Primary Flexor Tendon Repair with Early Active Motion: Experience in Europe

Thomas Giesen, MD[a,*], Maurizio Calcagni, PD, MD[a], David Elliot, MA, BM BCh, FRCS[b]

KEYWORDS

• Primary flexor tendon repair • No circumferential suture • Pulley management • FDS resection • Early active motion

KEY POINTS

- A 6-strand core suture is performed using the M modification of Tang's original technique.
- No circumferential suture is added after a 6-strand core suture.
- The pulleys are divided as much as needed to allow free excursion of the repaired tendon within the tendon sheath, including, when necessary, full division of the A4 or A2 pulley.
- To avoid the repaired structures within the sheath being too bulky, the authors generally repair only half of the flexor digitorum superficialis, resecting the other half. In zone 2C, and in specific cases, the flexor digitorum superficialis is excised completely.
- Rehabilitation is controlled active motion, but with modifications.

INTRODUCTION

Immediate flexor tendon repair of the hand is common practice in European countries. However, routinely achieving a successful outcome from this treatment of flexor tendon lesions in zone 2 has remained an unsolved problem for many decades. Excluding complex cases with associated partial amputation, devascularization or concomitant fractures, immediate repair has traditionally suffered ruptures in approximately 5% of cases and symptomatic adhesions in another 5% of cases, giving unsatisfactory results in 10% of cases.[1]

Various changes of management are being reported worldwide, seeking to reduce these problems and improve results. Both the operative technique and the rehabilitation of the authors' own protocol have been modified in recent years to try to make the surgery easier and achieve excellent results more regularly.

Alterations of Surgical Technique

These are aims that any suturing technique for flexor tendon repair should include:

- It is simple to perform, particularly by trainees.
- It minimizes tendon manipulation.
- It minimizes the amount of foreign material exposed on the surface of the tendon.
- It provides enough strength for early active mobilization.

Many suturing techniques have been published that attempt to achieve these goals. The authors

The authors have nothing to disclose.

[a] Plastic Surgery and Hand Surgery Division, University Hospital Zurich, Raemistrasse 100, Zurich 8091, Switzerland; [b] St. Andrew's Centre for Plastic Surgery and Burns, Broomfield Hospital, Court Road, Broomfield CM1, UK

* Corresponding author.

E-mail address: Thomas.giesen@usz.ch

Hand Clin 33 (2017) 465–472

http://dx.doi.org/10.1016/j.hcl.2017.03.001

have moved away from the techniques based on the Kessler suture and circumferential suturing, which have dominated practice in Europe for half a century.

The authors currently use the M modification of the Tang technique[2] using a 4-0 loop suture, without circumferential suturing,[3] which the authors believe achieves more of the previously mentioned aims than the more traditional suture techniques.

The authors have also modified management of the tendon sheath, moving away from the belief that the A2 and A4 pulleys are sacrosanct.[4] When necessary, they completely divide one or other. The authors also divide the oblique pulley in the thumb when necessary.

Management of the divided flexor digitorum superficialis (FDS) has also been modified, moving to a policy of partial repair or no repair, depending on the level of FDS division. In selected cases (Fig. 1), the authors partially resect the FDS tendon; they resect the FDS completely only when A1 is completely divided, and the lesion is in zone 2C under the A2 pulley. In these cases, the authors do not divide the A2 pulley completely because of the risk of bowstringing. This is based on the evidence that the tendon diameter at a suture site increases by 1.6-fold after repair.[5]

Alterations of Rehabilitation

The authors use a modified controlled active mobilization regime to achieve earlier extension of the wrist, as will be described in the postoperative care section.

CHEMICAL MANIPULATION

The other factor currently being reinvestigated is chemical modification of the tendon and tendon sheath.[6] Until now, this has been by a variety of local chemicals, with limited success, but the future for this avenue of research may lie in manipulation of the growth factors that control tendon healing.

INDICATIONS AND CONTRAINDICATIONS

In the authors' opinion, acute flexor tendon divisions should be repaired within 48 hours. However, late presentation is not uncommon; the authors have all performed delayed primary repair up to 30 days after the injury. Successful delayed primary repair has been reported after much longer delays, even after 1 year.[7] This may require lengthening of the injured tendon proximal to the musculotendinous junction, as described by Le-Viet.[8] Contraindications to delayed repair include infection and significant edema with stiffness in the digit because of a tethering of the extensor

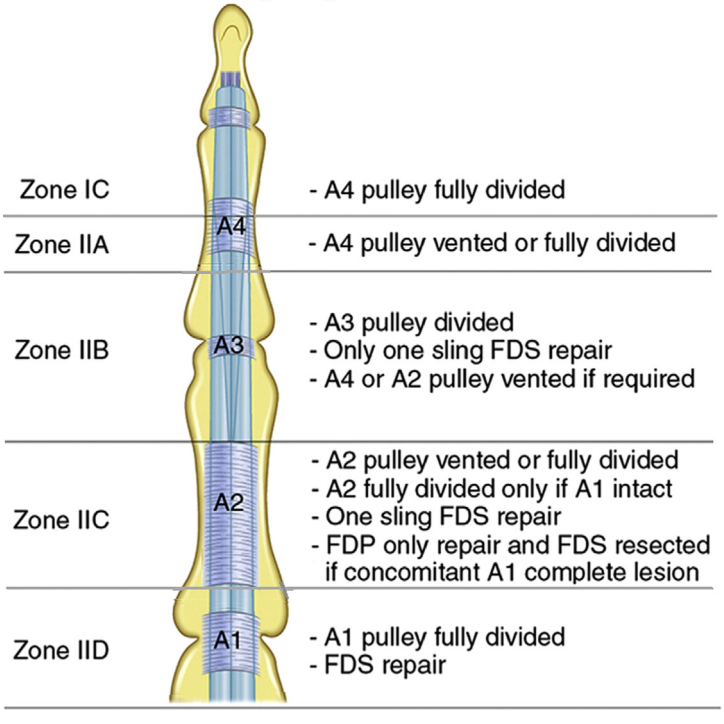

Fig. 1. Zone 1C and subdivisions of zone 2 in fingers and recommended surgical treatments.

tendons. If delayed repair is found to be impossible at surgery because of scarring in the flexor tendon canal or excessive retraction of the proximal stump, the authors would insert a tendon rod as the first stage of a 2-stage tendon graft. The authors personally prefer a 2-stage to a single-stage tendon graft in order to provide an optimal flexor tendon tunnel to the reconstructed tendon, but they are currently considering changing their practice toward a single-stage graft.

SURGICAL PROCEDURES

Preoperative Planning

Local anesthesia in the form of wide-awake surgery[9] is used according to patient wish and compliance and the clinical situation. Otherwise the procedure is performed under brachial block or general anesthesia. If the patient is going to be operated on using wide-awake surgery, the authors still apply a tourniquet to the arm, but without inflating it, in case it is needed during surgery. Although wide-awake surgery has the advantage of allowing one to check that the repair can move through a full range of movement during active flexion and extension, in reality, this can be checked adequately using passive movement of the repair. The main benefit of the newer technique is one of returning anesthesia to the control of the surgeon.

Surgical Approach

The authors routinely use a modified Bruner incision, with the points of the flaps less lateral than the midlateral line in order to avoid necrosis of the tip of the flaps, which would increase scarring. In the thumb, at the metacarpophalangeal (MP) crease, the authors avoid putting the apex of the Bruner incision flap on the ulnar side, as the healing scar may attach to the subcutaneous fibrous tissue of the first web space, causing a web contracture.

Step 1

Contrary to the common practice of classifying the tendon division according to the zone, or subzone, where the tendon sheath has been penetrated, the authors base their decision making on the level of the distal stump of the flexor digitorum profundus (FDP) tendon with the finger fully extended. This identifies the level of the FDP tendon division. In the authors' view, this is a more practical criterion for decision making. Concomitant injuries to the FDS tendon and the nerves and vessels are also noted.

The authors use the Tang subdivisions of zone 2 into subzones 2A to 2D[10] and Elliot's subdivisions of zone 1 into subzones 1A, 1B, and 1C[11] as a basis for planning subsequent management of the FDP tendon. Although mostly discussing zone 2 injuries, it is sensible to include most zone 1 injuries here, as zone 1B and 1C injuries will also be treated with an intratendinous suture. They will also require venting of the A4 pulley; the 1B repair will catch on the pulley on finger flexion, and the 1C injury lies directly under this pulley and can only be repaired after complete division of the pulley. Decision making about tendon repair and pulley and FDS management is summarized in the flow chart (see **Fig. 1**).

For the thumb, the pulleys are opened sufficiently to perform the repair, but taking care not to completely release both the first pulley and the oblique pulley completely; otherwise there is a risk of appreciable bowstringing.

Step 2

The authors retrieve the proximal stump. When retrieving the proximal stump of the tendon, it is not usually necessary to divide the proximal finger pulleys. If retrieving the proximal stump of the tendon is impossible because of swelling of the tendons, the authors either resect one slip of the FDS and repair only 1 slip or do not repair the FDS at all. If partial FDS repair is carried out, this is done before repairing the FDP tendon. The authors use a single 4-0 loop Tsuge suture; the slip of the FDS that is resected is divided as far proximally as possible to avoid the proximal end catching on the A1 or proximal A2 pulley on finger extension. In the authors' experience, this problem is more likely to arise when attempting delayed primary repair (ie, after 2 days) or when there is more significant trauma to the distal palm or proximal finger than a simple laceration.

The tendon is then manipulated delicately with fine-toothed surgical forceps. Often, only the tendon ends can be held, avoiding gripping the outer surface of the tendon, until a suture has been inserted into the tendon. Thereafter, the tendon is held through the suture. If the surgeon has to grip the surface of a tendon, the authors believe that sharp instruments cause less damage to the tendon than blunt instruments, as the latter do not guarantee a secure grasp of the slippery tendon tissue, leading to multiple attempts at grasping and, therefore, more handling of the tendon.

Step 3

The authors use the M modification of the Tang technique using two 4-0 loop sutures as the core suture of the FDP tendon, as they believe this is an easier technique to master than the Kessler

system.[2] Tang introduced this modification of his original Triple Tsuge technique to reduce the number of loop sutures needed from three to two, for economic reasons. The authors first insert the Tsuge suture into the center of the proximal part of the FDP tendon. Because of the double-barreled nature of the distal part of the FDP tendon, it can be difficult to pass this suture into the center of the distal end, in which case it is inserted into 1 side of the distal tendon end. The authors bury the knots of both sutures in the tendon.

Then, a second loop suture is used to complete the M configuration, placing the 2 strands of the second suture in the dorsal part of the tendon so the load on the repair is dorsal, as this is the part of the tendon mainly stressed in flexion.[12] The authors intentionally let the tendon bulge slightly at the repair site, indicating that more tension than required is being applied, as this ensures good approximation of the tendon stumps. If using a braided looped suture, it is of paramount importance that the tension across the suture is maximized, then maintained, at each step. Otherwise the braided suture may lock before completion of the repair, such that fewer than 6 strands are holding the repair. Monofilament looped sutures are easier to use as they run through the tendon more freely, and this problem does not arise. The authors previously used the 4-0 Fiberloop suture (Arthrex, Naples, Florida) but recently switched to a 4-0 reinforced nylon loop suture. The authors think a 3-0 suture is too bulky.

Traditionally, a circumferential suture was used to tidy the repair and avoid catching. It was later realized that the circumferential suture added strength to the overall repair. The authors believe the tidying process to be unnecessary as the tendon stumps align sufficiently without the circumferential suture. Additional strength is also not needed when a 6-strand core repair is used.[3]

Step 4

Following tendon suture, the repair is moved through a full range of motion, either actively or passively. Any pulley limiting full and free excursion of the repaired tendon is vented or divided as necessary (**Fig. 2**).

Step 5

Repairs of the neurovascular structures are completed, as required, and the skin is closed. A temporary dorsal splint is then made with plaster of Paris and applied with the wrist in neutral and the metacarpophalangeal (MP) joints flexed as much as allowed by the dressings.

POSTOPERATIVE CARE

The principle that immediate mobilization must follow immediate repair was introduced by Kleinert, Verdan, and several others 50 years ago as a sine qua non, without which the fibrin in the edema, described by Watson-Jones in an earlier era as physiological glue, would cause tendon adherence to their surrounds and failure of active tendon and finger movement. Although the degree to which tendon tethering by fibrin occurs may vary between individuals. The authors' protocol is based on the Chelmsford CAM (controlled active motion) regimen of 1994,[13] with several modifications. The

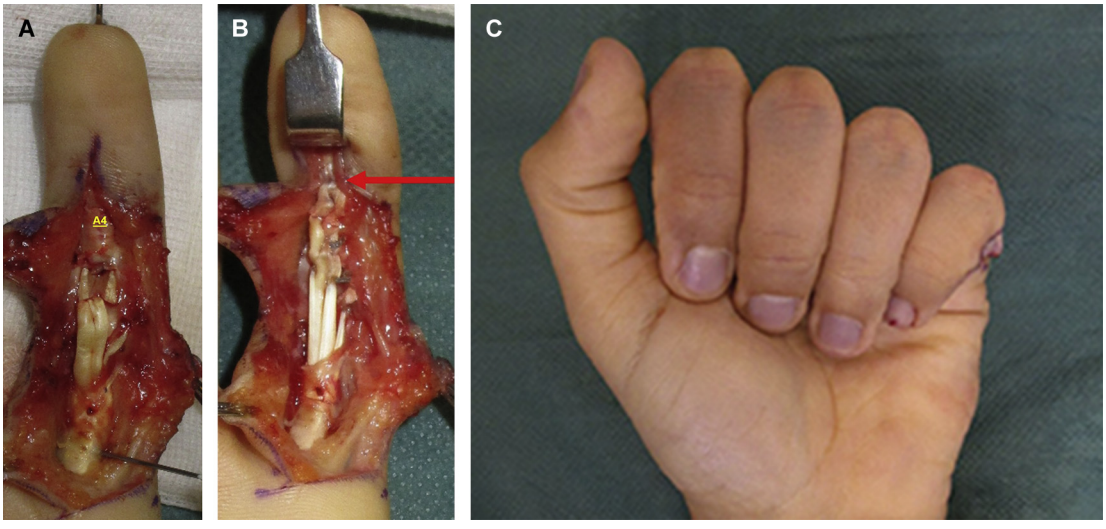

Fig. 2. An FDP tendon repair in the area close to the A4. (*A*) An intact A4 pulley and a disrupted FDP tendon. (*B*) The A4 pulley was entirely divided (*red arrow*) and the FDP tendon was repaired with M-Tang repair method. (*C*) Smooth FDP tendon gliding was confirmed in passive full flexion of the finger during surgery.

protocol highlights briefly the steps taken during the course of hand rehabilitation with the most important message for the patient being that the hand can be mobilized but not used.[14] Other important points not highlighted in the following protocol are early edema control and purposeful patient education.

Days 1 to 5

During these first days

- Dorsal thermoplastic splint should be applied to the whole hand
- Wrist in 20° of extension; metacarpophalangeal joints 40° flexion; interphalangeal joints straight
- During the first 3 weeks the patient is normally seen twice a week by the hand therapists, after this period the frequency is depending on different factors, such as edema, pain, and patient compliance

Week 1

Exercise sessions are carried out hourly, and all exercises are repeated 10 times. The patient starts each exercise session with 10 passive full flexions of the fingers while keeping still wearing the splint. The patient is then allowed to achieve full active finger extension within the splint, followed by active flexion of only 25% of full flexion, using the opposite hand, creating a so-called 3-finger block. Finger flexion is initiated by the FDP.

Week 2

The same regimen is used as for the first week, except that active flexion is taken to 50% of full flexion (2-finger block).

Week 3

The same regimen is used as for the first 2 weeks, except the patient is allowed to perform a full fist without provoking discomfort in form of tension or pain.

Weeks 4 and 5

The patient is allowed to remove the splint and to perform active tenodesis exercises, 10 repetitions, 4 times a day.

Weeks 6 and 7

The patient is seen by the surgeon. The splint is removed during the day, allowing the patient to perform light activities. The splint has to be worn at night and in dangerous situations (eg, in crowds). Progression to full active range of motion of the wrist and fingers continues.

Week 8

Loading exercises are initiated, if it is estimated by the therapist as a 10% difference between passive and active motion of the digits involved; the progression of loading is carefully guided by the hand therapist.[13]

Week 9

The splint is discarded completely. If passive motion is not fully achieved, dynamic splinting is initiated. All but heavy activities are allowed. Driving is allowed. Return to work is allowed for all except heavy manual workers. Return to heavy work is usually allowed from week 12.

Complications

Reduced range of finger movement

Although the injury in these cases is to the palmar surface of the hand, movement of edema onto the dorsum carries fibrin with it, and movement of the digits into flexion is then restricted by fibrin tethering of the extensor tendons. The extensor tendons, moving between interstitial tissue layers and without synovial sheaths, are more susceptible to this problem after any edema-inducing episode in the hand and are responsible for much of the failure of flexor tendon surgery to restore a full range of digital motion. This pathology is far the greatest cause of morbidity after all flexor tendon surgery, wherever and however it is done and whoever does the surgery. The authors try to reduce the edema with antiedema bandage to every finger as soon as the wounds are healed.

Rupture of the repair

In cases of rupture of the repair, the authors reoperate on the patient if he or she returns within 72 hours of rupture. Patients with infection, skin breakdown or swollen, stiff fingers are excluded, as are uncooperative patients. It has been recognized that ruptures of primary repairs of the little finger flexor tendons, albeit with a 2-strand repair, are much more common than ruptures in the other fingers, and second ruptures of rerepairs in this finger are also much more common.[15] It is not known whether this is true for 6-strand core repairs, but technical difficulties, because of the small size of the finger, make use of a 6-strand suture in this finger more difficult, especially after a rupture. If rerepair is found to be impossible, the authors insert a tendon rod as the first stage of a 2-stage tendon grafting procedure.

Flexor tendon adhesion

Fibrin, then scar, adhesion can also occur anywhere along the length of a flexor tendon, with loss of active flexion, but is a particular problem in the fingers themselves, where the flexor tendons are confined within the tendon sheath in a system as finely bored as the pistons in an engine. While this is the third major failure of primary flexor tendon surgery, it gives rise to delayed treatment, and, for the purpose of discussion, falls within the heading of secondary flexor surgery. It is not discussed further in this article.

Hidden rupture of the repair

Although occurring early in the postoperative period after immediate flexor tendon repair, this pathology presents as tendon adhesion. The tendon repair gaps; the tendon is then too long to move through a normal range of motion on activation of the flexor muscle proximally, and the tendon becomes adherent along its length. The possibility of this pathology being recognized at tenolysis surgery, and the need for converting of the operation from one of tenolysis to one of tendon grafting should be discussed preoperatively with the patient.

The authors are currently achieving no rupture status after primary flexor tendon repair in all cases treated in the manner described. This has been the case for 32 months in 35 FDP tendon repairs in the fingers. However, the authors are still seeing cases requiring tenolysis and do not have 100% good and excellent results.

ROOM FOR IMPROVEMENT

Assessment of Fine Flexor Tendon Function

The authors' means of assessment of flexor tendon repair is far from adequate,[16] and while

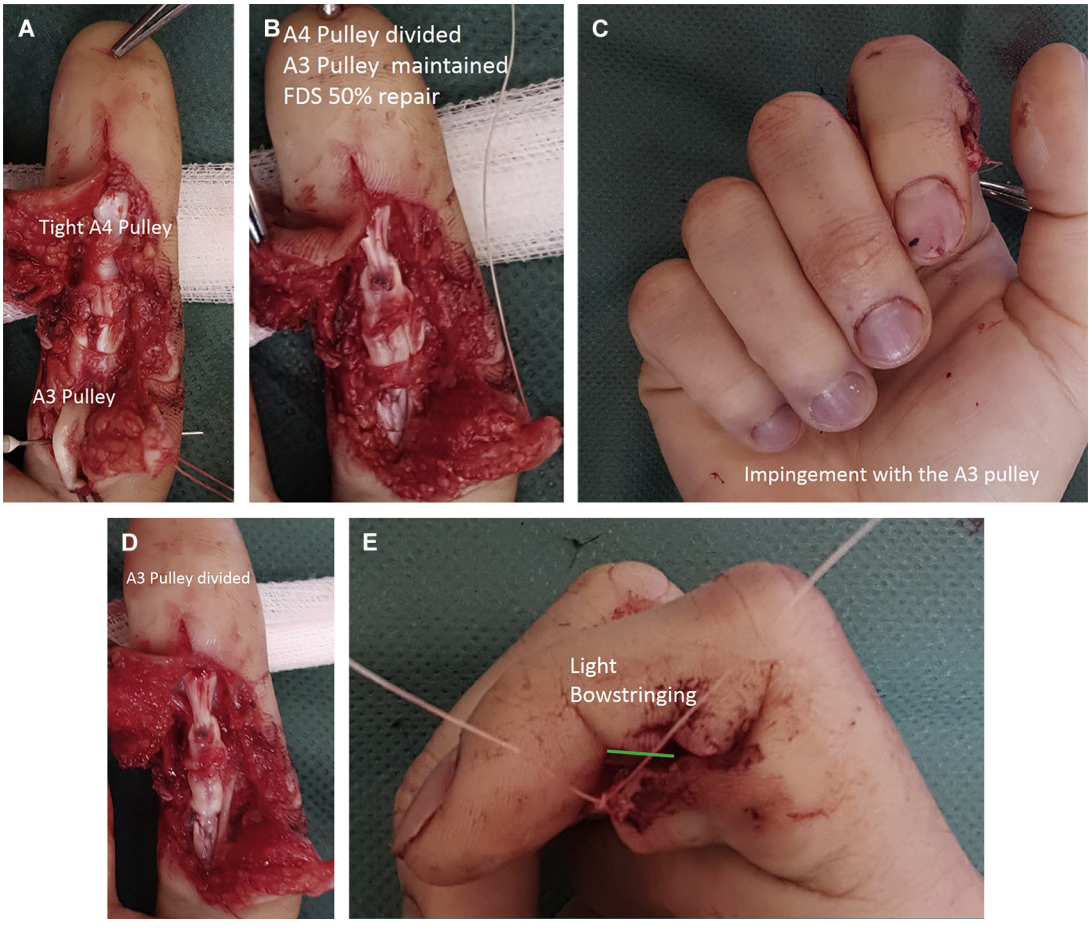

Fig. 3. An example of improving tendon gliding with minor tendon bowstringing at the proximal interphalangeal (PIP) joint level in a zone 2B FDP tendon cut. (*A*) Complete laceration of the FDP tendon at the segment between the A3 and A4 pulleys. (*B*) The A4 pulley was entirely vented. The FDP tendon was repaired with an M-Tang repair; only half of the FDS tendon was repaired, and the A3 pulley was preserved. (*C*) Passive finger flexion cannot fully flex the repaired finger after repair. (*D*) Therefore, the A3 pulley was vented entirely. (*E*) Minor tendon bowstringing noted after venting both the A4 and A3 pulleys.

patient assessments such as the disabilities of the arm, shoulder and hand (DASH) score may be of some additional value, they do not tell any more about the physiology of the flexor tendons and how it is downgraded after tendon repair. This is particularly important at a time when surgery to both the FDS tendon and the tendon sheath is being advocated to accommodate for the bulk of the FDP tendon repair.

The Flexor Digitorum Superficialis Tendon

Although division of half or all of the FDS tendon is being practiced for practical reasons, the precise value to the finger of this tendon remains uncertain. It is possible that this tendon deserves more respect and the bulk of 2 tendon repairs in the fingers be accommodated entirely by modification of the sheath.

The Pulleys

The venting or division of the pulley seems to be the key point to achieve a marked reduction in ruptures rate. The authors have no knowledge of the state of the vented pulleys at the completion of healing. Do they remain vented? Do they heal with lengthening of the pulleys? or do they heal with scar, which contracts, as do all scars, and brings them back to their original size as the tendon repair remodels? The authors are aware from research into the rupture of pulleys among mountain climbers that the pulleys repair in these (closed) cases of rupture if the fingers are mobilized while wearing external circumferential splints on the fingers.[17]

As with modification of the FDS tendon, the assumption that division of the A3 and/or A4 pulleys causes no long-term problems of flexor tendon function[18] is based on relatively crude tests of flexor tendon function (**Fig. 3**). It is possible that finer function of the system is reduced and might be improved by mobilization of the fingers postoperatively in finger ring splints in the hope of pulley repair. The authors are currently investigating whether there is loss of grip strength in digits that have had both the A3 and A4 pulleys completely vented at the same time.

The authors divide the pulleys as much as needed to allow free excursion of the repaired tendon within the tendon sheath, including, when necessary, full division of the A4 or A2 pulley, which is in agreement with the practice and evidence reported in more recent literature that indicate a strong repair should be used,[19–28] as well as critical pulleys vented.[29–38]

SUMMARY

The authors' protocol for primary flexor tendon repair in zones 1 and 2 of the hand is changing to try to make the surgery easier and achieve excellent results more regularly. This article discusses some of the changes made recently. The authors now perform an immediate repair within 48 hours whenever possible but have operated on suitable cases up to 1 month after injury. The authors perform a 6-strand core suture using the M modification of Tang's original technique, with no circumferential suture. They divide the pulleys as much as needed to allow free excursion of the repaired tendon within the tendon sheath, including, when necessary, full division of the A4 or A2 pulley. To avoid the repaired structures within the sheath being too bulky, the authors also, mostly, repair only half of the FDS, resecting the other half. In zone 2C, and in specific cases, the authors excise the FDS completely. Rehabilitation remains based on controlled active motion,[15,39] but with modifications.

ACKNOWLEDGMENTS

The authors would like to thank Vera Beckmann-Fries and the Hand Therapy Department of the University Hospital Zurich for their contribution.

REFERENCES

1. Elliot D, Giesen T. Primary flexor tendon surgery: the search for a perfect result. Hand Clin 2013;29:191–206.
2. Wang B, Xie RG, Tang JB. Biomechanical analysis of a modification of Tang method of tendon repair. J Hand Surg Br 2003;28:347–50.
3. Giesen T, Sirotakova M, Copsey AJ, et al. Flexor pollicis longus primary repair: further experience with the tang technique and controlled active mobilization. J Hand Surg Eur Vol 2009;34:758–61.
4. Rigo IZ, Røkkum M. Predictors of outcome after primary flexor tendon repair in zone 1, 2 and 3. J Hand Surg Eur Vol 2016;41:793–801.
5. Puippe GD, Lindenblatt N, Gnannt R, et al. Prospective morphologic and dynamic assessment of deep flexor tendon healing in zone II by high-frequency ultrasound: preliminary experience. Am J Roentgenol 2011;197:W1110–7.
6. Tang JB, Wu YF, Cao Y, et al. Gene therapy for tendon healing. In: Tang JB, Amadio PC, Guimberteau JC, et al, editors. Tendon surgery of the hand. Philadelphia: Elsevier Saunders; 2012. p. 59–70.
7. McFarlane RM, Lamon R, Jarvis G. Flexor tendon injuries within the finger. A study of the results of tendon suture and tendon graft. J Trauma 1968;8:987–1003.
8. Le Viet D. Flexor tendon lengthening by tenotomy at the musculotendinous junction. Ann Plast Surg 1986;17:239–46.

9. Lalonde DH, Martin AL. Wide-awake flexor tendon repair and early tendon mobilization in zones 1 and 2. Hand Clin 2013;29:207–13.
10. Tang JB. Outcomes and evaluation of flexor tendon repair. Hand Clin 2013;29:251–9.
11. Moiemen NS, Elliot D. Primary flexor tendon repair in zone 1. J Hand Surg Br 2000;25:78–84.
12. Tang JB, Pan CZ, Xie RG, et al. A biomechanical study of Tang's multiple locking techniques for flexor tendon repair. Chir Main 1999;18:254–60.
13. Elliot D, Moiemen NS, Flemming AF, et al. The rupture rate of acute flexor tendon repairs mobilized by the controlled active motion regimen. J Hand Surg Br 1994;19:607–12.
14. Higgins A, Lalonde DH. Flexor tendon repair postoperative rehabilitation: the Saint John Protocol. Plast Reconstr Surg Glob Open 2016;4:e1134.
15. Groth GN. Pyramid of progressive force exercises to the injured flexor tendon. J Hand Ther 2004;17:31–42.
16. Elliot D, Harris SB. The assessment of flexor tendon function after primary tendon repair. Hand Clin 2003;19:495–503.
17. Schreiber T, Allenspach P, Seifert B, et al. Connective tissue adaptations in the fingers of performance sport climbers. Eur J Sport Sci 2015;15:696–702.
18. Franko OI, Lee NM, Finneran JJ, et al. Quantification of partial or complete A4 pulley release with FDP repair in cadaveric tendons. J Hand Surg Am 2011;36:439–45.
19. Leppänen OV, Linnanmäki L, Havulinna J, et al. Suture configurations and biomechanical properties of flexor tendon repairs by 16 hand surgeons in Finland. J Hand Surg Eur Vol 2016;41:831–7.
20. Hoffmann GL, Büchler U, Vögelin E. Clinical results of flexor tendon repair in zone II using a six-strand double-loop technique compared with a two-strand technique. J Hand Surg Eur Vol 2008;33:418–23.
21. Moriya K, Yoshizu T, Maki Y, et al. Clinical outcomes of early active mobilization following flexor tendon repair using the six-strand technique: short- and long-term evaluations. J Hand Surg Eur Vol 2015;40:250–8.
22. Edsfeldt S, Rempel D, Kursa K, et al. In vivo flexor tendon forces generated during different rehabilitation exercises. J Hand Surg Eur Vol 2015;40:705–10.
23. Tang JB. Clinical outcomes associated with flexor tendon repair. Hand Clin 2005;21:199–210.
24. Savage R, Tang JB. History and nomenclature of multistrand repairs in digital flexor tendons. J Hand Surg Am 2016;41:291–3.
25. Savage R. The search for the ideal tendon repair in zone 2: strand number, anchor points and suture thickness. J Hand Surg Eur Vol 2014;39:20–9.
26. Kozono N, Okada T, Takeuchi N, et al. Asymmetric six-strand core sutures enhance tendon fatigue strength and the optimal asymmetry. J Hand Surg Eur Vol 2016;41:802–8.
27. Agrawal AK, Mat Jais IS, Chew EM, et al. Biomechanical investigation of 'figure of 8' flexor tendon repair techniques. J Hand Surg Eur Vol 2016;41:815–21.
28. O'Brien FP 3rd, Parks BG, Tsai MA, et al. A knotless bidirectional–barbed tendon repair is inferior to conventional 4-strand repairs in cyclic loading. J Hand Surg Eur Vol 2016;41:809–14.
29. Elliot D, Lalonde DH, Tang JB. Commentaries on clinical results of releasing the entire A2 pulley after flexor tendon repair in zone 2C. K. Moriya, T. Yoshizu, N. Tsubokawa, H. Narisawa, K. Hara and Y. Maki. J Hand Surg Eur 2016, 41: 822–28. J Hand Surg Eur Vol 2016;41:829–30.
30. Moriya K, Yoshizu T, Tsubokawa N, et al. Outcomes of release of the entire A4 pulley after flexor tendon repairs in zone 2A followed by early active mobilization. J Hand Surg Eur Vol 2016;41:400–5.
31. Moriya K, Yoshizu T, Tsubokawa N, et al. Clinical results of releasing the entire A2 pulley after flexor tendon repair in zone 2C. J Hand Surg Eur Vol 2016;41:822–8.
32. Zhou X, Li QR, Qing J, et al. Outcomes of the 6-strand M-Tang repair for zone 2 primary flexor tendon repair in 54 fingers. J Hand Surg Eur Vol 2017;42:462–8.
33. Tang JB. Indications, methods, postoperative motion and outcome evaluation of primary flexor tendon repairs in Zone 2. J Hand Surg Eur Vol 2007;32:118–29.
34. Tang JB. Release of the A4 pulley to facilitate zone II flexor tendon repair. J Hand Surg Am 2014;39:2300–7.
35. Tang JB, Chang J, Elliot D, et al. IFSSH Flexor Tendon Committee report 2014: from the IFSSH Flexor Tendon Committee. J Hand Surg Eur Vol 2014;39:107–15.
36. Tang JB, Amadio PC, Boyer MI, et al. Current practice of primary flexor tendon repair: a global view. Hand Clin 2013;29:179–89.
37. Wong JK, Peck F. Improving results of flexor tendon repair and rehabilitation. Plast Reconstr Surg 2014;134:913e–25e.
38. Khor WS, Langer MF, Wong R, et al. Improving outcomes in tendon repair: a critical look at the evidence for flexor tendon repair and rehabilitation. Plast Reconstr Surg 2016;138:1045e–58e.
39. Elliot D. Primary flexor tendon repair–operative repair, pulley management and rehabilitation. J Hand Surg Br 2002;27:507–13.