Traumatol 2019;84(3):85-9.