Full Length Article

JHS(E)

Journal of Hand Surgery
(European Volume)
0(0) 1–6

DOI: 10.1177/1753193418758269
journals.sagepub.com/home/jhs
SAGE

Flexor tendon repair in the hand with the M-Tang technique (without peripheral sutures), pulley division, and early active motion

Thomas Giesen, Lisa Reissner, Inga Besmens, Olga Politikou and Maurizio Calcagni

Abstract

We report outcomes in 29 patients with flexor tendon repairs in 32 digits (five thumbs and 27 fingers) with our modified protocols. We repaired the lacerated flexor digitorum profundus tendons with core suture repairs using the 6-strand M-Tang method and without circumferential sutures. We divided the pulleys as much as needed to allow excursion of the repaired tendons, including complete division of the A4 or A2 pulleys when necessary. In nine fingers, we repaired one slip of the flexor digitorum superficialis tendon and resected the other half. When the flexor digitorum profundus tendon would not glide under the A2 pulley, we excised the remaining slip of the flexor digitorum superficialis tendon. The wrist was splinted in mild extension post-surgery with early commencement of tenodesis exercises. No tendon repair ruptured. By the Strickland criteria, out of 27 fingers, 18 had excellent, six had good, two had fair, and one had poor results. We conclude that a strong core suture (such as the M-Tang repair) without peripheral sutures, and with division of pulleys as necessary is safe for early active motion and yields good outcomes.

Level of evidence: IV

Keywords

Primary flexor tendon repair, no circumferential suture, pulley management, flexor digitorum superficialis resection, early active motion

Date received: 24th October 2017; revised: 17th January 2018; accepted: 18th January 2018

Introduction

Flexor tendon repair has traditionally resulted in ruptures in approximately 5% of cases and symptomatic adhesions in another 5%, giving unsatisfactory results in 10% (Elliot and Giesen, 2013). Flexor pollicis longus (FPL) repair in zone 2 has an even higher rate of ruptures and worst outcomes (Sirotakova and Elliot, 1999) except for a few recent reports (Giesen et al., 2009; Pan et al., 2017). Major changes of tendon repair technique are being reported worldwide and seek to prevent repair rupture and improve the outcomes. Lately, venting of the pulleys became a new routine (Moriya et al., 2016a, 2016b, 2017; Rigo and Røkkum, 2016). The rehabilitation protocols have also slowly shifted in the last 30 years from classic Kleinert-type regimes to controlled active mobilization (CAM) protocols (Moriya et al., 2017; Tang, 2013; Zhou et al., 2017).

To further improve our clinical outcomes, we modified our treatment protocols a few years ago. The major modifications in our protocols included: (1) Use of a simple 6-strand core suture technique known as the M modification of the Tang technique (Tang, 2005; Tang et al., 1999; Wang et al., 2003), with no circumferential suture, to repair the flexor digitorum profundus (FDP) tendons. (2) A protocolled approach to the tendon sheath that includes partial

Division of Plastic Surgery and Hand Surgery, University Hospital Zurich, Zurich, Switzerland

Corresponding Author:
Thomas Giesen, Division of Plastic Surgery and Hand Surgery, University Hospital Zurich, Raemistrasse 100, 8091 Zurich, Switzerland.
Email: t_giesen@hotmail.com

or full division of different pulleys, including A2 and A4 in the fingers and the oblique pulley in the thumb according to the level of the tendon laceration. (3) A protocolled flexor digitorum superficialis (FDS) tendon management, including repair of one slip and resection of the other slip or complete resection of the FDS. (4) A CAM protocol for rehabilitation supported by a splint with 20° wrist extension and 40° of metacarpophalangeal (MCP) joint flexion.

In this report, we present the outcomes of our most recent series of primary tendon repairs in the digital sheath area after adopting our modified protocols.

Patients and methods

Between January 2014 and December 2016, 29 patients with complete divisions of the FDP tendon in zone 1C or zone 2 and FPL tendon in zone 2 were treated by primary or delayed primary repair with the below-described protocol. This comprised a total of 32 digits including five thumbs and 27 fingers. Patients with bone and joint injuries in the hand, complex skin or soft tissue defects, revascularizations and replantations, or incomplete or multi-level divisions of the flexor tendons were excluded. Patient who were not treated according to the proposed protocol by the surgeons of our unit were also excluded. The study was approved by the local ethics committee, and all patients provided written informed consent for their data to be used for this analysis.

There were 10 women and 19 men with a mean age of 34 years (range 17–59). Two injuries were in zone 1C of two fingers, and 29 were in zone 2 of either thumbs or fingers. Eighteen patients sustained injury to the right hand and 11 to the left hand. The dominant hand was involved in 18 patients. Twenty-one digits had no digital nerve or artery injuries. The other 11 digits had divisions of a total of 12 digital nerves and four proper digital arteries. The time from the injury to tendon repair was of 2.5 days (range 0–38). There were five thumbs, eight index fingers, four middle fingers, five ring fingers, and ten little fingers in this series (detailed in online supplement Table S1).

Surgical techniques

Local anaesthesia as described by Lalonde and Martin (2013) and Lalonde (2017) was used in eight patients. Otherwise the procedure was performed under brachial block or general anaesthesia. The wounds were explored and extended with a Bruner incision.

We noted the level of the distal stump of the FDP tendon while the finger was fully extended. The level of the FDP or FPL tendon division dictated decision-making regarding the management of the pulleys and FDS tendon. We recorded the location of tendon lacerations in fingers using the Tang subdivisions of zone 2 (subzones 2A to 2D) and Elliot subdivisions of zone 1 (subzones 1A to 1C) (Moiemen and Elliot, 2000; Tang, 2013).

We retrieved the proximal stump without dividing proximal annular pulleys. If retrieving the proximal stump of the FDP tendon was impossible because of swelling of the tendons, we either resected one or both slips of the FDS tendon. In fingers with FDS repair, we used a 4-0 Fiberloop suture (FiberWire, Arthrex, Naples, FL, USA) to make a Tsuge repair. The resected slips of the FDS were resected as far proximally as possible to avoid the proximal end catching on the A1 or proximal portion of the A2 pulley when the finger was extended. The management of the FDS tendon is summarized in Figure 1. In total, we completely resected the FDS in three digits. We repaired 50% of the FDS and resected the other 50% in seven digits. We resected 50% of the FDS in two digits with partial lesion of this tendon. We repaired all the FDS in six digits.

We repaired each of the FDP tendon in the fingers and the FPL tendon in the thumbs with two 4-0 Fiberloop sutures (Arthrex) using the M modification of the Tang technique, a 6-strand core suture (Tang, 2007; Wang et al., 2003). We did not add a circumferential suture to any of these FDP or FPL tendons.

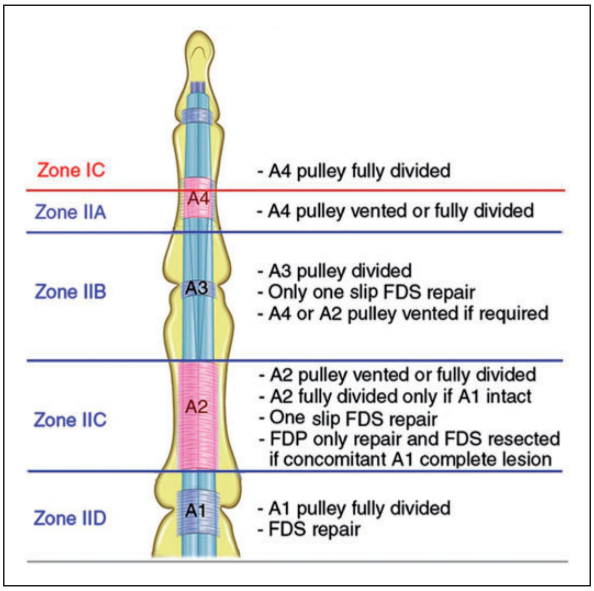

Figure 1. The proposed algorithm for pulleys and FDS management according to the subzone of tendon lesion.

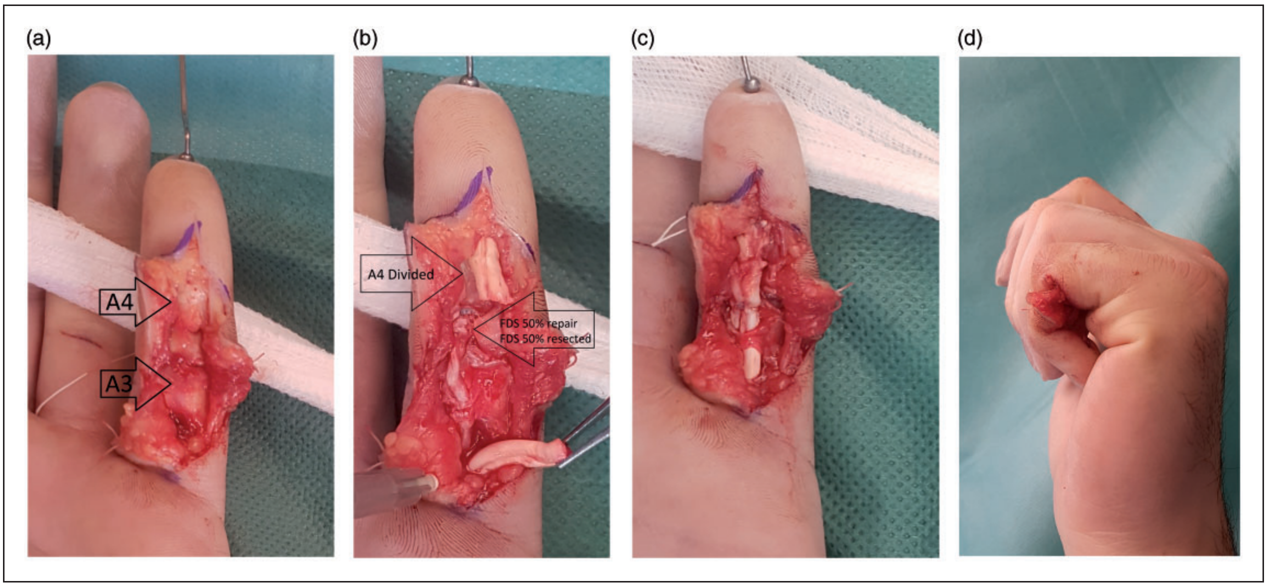

Figure 2. (a) A finger with tendon injuries in zone 2A repaired under local anaesthesia. (b) One slip of the FDS was repaired with a 4-0 loop suture and the A4 pulley was completely vented. (c) The A3 pulley was preserved. The FDP tendon was passed through the intact A3 pulley and repaired with the M-Tang technique. (d) Intraoperative active flexion of the finger.

The core suture repair was made with some tension to prevent gapping at the repair site. Following tendon suture, the digit was moved through a full range of motion either actively or passively. Any pulleys limiting full and free excursion of the repaired tendon were partially or completely divided as necessary (Figure 2). After full division of any pulley, we did not perform any reconstructive procedures and left the pulley ends lying on the repaired tendon.

In the fingers (non-thumb digits), the A4 pulleys were divided or completely injured in 13 fingers, the A3 pulleys in 14 fingers, the A2 pulleys in one finger, and the A1 pulleys in four fingers. In five fingers, the A4 and A3 pulleys were both completely divided. The A4 pulley was 50% vented in one finger, the A2 pulley in six fingers. We never completely opened the A1 and A2 pulley in the same case. In two fingers we marginally vented the A2 pulley (15% length) and completely opened the A4 pulley. In thumbs we completely opened the oblique pulley in two cases and the A2 pulley in one. We never opened the oblique and A1 pulley in the same thumb.

Nine surgeons repaired these tendons. Their expertise levels for tendon repair were: One surgeon level 4, two surgeons level 3, two surgeons level 2, and four level 1 or trainees, according to the criteria of surgeons' expertise (Tang, 2009; Tang and Giddins, 2016). Thirteen repairs were performed by level 1 surgeons (trainees) who were supervised by a level 3 surgeon in ten digits and by a level 4 surgeon in three digits.

Post-operative care

Our protocol was based on the Chelmsford CAM regimen (Elliot et al., 1994) with several modifications (Giesen et al., 2017). A thermoplastic splint with the wrist in 20° of extension and the MCP joints in 40° flexion was applied as soon as possible after surgery. Tenodesis exercises outside the splint were allowed from the fourth post-operative week. The progression of active flexion in the first three weeks was identical to the original protocol (Elliot et al., 1994).

Assessment of outcomes

All patients were followed for an average of 9 months (range 5–14). The final total range of active motion (TAM) of the fingers was assessed using the sum of active ranges of motion of the two interphalangeal joints and MCP joint of the finger or the sum of active ranges of motion of the interphalangeal joint and the MCP joint in the thumb.

The outcomes in the fingers were graded with the criteria described by Strickland and Glogovac (1980). The outcomes in the thumbs were graded with the method described by Buck-Gramcko and Dietrich (Buck-Gramcko et al., 1976). The final grip strength was measured using the Jamar dynamometer (Sammons Preston Rolyan Inc, Bollingbrook IL, USA) set in the next to smallest position.

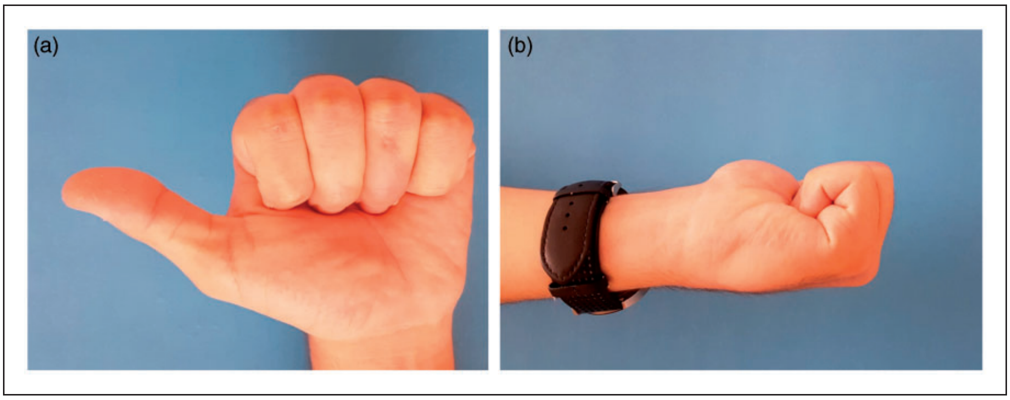

Figure 3. Motion of the repaired finger 5 months after surgery. (a) Flexion. (b) Extension.

Post-operative complications as such tendon ruptures, infections, complex regional pain syndrome, adhesions, and secondary surgeries were recorded during the follow-up.

Results

There were no ruptures of the repaired tendons. Four patients (four fingers) needed tenolyses. Two of them with a zone 2B FDP repair were operated because of need to remove heterotopic ossification from around the suture material. The tenolyses were performed 5 to 8 months after tendon repair surgery. The results reported below are those before tenolysis.

TAM

The final TAM for the fingers was 219° (range 100°–275°). The eight index fingers had a TAM of 226° (range 180°–275°). The four middle fingers had a TAM of 203° (range 100°–255°). The five ring fingers had a TAM of 224° (range 2015°–245°). The ten little fingers had a TAM of 220° (range 140°–260°). The TAM of the thumbs was 98° (range 60°–138°).

Functional outcomes

The outcomes of the 27 fingers were excellent in 18, good in six, fair in two, and poor in one. The details in each of these fingers are available in the online supplementary Table S2. The 17 fingers rated excellent included three fingers in three patients who had tenolysis. The excellent results in the three fingers were after tenolysis. One patient had a fair result after tenolysis.

Among five thumbs, two had excellent, two had good, and one had poor outcomes. The thumb with a poor outcome required tenolysis 6 months after the repair. This patient still had a poor result after tenolysis 12 months later.

Grip strength

The grip strength was 78% (range 25%–113%) of the contralateral side. Five patients with concomitant division of A3 and A4 pulleys had a grip strength of 92% of the contralateral side.

Complications

Four out of 32 digits developed adhesions that needed tenolysis. As detailed previously, after tenolysis two fingers achieved excellent outcomes and one fair. The thumb requiring tenolysis did not improve.

We did not find any bowstringing, and no patients complained of such (Figure 3). No patient with partial or total resection of the FDS tendon complained about loss of finger movement or decrease in strength. One patient who developed chronic regional pain syndrome was treated with oral steroids and hand therapy and had a poor result at 1-year follow up.

Discussion

Any suturing technique for flexor tendon repair should be simple to perform, minimize tendon manipulation, and minimize the amount of foreign material exposed on the surface of the tendon. The repair should provide enough strength for early active mobilization. We use the M modification of the Tang technique (M-Tang method) with two 4-0 loop core sutures. We believe this is an easier technique to master than the Kessler system (Tang, 2007; Wang et al., 2003).

A circumferential suture is traditionally added after completion of the core suture to smooth the repair site to prevent catching of the repair site by the sheath and to add strength to the tendon repair. We believe the smoothing procedure is unnecessary because our core sutures aligned the tendon stumps and closed the repair site sufficiently without the need for a circumferential suture. Additional strength seems unnecessary when this six-strand core repair is used (Giesen et al., 2009).

We vented the pulleys when necessary. The venting or complete division of the pulley seems to be the key point to achieve a marked reduction in rupture incidence. The assumption that division of the A2, A3, and/or A4 pulleys causes long-term problems of flexor tendon function is based on relatively crude tests of flexor tendon function (Franko et al., 2011). Recent clinical reports (Moriya et al., 2016a, 2016b) have shown little effect on the overall functional outcome by fully dividing the A2 or A4 pulley. Moriya et al. (2016a) incised the entire A2 pulley in seven fingers when such a division was necessary. Lalonde also vented the pulleys as much as needed (Elliot et al., 2016). In our patients, we did not observe any evident bowstringing, and no patient complained about such. In patients with concomitant A3 and A4 pulley division, the average grip strength was 91% of the contralateral hand. However, the small number of patient with concomitant A3 and A4 pulley divisions prevented us from performing any statistical analysis, and therefore we are unable to draw a definitive conclusion. However, based on our patients and published reports, we think that opening the A4 and A3 pulleys at the same time does not result in any functional deficit.

We have also modified the management of the divided FDS tendon, moving to a policy of partial repair or no repair, depending on the level of FDS division. In selected cases as explained in Figure 1, we partially resect the FDS tendon, that is, one slip when it is partially divided. These changes of pulleys management and FDS management are based on acceptance that the tendon diameter at a suture site increases by 1.6-fold after repair (Puippe et al., 2011).

The relatively aggressive manipulation of the structures of the flexor tendon system in the digits is intended to create space for the repaired FDP or FPL to heal and to avoid friction that might lead to rupture. It is difficult to measure any change in fine manipulation skills related to management of the FDS because the bifurcated FDS tendon is structurally small. While division of half or the entire FDS tendon is performed for practical reasons, the precise value to the finger of this tendon remains uncertain. It is possible that this tendon deserves more respect and that the bulk of two tendon repairs in the fingers should be accommodated entirely by modification of the sheath.

Using this tendon technique together with pulley venting in our practice, we have not had a flexor tendon repair rupture in the past 24 months. We found that wrist splinting in extension and early commencement of tenodesis exercises do not risk repair rupture. However, we still have repairs requiring tenolysis and do not have 100% good and excellent results. The observation of two cases of calcifications around the repaired tendon prompt us to change the suture material to use a reinforced 4-0 loop nylon pseudo-monofilament currently.

It is possible that without these unfavourable calcifications our incidence of good and excellent results might have been higher. The coated suture (Fiberloop) we used in this study was quite stiff and difficult to pass through the tendon substance, while trying to achieve the desired tension distribution among the strands of the core suture. In a biomechanical test, Hay et al. (2017) recently reported that Fiberloop does not produce secured locks in the tendons. A loop monofilament suture might be more desirable and is our most recent modification.

Acknowledgement We would like to thank Mr David Elliot as we are standing on the shoulders of a giant. We would like to thank the Hand Therapy Department of the University Hospital of Zurich for their support.

Declaration of conflicting interests The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding The authors received no financial support for the research, authorship, and/or publication of this article.

Ethical approval The study was approved by the University of Zurich ethics committee and all patients provided written informed consent for their data to be used for this analysis.

Supplementary material Supplementary material for this article is available online.

References

Buck-Gramcko D, Dietrich FE, Gogge S. Bewertungskriterien bei Nachuntersuchungen von Beugesehnenweiderherstellungen. Handchirurgie. 1976, 8: 65–9.

Elliot D, Giesen T. Primary flexor tendon surgery: the search for a perfect result. Hand Clin. 2013, 29: 191–206.

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: 822–8. J Hand Surg Eur. 2016, 41: 829–30.

Elliot D, Moiemen NS, Flemming AF, Harris SB, Foster AJ. The rupture rate of acute flexor tendon repairs mobilized by the controlled active motion regimen. J Hand Surg Br. 1994, 19: 607–12.

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.
Giesen T, Calcagni M, Elliot D. Primary flexor tendon repair with early active motion: experience in Europe. *Hand Clin*. 2017; 33: 465–72.
Giesen T, Sirotakova M, Copsey AJ, Elliot D. Flexor pollicis longus primary repair: further experience with the Tang technique and controlled active mobilization. J Hand Surg Eur. 2009, 34: 758–61.
Hay RAS, Wong YR, Loke AM, Tay SC. Biomechanical investigation of uneven load bearing in six-strand Lim-Tsai flexor tendon repair using Fiberloop®. J Hand Surg Eur. 2017, 42: 457–61.
Lalonde DH. Conceptual origins, current practice, and views of wide awake hand surgery. J Hand Surg Eur. 2017, 42: 886–95.
Lalonde DH, Martin AL. Wide-awake flexor tendon repair and early tendon mobilization in zones 1 and 2. Hand Clin. 2013, 29: 207–13.
Moiemen NS, Elliot D. Primary flexor tendon repair in zone 1. J Hand Surg Br. 2000, 5: 78–84.
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. 2016a, 41: 822–8.
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. 2016b, 41: 400–5.
Moriya K, Yoshizu T, Tsubokawa N, Narisawa H, Matsuzawa S, Maki Y. Outcomes of flexor tendon repairs in zone 2 subzones with early active mobilization. J Hand Surg Eur. 2017, 42: 896–902.
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: 909–14.
Puippe GD, Lindenblatt N, Gnannt R, Giovanoli P, Andreisek G, Calcagni M. 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.
Rigo IZ, Røkkum M. Predictors of outcome after primary flexor tendon repair in zone 1, 2 and 3. J Hand Surg Eur. 2016, 41: 793–801.
Sirotakova M, Elliot D. Early active mobilization of primary repairs of the flexor pollicis longus tendon. J Hand Surg Br. 1999, 24: 647–53.
Strickland JW, Glogovac SV. Digital function following flexor tendon repair in Zone II: a comparison of immobilization and controlled passive motion techniques. J Hand Surg Am. 1980, 5: 537–43.
Tang JB. Clinical outcomes associated with flexor tendon repair. Hand Clin. 2005, 21: 199–210.
Tang JB. Indications, methods, postoperative motion and outcome evaluation of primary flexor tendon repairs in Zone 2. J Hand Surg Eur. 2007, 32: 118–29.
Tang JB. Re: Levels of experience of surgeons in clinical studies. J Hand Surg Eur. 2009, 34: 137–8.
Tang JB. Outcomes and evaluation of flexor tendon repair. Hand Clin. 2013, 29: 251–9.
Tang JB, Giddins G. Why and how to report surgeons' levels of expertise. J Hand Surg Eur. 2016, 41: 365–6.
Tang JB, Pan CZ, Xie RG, Chen F. A biomechanical study of Tang's multiple locking techniques for flexor tendon repair. Chir Main. 1999, 18: 254–60.
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.
Zhou X, Li XR, Qing J, Jia XF, Chen J. Outcomes of the six-strand M-Tang repair for zone 2 primary flexor tendon repair in 54 fingers. J Hand Surg Eur. 2017, 42: 462–8.