Clinical Results of Flexor Tendon Repair in Zone II Using a six Strand Double Loop Technique

Christiana Savvidou · Tsu-Min Tsai

Received: 11 April 2014 / Accepted: 18 August 2014 / Published online: 28 August 2014
© Society of the Hand & Microsurgeons of India 2014

Abstract The purpose of this study is to report the clinical results after repair of flexor tendon zone II injuries utilizing a 6-strand double-loop technique and early post-operative active rehabilitation. We retrospectively reviewed 22 patients involving 51 cases with zone II flexor tendon repair using a six strand double loop technique from September 1996 to December 2012. Most common mechanism of injuries was sharp lacerations (86.5 %). Tendon injuries occurred equally in manual and non-manual workers and were work-related in 33 % of the cases. The Strickland score for active range of motion (ROM) postoperatively was excellent and good in the majority of the cases (81 %). The rupture rate was 1.9 %. The six strand double loop technique for Zone II flexor tendon repair leads to good and excellent motion in the majority of patients and low re-rupture rate. It is clinically effective and allows for early postoperative active rehabilitation.

Keywords Zone II flexor tendon · Six strand technique · Early active rehabilitation

Introduction

Flexor tendon injuries are difficult and serious problems. Primary repair of zone II flexor injuries is now a well accepted surgical procedure following the pioneering work published by Kleinert et al., in 1967 [1]. The functional results after flexor tendon zone II repair have improved significantly over the years [2]. However, the conflict between less scar formation and the risk of re-rupture remains. The technique used for

tendon repair and the postoperative therapeutic protocol should keep a balance between scar formation and rupture risk. Many studies demonstrate that the strength of the repair increases with the number of core sutures and the addition of epitendinous suture [2–9].

Biomechanical studies on cadavers have established the strength of the six strand technique described by Lim and Tsai [3–5] over both the modified Kessler and Tsuge core suture techniques [10]. While the looped six strand repair has uniformly higher mean strength than the other repairs, is this increase sufficient to support more aggressive rehabilitation protocols? The literature has not revealed much on the clinical effectiveness of this technique in combination with more aggressive mobilization.

Materials-Methods

A retrospective analysis was conducted on 51 cases of isolated zone II flexor tendon injuries repaired at our center using a six strand double loop technique from September 1996 to December 2012. The project was approved by the Institutional Review Board of University of Louisville. The procedures followed were in accordance with the ethical standards and with the Helsinki Declaration of 1975, as revised in 2000.

22 patients involving 51 cases were included in the study. Patients with isolated zone II FDP and FDS lacerations only were included in the study. All other injuries with combined flexor tendon, bone and neurovascular bundle injury were excluded to minimize confounders. The surgery was performed in hospital and the patients returned home the same day. Only patients with minimum follow up of 3 months were reviewed. The primary data recorded were patient's demographic data and clinical data including: mechanism of injury, surgery delay, complications, secondary surgeries, rapidity of return to work, work pattern post-surgery and change of

C. Savvidou (✉) · T.-M. Tsai
Christine M. Kleinert Institute for Hand & Microsurgery, 225
Abraham Flexner Way, Suite 800, Louisville, KY 40202, USA
e-mail: csavvidou24@gmail.com

employment status, range of motion (ROM) and strength of the operated and of the non-operated extremity (Jamar 2, Lafayette Instrument, IN, USA). Active and passive ROM were measured using the Strickland grading system [8], thus ROM only included PIP and DIP joint measurements.

Surgical Technique

After wound exploration and identification of tendon cut, the tendon ends were positioned with very slight overlap and held in this position with transverse 25-gauge needles. A superficial bite of the tendon was made 1.25 cm from the proximal end of the tendon, transverse to the length of the tendon fibers. This stitch was locked by passing the needle through the loop suture and tightened with firm pressure to remove slack and increase resistance to gapping (Fig. 1). Next, the needle was inserted close to the locked suture, taking a deeper, longitudinal bite of the tendon parallel to the tendon fibers. This bite was through the medial volar quadrant of the tendon, exiting out of the cut end. The needle was then reinserted into the facing cut end of the distal tendon and exited at least 1 cm from the tendon end. A second locking suture was placed starting from the distal cut end of the tendon (Fig. 2). The posterior wall of the tendon was approximated with 6–0 Prolene running epitendon sutures. The ends of the 2 core sutures (which surface 1 cm from each tendon end) were then locked by first making a transverse bite and then passing the needle through the loop (Fig. 3). The position of the tendon ends was set before making these second locking sutures. Tendon gapping or bunching could not be adjusted once the suture was locked. The needles were then inserted close to the second set of locked sutures and surfaced through the tendon ends. The loop sutures were then divided, with the proximal loop ends left longer than the distal loop ends, making identification of the 4 suture ends easier. The suture ends were tied

Fig. 1 Sutures start at least 1.25 cm from the proximal end of the tendon. This stitch is placed superficial transverse to the length of the tendon fibers and locked by passing the needle through the loop suture

Fig. 2 Next, the needle inserts close to the locked suture deeper with longitudinal direction parallel to the tendon fibers. The needle then reinserts into the distal tendon and exits 1 cm from the tendon end. A second suture is placed from distal to proximal direction parallel to the first one

intratendinously (Fig. 4). Finally the anterior walls of the tendon ends were smoothed with a simple running epitendon suture [3–5].

Postoperative Splinting Protocol

A dorsal block splint was applied with position of joints as follows: wrist in 20° extension, MPJ in 70° flexion and IPJ in full extension. An additional volar splint was applied from distal forearm to the distal palmar crease in order to keep the wrist more stable. Both splints were applied postoperatively and remained for 8 weeks. Modifications of the splints were

Fig. 3 The posterior wall of the tendon is approximated with 6–0 Prolene running epitendon sutures. The ends of the two core sutures are then locked carefully. First we lock the suture that is placed from distal to proximal (1) and then the suture that is placed from proximal to distal (2) with attention to avoid gap formation

Fig. 4 The sutures come out through the tendon ends, divided, with the proximal loop ends left longer than the distal loop ends, and then tied intratendinously

done in cases of position loss or damage. The patients visited the therapy department twice a week.

Postoperative Physical Therapy

Postoperative physical therapy consisted of an early active motion protocol as follows:

Week 1–3:

The patient was in a dorsal block splint (wrist 20° extension, MPJ 70° flexion, IPJ full extension) with an additional volar splint from distal forearm to the distal palmar crease. Therapy consisted of passive flexion, passive place-active hold, with progressive active composite flexion, scar massage and edema control. Therapy begun with isolated passive flexion to PIP & DIP joints, followed by composite passive flexion to each digit at least 5 times per hour. Patients in the early active program began passive place – active hold exercises (the patient or therapist passively flexed the involved digit then the patient very gently tried to actively hold this position), 2–5 repetitions per hour. Patients additionally performed gentle active composite flexion (the patient was allowed to actively flex the fingers from the fully extended position in the dorsal block splint to the maximally achievable level with gentle effort), 2–5 repetitions every 1–2 h. If extension was limited then active assisted extension was added (the patient or therapist gives gentle assistance to active extension effort of the IP's) as needed. Special attention was given to inflamed tissues with appropriate degree of aggressiveness of exercise, especially during the 1st week postoperatively. Patients were encouraged to repeat exercises at home at least every hour.

Week 3–8:

The patient remained in a dorsal block splint (wrist 20° extension, MPJ 70° flexion, IPJ full extension) with an additional volar splint. From the third to seventh week while still in the same splint, active place – active hold exercises were continued more aggressively, with addition of individual tendon gliding exercises. Scar massage and edema control continued as needed. During the rehabilitation period any IPJ contractures were treated with a cast on the operated finger (cast from fingertip to base of finger with PIP and DIP joints in extension). Patients were encouraged to repeat exercises at home at least every hour.

Week 9–12:

The splints were removed and exercises focused on progressive improvement of ROM of all joints including wrist and MP joints and strengthening exercises. In addition exercises improving hand usage according to patients' work and everyday activities were started. Patients were allowed to return to full functional activity at 12 weeks postoperatively.

Results

In 22 patients, a total of 51 tendons were repaired. From the 22 patients, 18 were male and 4 were female with mean age 27.5 years (18–61, range). The right hand was affected in 12 patients (54.4 %) and the left hand was affected in 10 patients (45.5 %). The small finger was affected most frequently (40 %) followed by the index and long (23.3 %). Specifically from the 51 tendons repaired 12 involved the index finger, 12 involved the long finger, 9 involved the ring finger and 18 involved the small finger. The lacerations occurred equally in manual and in non-manual workers. Only 33 % of the injuries were work related.

Postoperative range of motion evaluation with the Strickland score showed functional motion in the majority of the repairs (81 %). Specifically 47 % achieved excellent motion, 34 % achieved good motion, 13 % achieved fair motion and 6 % achieved poor motion (Table 1).

Mechanisms of injury included: sharp lacerations (86.5 %), crush injury (9 %) and table saw injury (4.5 %). We divided

Table 1 Postoperative range of motion results assessed by the original Strickland system

Strickland classification		Six strand loop technique	
Group	ROM (degrees)	Group	
Excellent	>150	Excellent	47 %
Good	125–149	Good	34 %
Fair	90–124	Fair	13 %
Poor	<90	Poor	6 %

tendon repair cases in two groups based on the type of injury, with one group being the patients with sharp clean laceration (86.5 %) and another group being the patients with crush injury and table saw injury (13.5 %). Patients who presented after having a clean cut laceration achieved better postoperative ROM. More specifically in clean cut lacerations the ROM was 25.3° more than in crush and table saw injuries. The cases with crush and table saw injuries did not reach excellent postoperative ROM. Comparison of the postoperative range of motion between the two groups revealed no statistically significant difference (Table 2).

Also comparison of the postoperative ROM between patients with manual work and patients with office work, resulted in better motion in the patients with office work. However this difference did not prove to be statistically significant (Table 3). The average time from injury to surgery was 1.5 days (0–8, range). The average time to return to unrestricted activities was 87 days (56–116, average). 86 % of the operated patients returned to their pre-injury employment 3 months after surgery. Mean Jamar 2 grip strength was 77.6 lb in the operated hand and 100.3 in the unaffected hand at the last follow up visit.

The rupture rate was 1.9 % of the repaired tendons and occurred in one non-compliant patient 10 days postoperatively. The patient removed the splint and started lifting heavy objects with the operated hand 1 week after surgery. Immediate exploration and repair was offered but the patient never returned to our office. Minor complications included PIPJ flexion contracture which occurred in 10 tendons (19.6 % of repaired tendons), which improved to insignificant deformity with serial finger cast application.

Other complications included granuloma formation at the repair site in one case that required surgical excision and tenolysis, and one case of DIP extension lag, which also resolved with splinting.

Discussion

Flexor tendon injuries are a difficult, serious and frustrating problem for every hand surgeon. Injuries in zone II remain the most difficult in treatment and have the less favorable results. Even after meticulous surgical repair, full motion is not

Table 2 Comparison of postoperative range of motion based on different mechanisms of injury

Type of laceration	Range of motion (Mean±SD) (degrees)	P value
Sharp	136.5±31.30	0.16
Crush injury	111.2±23.20	

Table 3 Comparison of postoperative range of motion based on patients' work type

Type of employment	Range of motion (Mean±SD) (degrees)	P value
Manual work	128.1±35.60	0.72
Non manual work	135.2±24.00	

consistently achieved. Nevertheless patients achieved functional motion and good usage of the hand [6–8, 11–14].

Reviewing the literature on the results of flexor tendon repairs in zone II there is a wide range in range of motion from 50 to 100 % [6, 7, 11, 12]. A strong six strand repair facilitates earlier and more aggressive physical therapy. This may lead to fewer adhesions, less scarring, faster swelling control and improvement of final range of motion [6]. Gill et al. [3] showed the superiority of the tensile strength of the six strand loop suture (Lim/Tsai) over the two and four strand techniques. The load to failure of the six strand was 49 N whereas of the two strand was 21.97 N and the four strand was 45.91 N. In a recent clinical study a comparison of the six strand technique (Lim/Tsai group) with the two strand technique (Kessler group) showed that the six strand group achieved significantly better postoperative range of motion. Evaluation with the Strickland system showed 78 % good and excellent results in the six strand group compared with 43 % in the two strand group [6].

It is often difficult to compare results on flexor tendon repair mainly due to the different motion evaluation systems used and the different suture techniques. Despite the fact that more recent studies report the insufficiency of all current classification systems [13], we decided to use the original Strickland classification system as well. In our present series the majority of patients ended up with excellent and good results (81 %). These results are comparable with the literature and our impression it that is not feasible to regain 100 % of motion after flexor tendon zone II repair regardless of the technique used.

Other factors like mechanism of injury and work type should be investigated when evaluating flexor tendon repair results to see if they affect postoperative motion. In our study patients with sharp lacerations and office work achieved better postoperative ROM than patients with crush injuries and manual work. The repaired tendons following crush and table saw injuries did not achieve excellent postoperative ROM and this could be due to tendon substance loss from the injury. Clean-cut tendon lacerations provide smooth edges for repair thus leading to less scar formation and better postoperative motion.

Usual complications after flexor tendon repair are tendon rupture, adhesion formation, joint stiffness especially in PIPJ, pulley system insufficiency and infection. Postoperative tendon rupture occurs between 4–6 weeks [6, 7, 12–14].

Ruptures of tendon repairs associated with early mobilization were noted in 0 to 30 % of the tendons, which seem inevitable with current motion regimens [9, 11, 15, 16]. The most common cause for rupture is a high load that exceeds the repair tolerance. This results from patient noncompliance, poor surgical technique, overzealous therapy or early splinting termination. Many times patients are noncompliant and the surgeon needs to follow them very closely. The reported rupture rate from our series (1.9 %) was significantly lower than most of the literature reports.

The most common complication after flexor tendon repair is adhesion formation, which limits active range of motion. Adhesion formation is affected by the initial trauma, the surgical repair, the tendon ischemia, the gapping at the tendon repair site and the postoperative immobilization [15]. With the double loop six strand technique we perform atraumatic tissue handling and strong repair with minimal gapping. This with the addition of early active motion therapy protocol leads to positive results with minimal adhesion formation.

Less common postoperative problems include finger stiffness and deformities. Quadriga syndrome can develop especially if the injury involves the ulnar digits. Another problem is swan-neck deformity. Also lumbrical plus deformity can develop as well. With meticulous surgical technique and early postoperative tendon mobilization in a well-supervised therapy program we can minimize the frequency and severity of these complications [17].

Our most common complication was joint contracture. Contractures of PIPJ and DIPJ are reported in the literature in up to 17 % [15]. The most common cause is postoperative protective splinting. We have to agree with this since 19.6 % of our cases developed PIPJ contractures that improved to insignificant deformity with serial 3-stage finger cast application.

The classic Kleinert therapy protocol was replaced with an early active controlled motion protocol as described previously. Rubber bands traction was not used. We believe that the addition of a volar component to the splint from the forearm up to level of the distal palmar crease keeps the wrist more stable and facilitates better finger ROM control during therapy.

Conclusions

The use of a strong, gap-resistant suture technique like the six strand double loop technique used in the present study followed by the application of early postoperative controlled motion

rehabilitation results in 81 % excellent and good postoperative range of motion.

Disclaimer Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article. This research project was approved by the Institutional Review Board Committee of University of Louisville.

References

1. Kleinert HE, Kutz JE, Atasoy E, Stormo A (1973) Primary repair of flexor tendons. *Orthop Clin North Am* 4(4):865–76
2. Strickland JW (2005) The scientific basis for advances in flexor tendon surgery. *J Hand Ther* 18(2):94–110
3. Gill RS, Lim BH, Shatford RA, Toth E, Voor MJ, Tsai TM (1999) A comparative analysis of the six-strand double-loop flexor tendon repair and three other techniques: a human cadaveric study. *J Hand Surg [Am]* 24(6):1315–22
4. Viinikainen A, Göransson H, Huovinen K, Kellomäki M, Törmälä P, Rokkanen P (2007) The strength of the 6-strand modified Kessler repair performed with triple-stranded or triple-stranded bound suture in a porcine extensor tendon model: an ex vivo study. *J Hand Surg [Am]* 32(4):510
5. Lim BH, Tsai TM (1996) The six-strand technique for flexor tendon repair. *Atlas Hand Clin* 1:65–76
6. Hoffman GL, Buchler U, Vogelin E (2008) Clinical results of flexor tendon repair in zone 2 using a six-strand double loop technique compared with a two-strand technique. *J Hand Surg Eur* 33(4):418–22
7. Tang JB (2005) Clinical outcomes associated with flexor tendon repair. *Hand Clin* 21:199–2
8. Strickland JW (1985) Flexor tendon repair. *Hand Clin* 1:55–68
9. Strickland JW, Glogovac SV (1980) Digital function following flexor tendon repair in zone II: a comparison of immobilization and controlled passive motion techniques. *J Hand Surg* 5:537–43
10. Tsuge K, Ikuta Y, Matsuishi Y (1975) Intra-tendinous tendon suture in the hand: a new technique. *Hand* 7(250):255
11. Jansen CWS, Watson MG (1993) Measurement of range of motion of the finger after flexor tendon repair in zone II of the hand. *J Hand Surg* 18A:411–7
12. Elliot D, Mioemen NS, Flemming AFS, Harris SB, Foster AJ (1994) The rupture rate of acute flexor tendon repairs mobilized by the controlled active motion regimen. *J Hand Surg* 19B:607–612
13. Libberecht K, Lafaire C, Van Hee R (2006) Evaluation and functional assessment of flexor tendon repair in the hand. *Acta Chir Belg* 106(5):560–5
14. Dy CJ, Hernandez-Soria A, Ma Y, Roberts TR, Daluiski A (2012) Complications after flexor tendon repair: a systematic review and meta-analysis. *J Hand Surg [Am]* 37(3):543–551
15. Momeni A, Grauel E, Chang J (2010) Complications after flexor tendon injuries. *Hand Clin* 26(2):179–89
16. Osada D, Fujita S, Tamai K, Yamaguchi T, Iwamoto A, Saotome K (2006) *J Hand Surg Am* 31(6):987–992
17. Lilly SI, Messer TM (2006) Complications after treatment of flexor tendon injuries. *J Am Acad Orthop Surg* 14(7):387–96