Management of the pulleys in acute flexor tendon injuries in zone II

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Rev Soc Can Traumatol Ortop. 2020; 1 (1): 36 – 39

Background

The central tenet of modern flexor tendon surgery is to repair and move divided flexor tendons within a few days of injury. Unfortunately, achieving normal, or near normal, function consistently remains a problem which has not yet solved. For fifty years, most of the drive in this field has been to create a system which allows us to keep the tendon repair moving after surgery, in the belief that this will prevent adhesions. Early mobilisation does not, of course, prevent adhesions entirely, but it does create a form of scarring which allows us to regain much of the range of movement and, sometimes, even return function to normal. Because rupture defeats this aim, there has been a need to use sutures and suture techniques strong enough to allow this movement. Current debate is largely concerned with the fine detail of 'best' ways to repair and rehabilitate, while avoiding the two pitfalls of healing, namely tendon adhesion and rupture of the repair.

The presumption for a long time was that the failures were due to poor suturing and/or inadequate movement to counter adhesion formation. Unfortunately, strengthening sutures and changes of mobilisation techniques have not entirely banished the problems and units publishing results still mostly average around 70-80% good and excellent results with up to 10% of cases failing to achieve a working result because 5% rupture and 5% become adherent. This is far from a good audit result.

In order to repair flexor tendon injuries in zones 1 and 2, it is inevitable that the tendon sheath be opened for access. For 50 years, treatment of the sheath on completion of the tendon repair(s) was given little thought and was determined partly on theoretical grounds and partly by interpretation of the tendon healing research at the time. From the 1940s until the 1960s, when it was thought that the flexors only healed if adhesions were allowed to form between the subcutaneous tissues and the tendons, segments of the sheath were excised and the hand immobilised after zone 1 and 2 injuries (Mason, 1940; Verdan, 1958).

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In the 1970s, Lundborg and others showed that tendon survived and healed in a synovial environment (Lundborg, 1978). There followed a period of almost obsessive closure of the tendon sheath although no one could prove any benefit to this practice and many of the best series of results at that time came from units which did not close the sheath.

The intrinsic capacity of the tendons to heal had been known to be very poor for a long time, hence the need to postulate adhesion or synovial healing in zones 1 and 2. In the 1990s, Gelberman and others showed that the tendon itself has an adequate healing mechanism: it was now realised that blood vessels grow along the epitendon on the surface of the tendon to bring nutrients to the repair site and heal the tendon (Gelberman, 1992).

So, we moved from radical sheath removal through obsessive sheath closure to calculated neglect, that is simply laying the sheath back after repairing the tendons. However, imperfect results continued.

It is now recognised that part of the problem is the repairs, no longer the same diameter as the original tendons, being too large for the sheath. We see various solutions in the literature of the past for various individual clinical problems resulting from the dilemma of the tendons, or their repairs, being too large for the tendon sheath. Sixty years ago, Kleinert and Verdan showed that it was preferable to repair both flexor tendons at primary surgery and, so, we all went on repairing both flexor tendons under nearly every circumstance, although Boyes, in the 1970s, had pointed out the problem of repairs sticking under the A2 pulley, which is the narrowest part of the sheath (Boyes and Stark, 1971).

More recently, Professor Tang re-examined this problem and showed better results when only the profundus was repaired for simple Zone II injuries under the A2 pulley (Tang, 1994).

During the last thirty years, I have performed a tenolysis on a number of patients with injuries of the distal palm or bases of the fingers in whom both tendons had been repaired at primary surgery.

In all of them, each of the two flexor tendons was so oedematous that it was double its normal size, with both tendons completely stuck under the A2 pulley and I had to remove the FDS tendon completely to get any movement through the pulley: single tendon primary repair would have avoided this secondary surgery.

So profundus repair only is wise for any injury under the A2 pulley.

The same is true in Zone 4: in the very narrow confines of the carpal tunnel, multiple tendon repairs will not move freely once post-operative swelling occurs. In a secondary tenolysis, if the tendons are too swollen to move comfortably under the A2 pulley, we simply remove the superficialis. An alternative, suggested previously by Kleinert, was to remove half of the superficialis.

When a profundus tendon is pulled-off distally, or (more rarely) is cut in Zone 1, and drops back through the A4 pulley, then presents late, it may be too swollen to pass through the pulley.

Even if we pull the tendon through by slow traction, we are likely to create an unmoving DIP joint as the tendon swells again postoperatively and locks under the A4 pulley.

Rather than abandoning primary surgery, which means grafting, this can be avoided by halving the profundus tendon and passing one half through the pulley to reattach it distally because the distal part of the profundus is double-barrelled (Elliot et al., 2001).

This is a reasonable procedure as half a profundus tendon is thicker than the palmaris longus tendon from the same hand, which would be used for the alternative (grafting) treatment and much easier to suture with conventional core sutures than the palmaris tendon, which is flat.

If we retain the normal tendon numbers and size something has to be done with the sheath. In the nineteen forties and fifties, when adhesions were thought necessary to achieve tendon healing, surgeons cut windows in the sheath. They were also aware of the need to compensate for the bulk of the tendon repairs and they completely excised long segments of the sheath to allow unimpeded tendon movement (Mason, 1940; Verdan, 1958).

Moving back to today, even if we do not completely close the sheath, there still remains the problem of repairs catching on the edges of the pulleys. Historically, various ways of dealing with the pulleys have been tried. Most of these have been directed at trying to get swollen profundus tendons and repairs through the very small A4 pulley. Use of urethral sounds in the 1970s and before did not work.

Pulley lengthening has also been around for a long time and has been reconsidered recently (Dona and Walsh, 2006). I doubt whether the small Z plasty flaps used and sutured with 5/0 or 6/0 nylon create pulleys capable of resisting the considerable tensions acting on the pulleys during flexor muscle activity and suspect that the rest of the sheath, not the repaired pulleys, are doing the work.

And finally, partial, sometimes complete, division, or 'venting' of the pulleys. Duran and Houser (1975), were the first to suggest partially releasing one side of any pulley on which a repair was catching. Strickland (1986) probably introduced the term 'venting' the pulley, meaning cutting the side of it. In the 1970s and 80s, Schneider was the only one author of note to confess to having been forced to completely divide the A4 pulley, but only occasionally in difficult cases (Schneider, 1985).

Probably in company with many other juniors at the time, I kept very quiet in lectures by the great men as I knew that many of my repairs would not glide freely under the pulleys and, more than occasionally, I had to cut the A4 pulley completely to get a full range of motion of the DIP joint.

It has taken a long time to make this procedure acceptable because, in practice, this entails interference with the A2 or the A4 pulley, the complete integrity of which was believed to be of great importance in maintaining the mechanical efficiency of the flexor system. This notion has its origin in a curious twist of logic: when doing secondary flexor surgery, the minimum one needs to preserve, or reconstruct, for the flexor system to achieve its mechanical intention of flexing the finger with power is an A2 and an A4 pulley. This was then carried over into primary flexor surgery as a mandate to preserve these two pulleys in their entirety at all costs.

Savage first identified that complete preservation of the A2 and A4 pulleys was not necessary provided sufficient of the remainder of the pulleys was intact (Savage, 1990).

More recently, other research papers have also identified that there is no absolute need to preserve the A2 or the A4 pulley so completely, or even at all, when most of the remainder of the sheath is intact (Tomaino et al, 1998; Mitsionis et al, 2000).

So, entire preservation of the A2 and A4 pulleys in their entirety under all circumstances is NOT necessary. However, one must ask, firstly, is it really necessary to vent pulleys and, secondly, does it definitely not have a deleterious effect on the ultimate function of the repaired flexor system for that finger.

Management of the Pulleys

Firstly, is it necessary to vent the pulleys?

Over a period of two and a half years, we examined 126 consecutive fingers with tendon divisions in zone 2 between zone 1 and the distal edge of the A2 pulley which were repaired by experienced Fellows in our unit to see how often they had to vent the A4 or A2 pulley (Kwai-Ben and Elliot, 1998). Sixty-four percent of the fingers required some degree of venting of one or other of the A2 or A4 pulley, answering this question in the positive.

The distal edge of the A2 pulley was vented in 10 fingers by between 20 and 50% of its length. All of these were zone 2B injuries in which the tendon was cut just distal to the A2 pulley with the finger in extension and the repair then caught on the distal edge of the A2 pulley on flexion of the finger. In clinical practice, when dealing with injuries in the distal palm and at the very base of the finger, venting of this amount of the A2 pulley has little consequence.

The A2 pulley is so long, that one can excise a half or more of it to repair the tendon, whether proximally, distally or in the middle part of the pulley to allow the repair a free range of motion without affecting pulley function and proximal bowstringing does not occur. Recently, there has been the suggestion that, when necessary, the whole of the A2 pulley can be divided to repair the tendons provided the rest of the sheath is intact.

However, such cases are rare events, while partial venting this pulley is not so uncommon. The idea of complete A2 division needs to be investigated more thoroughly and, at this time, we prefer reducing the number of tendons by repairing only the FDP tendon under these circumstances.

The other problem is the A4 pulley after tendon divisions around the PIP crease with the finger partially flexed.

When the finger is straightened, the profundus has to be repaired more distally and the proximal part of the A4 pulley may need to be vented either to pass the distal half of the core suture or to allow the repair to move distally to achieve full DIP extension, or, often, for a mixture of both reasons. In our study, the degree of venting of the A4 varied considerably from 10 to 100% of its length, with a mean of 52% or about half of the pulley being cut. In fourteen fingers, the A4 pulley had to be completely divided to allow full distal joint extension.

The larger core and circumferential sutures we are now using are likely to lead to greater need for venting pulleys, both for access to get the sutures in and then to allow the repairs to move, as they create added bulk at the repair site.

The second question I posed was 'does venting definitely NOT have a deleterious effect on ultimate function?' There were 14 fingers in our venting study who required complete division of the A4 pulley.

More recently, a cadaveric study from the United States of America (Franko et al., 2011) showed that work of flexion did not increase by more than 3% from control conditions after partial or complete A4 pulley release, and work of flexion was significantly less than that achieved by performing a repair and leaving the A4 pulley intact. This finding has since been supported by further published studies.

Whether one does this venting, or leaves the A4 pulley intact and accepts a loss of full extension of the DIP joint, could be debated. Given the findings above, if one does not vent the A4 pulley, the most likely consequence is that finger will lose DIP extension and may cause a slight increase in the work of flexion for that finger.

Alternatively, common sense dictates that completely cutting the A4 pulley will not cause significant bowstringing. Try this experiment, grip your right index finger between your left thumb and index finger to prevent the PIP flexing. Now bend the DIP joint. If the A4 pulley was absent, you can see how little the flexor could bowstring at this level because the distance across the flexor aspect of the DIP joint is so small. Put something into the hand and grip it and the external object becomes the pulley to push the tendon back against the skeleton.

I think distal bowstringing only occurs when there is a complete absence of the sheath beyond the A2 pulley, which is a very rare situation.

I believe this is an iatrogenic problem. In secondary flexor surgery, we are taught that we must retain part of the A2 and the A4 pulleys to maintain function. Our entry to the tendon sheath to visualise the tendons is usually at the level of the A3 pulley.

Often, when scarring is extensive, it is achieved by total excision of the A3 and the adjoining C pulleys, as they are adherent to the tendons. This is done, safe in the belief that we will subsequently preserve the A2 and A4 pulleys. Later in the dissection, we find the A4 is small and very flimsy and, also, tightly bound to the underlying profundus tendon.

During the subsequent tenolysis, it is too easy to snap the A4. Then we have no pulley system beyond the distal edge of the A2 pulley and distal bowstringing occurs.

This can be avoided at secondary surgery by retaining part of the sheath around the PIP intact as an A3 pulley, just in case we snap the A4 pulley later in the dissection.

This should not occur in primary flexor tendon surgery unless we remove all of the sheath between the site of penetration of the sheath at proximal phalangeal or PIP level and the A4 pulley then find ourselves having to completely vent the A4 pulley to achieve a fully gliding repair and a straight DIP joint.

As we are taught to work through windows in the sheath, leaving most of the sheath intact, this should not arise.

Recently, Professor Tang has suggested that we routinely test our flexor repairs before closing the finger to see that the repair moves through a full range of movement without catching on a pulley at either end of its range of motion.

This is logical and, of course, was what Verdan was telling us 60 years ago!

In 2002, I wrote a review in which I discussed the need for venting of pulleys and the importance of this addition to our management if results were to improve. This was updated in 2007 by Professor Tang in an excellent paper going into much greater detail on the actual venting necessary for specific injuries of the flexor tendons at different sites along the finger.

This is also covered extensively in a book on tendon surgery edited by Professor Tang, which I would recommend to you.

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