Original Article

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Wide-Awake Flexor Tendon Repair Under Tumescent Injection

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ABSTRACT

Background. Flexor tendon injuries are frequent, due to variable hand activities, and the repair is challenging to hand surgeons, especially in zone II, because of the coexistence of two tendons within a tight fibro-osseous tunnel. Flexor tendon repair under tumescent infiltration provides anesthesia and a bloodless field, so that no tourniquet or sedation is needed.

Aim of study. The goal of this study was to identify a surgical adjustment and intraoperative total active movement examination of the repaired tendon so that no gapping is formed, and smooth gliding is obtained, avoiding tendon rupture and producing an optimal range of motion.

Patients and method. From January 2016 to April 2017, 9 patients (17 tendons), with a mean age of 31.8 years, presented within 3 to 14 days of injury to zone I or zone II of their flexor tendons. Tendon repair was done under tumescent infiltration (lidocaine 1% with adrenaline 1:200,000) only, with no tourniquet or sedation, and with an intraoperative total active movement examination.

Result. After 6 months of follow up, all the patients had excellent range of motion according to the Boyes outcome scale, and none showed signs of postoperative tendon rupture.

Conclusion. Tumescent infiltration for flexor tendon repair allows intraoperative surgical adjustment and total active movement examination, which will minimize postoperative rupture and adhesion. This procedure will also facilitate the surgeon's work by eliminating the need for general anesthesia or sedation; however, this procedure is not applicable for children, major trauma, or those who are mentally challenged.

INTRODUCTION

One of the difficult problems in hand surgery is flexor tendon repair, especially in zone I and II. Flexor tendon injuries are a common problem in industrialized countries and are estimated to be 1:7000, with a predominant age of 15–30 years. (1)

In order to achieve a bloodless field, the tumescent technique has been adopted, using a diluted local anesthetic mixed with adrenaline and normal saline. (2) The use of adrenaline with a local anesthetic has the benefit of producing a hemostatic effect and prolonging the effectiveness of the local anesthesia. The vasoconstrictive effect of adrenaline is mediated by activation of the phosphatidylinositol system and the adenylate cyclase pathway. (3)

One of the pioneers in the use of wide-awake hand surgery was John Fielding, the first surgeon to adopt the use of the tumescent technique in hand surgery. [(4)] In the present study, tumescent infiltration (i.e., wide-awake flexor repair) was chosen for repairing flexor tendon injuries in zone I and zone II by using a local injection of lidocaine and epinephrine without any sedation or tourniquet application.

PATIENTS AND METHODS

Between January 2016 and April 2017, at Al- Shaheed Ghazi Al- Hariri hospital and Al-Wasity teaching hospital, 9 patients (17 flexor tendons), with a mean age 31.8 years, presented to us within 3 to 14 days of experiencing flexor tendon injuries in zone I and zone II, caused by sharp objects. These patients were subjected to tumescent infiltration, using local anesthesia with adrenaline only and without any tourniquet or sedation. Follow up was conducted with all patients within 6 months after the surgery.

Patients' data are shown in Table 1.

Table 1. Patients' data

Pt. #	Sex	Age (years)	Injured hand	Digits involved	Time of presentation after injury (days)	Zone of injury (I, II)	Injured tendon (FDS, FDP, FPL)
1	F	27	Right	Small, ring, middle	3	II	FDS, FDP FDS, FDP FDS, FDP
2	M	35	Left	Middle	11	II	FDS, FDP
3	M	25	Left	Middle	14	I	FDP
4	M	24	Right	Small	7	II	FDS, FDP
5	M	60	Right	Ring	5	II	FDP
6	M	29	Right	Small	4	II	FDP
7	M	23	Left	Thumb	12	II	FPL
8	M	28	Right	Small	7	II	FDP
9	M	36	Right	Small	3	II	FDS, FDP

Exclusion criteria precluded the following from participation in the study:

- Patients who were uncooperative;
- Patients with associated injuries other than injuries to the digital nerve;
- Anyone who was younger than 15 years of age;
- Those whose injuries were outside of zone I and zone II;
- Anyone who presented to us more than 14 days after injury;
- Patients with mental problems;
- Patients with cardiovascular disease and uncontrolled hypertension;
- Anyone with a previously replanted digit; and
- Anyone with peripheral vascular disease (Raynaud disease).

A routine preoperative clinical examination was carried out, with a preoperative investigation that included hemoglobin levels and biochemical and virology profiles. An X-ray was taken to exclude any associated fracture or dislocation, or the presence of any foreign bodies. Preoperative consent was obtained from all patients, at which time our team discussed with them the surgical method and our expectations. Documentation was done by way of photos and videos, taken intraoperatively as well as during the follow-up period.

SURGICAL TECHNIQUE

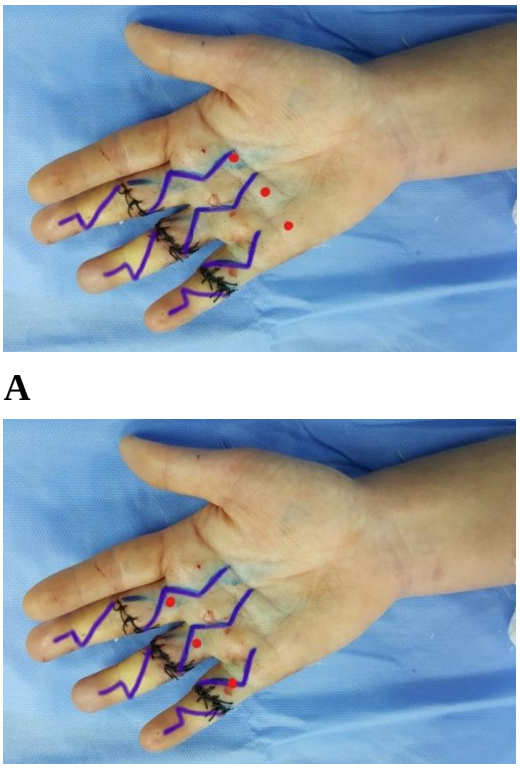
All operations were done under local anesthesia with adrenaline, without the use of sedation or tourniquet. The

patients remained awake during the operation. After sterilization of the patient, we used a 50 ml vial of 1% xylocaine mixed with 0.25 mg adrenaline, resulting in a 1:200,000 dilution of adrenaline. We kept the total dose of xylocaine infiltration to less than 7mg/kg.

All the operations were done in the major operating room, and pulse oximetry was used for monitoring pulse rate and oxygen saturation.

The injection started proximally, using a 27-gauge needle. The site of the first injection was approximately 5–10 mm proximal to the nearest area of dissection in zone II (i.e., the distal palmar crease). We introduced the needle vertically and slowly injected 5–6 ml of local anesthesia with adrenaline into the subcutaneous tissue. We began by first injecting 1 ml of the anesthesia-adrenaline mixture; then, when the patient indicated that the sting had dissipated (approximately 30 seconds), we completed the injection for the rest of the infiltration over the course of 1 minute.

The second injection was done 10–15 minutes after the first injection. At that time, the whole distal area was numb. The site of the second injection was between the digital nerves at the Palmo-digital crease, and the amount of the injection was 1–2 ml (see figure 4).



A

B

Figure 4. Tumescent infiltrations in a zone II flexor tendon laceration for a 27-year-old female. **(A)** The first injection was just proximal to the nearest area of dissection. **(B)** The second injection was at the Palmo-digital crease. The red spots refer to injection sites.

The third and the fourth injections were done immediately after the second injection, at the digital crease of the proximal and distal interphalangeal joints, respectively. The amount of each injection was also 1–2 ml. The level of the 2nd, 3rd, and 4th injections was the same as that of the first injection (i.e., into the subcutaneous tissue, noticing the blanching and firmness of the skin and subcutaneous tissue during the injection. See figure 5).

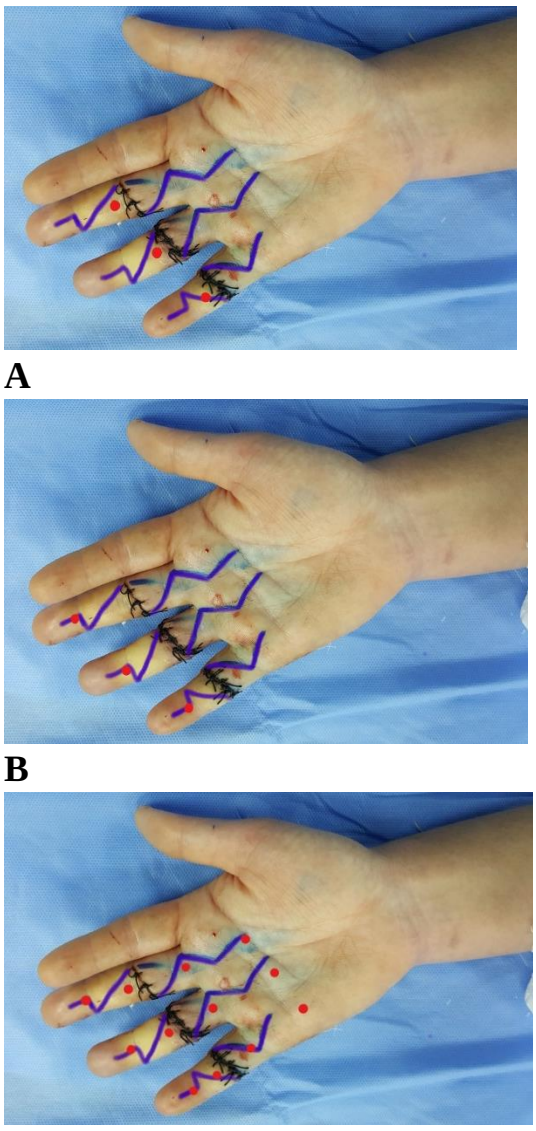


Figure 5. **(A)** and **(B)** injection at the digital crease of proximal and distal interphalangeal joints respectively. **(C)** The whole site of tumescent infiltration.

For the thumb, the first injection of 5 ml in zone 5 was introduced into the soft tissues and subfascial plane. We then proceeded distally to the subcutaneous tissue of zone IV and injected 5 ml. Then 5 ml was injected into the thenar area (zone III). After 15 minutes, the second injection of 1–2 ml was made in the subcutaneous tissue of the proximal phalanx and the interphalangeal joint (see figure 6).

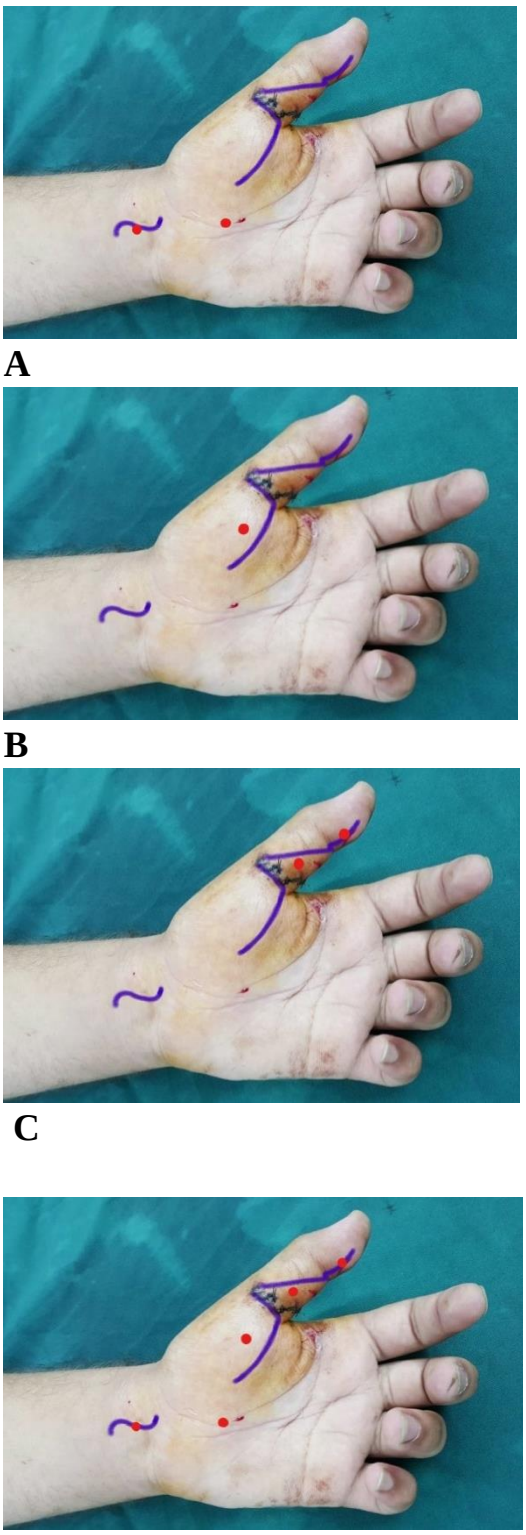


Figure 6. Tumescent infiltrations for a zone-II FPL laceration in a 23-year-old male. **(A)** Zone V and zone IV tumescent infiltration. **(B)** Thenar-area subcutaneous tissue infiltration. **(C)** Subcutaneous tissue injection into the proximal phalanx and interphalangeal joint. **(D)** The whole site of infiltration.

The surgical procedure began 15 minutes after the last injection (or 30 minutes after the first injection), and the anesthesia was confirmed by doing needle pricking along the planned dissection, ensuring that the patient was experiencing no pain.

The patient's hand was then sterilized again and draped. The surgery began with a zigzag Bruner incision along the digit, which was extended from the distal phalanx to just proximal to the palmar crease. This incision is used for zone-I and zone-II injuries (see figure 7).

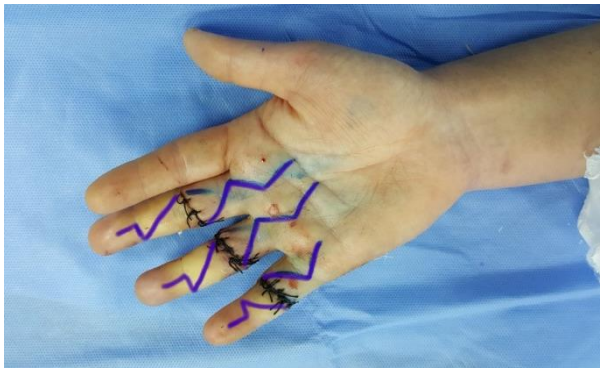


Figure 7. Bruner incision for a zone-II flexor injury.

Using a no. 15 scalpel, the incision was begun along the previously marked Bruner incision lines, with the wound gradually deepened until the flexor sheath was exposed. Then the flexor sheath was opened through a small midline incision of about 1.5–2 cm. When the proximal tendon was retracted in zone II, we did a flexion of the wrist joint to help us to retrieve the proximal end of the tendon, sometimes milking the forearm or even asking the patient to actively extend the digits to retrieve the proximal stump of the injured flexor tendon in zone II. Then the tendon was pulled out distally and fixed temporarily with a 27-gauge needle (see figure 8).

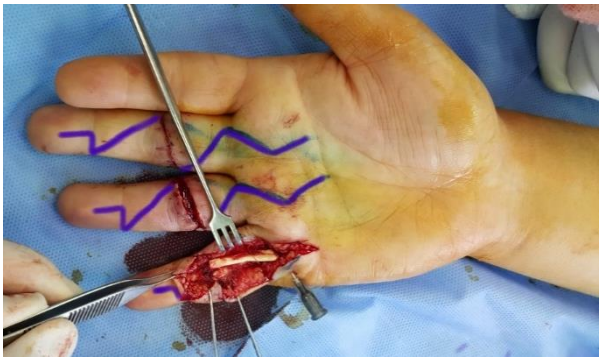


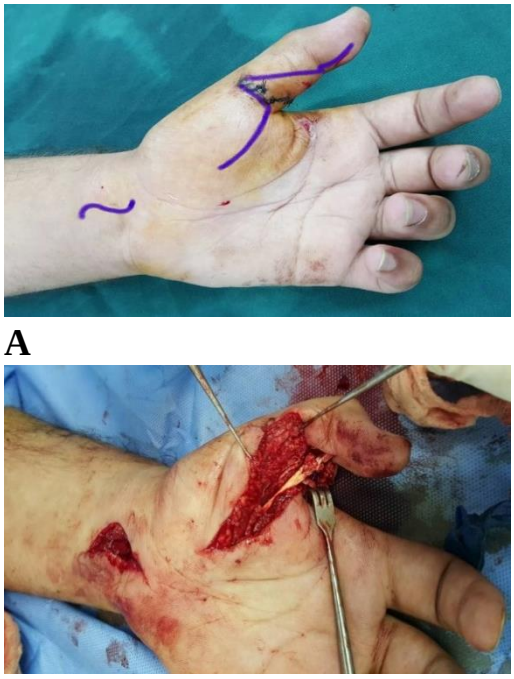
Figure 8. Retrieval of the proximal end of the FDP tendon of the small finger, and temporary fixation with a 27-gauge needle.

Regarding zone I, we did not encounter proximal retraction of the FDP tendon, since it was entrapped in an A4 pulley. The distal stump of the tendon was found easily since we used a Bruner incision that extended to the distal phalanx.

For the zone-I injury, after refreshing both ends of the tendon, primary Tenorrhaphy was done, with no need for FDP advancement or primary repair to the bone, since the available distal stump of the FDP was more than 1 cm in all cases.

Regarding the zone-II injury, both proximal and distal tendon ends of the FDS and FDP were sutured independently. Tenorrhaphy was done by using a 4/0 Prolene modified Kesseler (2-strand core) suture. The modified Kesseler technique is a quadrilateral suture with small grasping bites at each corner.

In the thumb (zone-II) laceration, we did a zigzag incision of the skin, extending to the thenar area, by curvilinear incision. The proximal stump was not found, so with a small S-shape incision, proximal to the transverse carpal ligament, the tendon's proximal stump was found and was retrieved by mosquito clamp under the thenar muscle and fixed temporarily by a 27-gauge needle to the nearby soft tissue. Tenorrhaphy was done by a double-modified Kesseler (4-strand core) suture, using a 3/0 prolene (see figure 9).

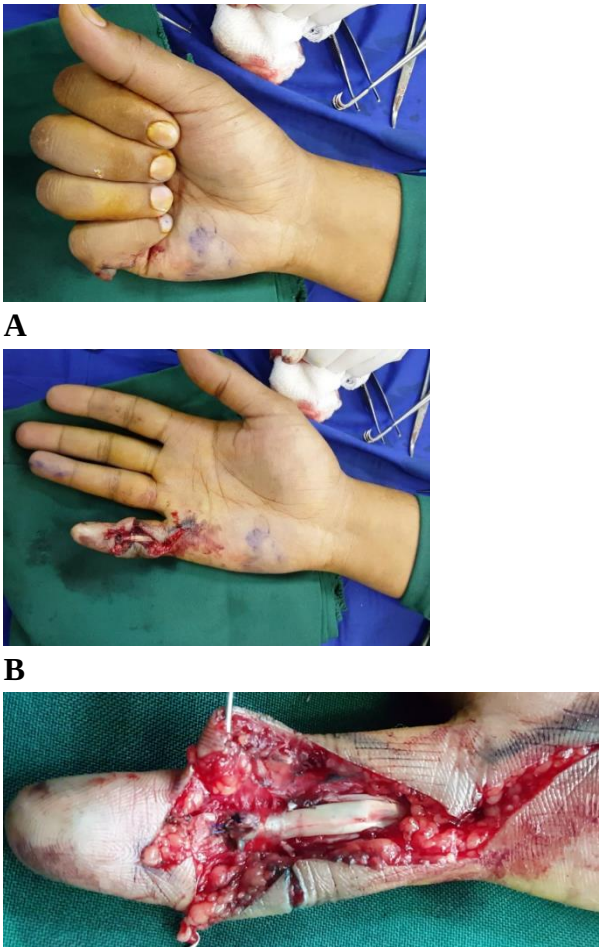


A

B

***Figure 9*. (A)** Incisions for approach in the FPL injury. **(B)** FPL tendon repair.

We asked the patient to actively flex and extend the repaired finger, and then we observed our repair to see if there was any gapping, which would indicate that our suture was not tight enough. In such a case, we corrected the gap by another core suture with adequate tightness, along with the removal of the first suture in order to avoid postoperative tendon rupture (see figure 9).



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C

***Figure 10*. (A, B)** Active flexion and extension of the repaired finger. **(C)** The *yellow arrow* points to the gap caused by the loose core suture of the repaired tendon.

Afterward, in order to increase strength and smoothing of the repaired site, and to avoid bunching of the repaired tendon, a circumferential epitendenous suture was employed, using a 5/0 prolene suture.

After the complete tendon repair, the patient was again asked to actively flex and extend the digits, while we observed

whether there was an interruption of the tendon gliding by pulleys. When interruption was observed, we did a release (vent) of 2/3 of the A2 or A4 pulley accordingly and asked the patient to actively flex and extend his digits again, ensuring smooth gliding without interruption.

Any bleeding point, if it existed, was stopped by using bipolar electro cautery, and then the skin was sutured by using a 3/0 prolene simple interrupted suture.

The duration of the surgery for a single flexor tendon repair was 20 minutes; for multiple flexor tendons the repair was 2 hours, and for the thumb, the repair took 45 minutes.

The dressing was done by using antibiotic-impregnated gauze as a first layer and then dry gauze as the second layer. The dressing was secured by using a crepe bandage.

POSTOPERATIVE CARE

Back-slab was used from the tips of the fingers to below the elbow, with wrist flexion of 20–30º, flexion of the MCP joint at 50º–70º, and the interphalangeal joints in extension.

In the case of FPL repair, a dorsal blocking splint was used with the wrist at 20º palmer flexion, the thumb at 15º MPJ flexion, the interphalangeal joint at 30º flexion, and the thumb carpometacarpal joint in palmar abduction.

Patients were instructed on hand elevation and were kept on injectable 3rd-generation cephalosporin for three days postoperatively, after which they were kept on oral antibiotics until the time that stitches were removed (by 12–14 days).

Patients were discharged on the same day as the surgical procedure; there was no need for hospitalization.

Postoperative rehabilitation protocol

- On day 3 after surgery, passive flexion and active extension began in the splint, with 5 sessions/day, 10 repetitions.
- On day 21 after surgery, active flexion of the digits began, and started with one-third of the total range of motion, continuing with protective splinting for another 2 weeks.
- At 4 weeks after surgery, the partial range of active motion was progressively increased to two-thirds.
- Active motion included 5 sessions/day, 20 repetitions.
- At the sixth week, the splint was removed, and full active finger flexion was encouraged.
- At 8 weeks, light strengthening was begun.
- At 12 weeks, normal activities were resumed.

The patients were kept on a regular follow-up schedule of monthly visits for up to 6 months.

RESULTS

Nine patients with 17 flexor tendon injuries in zone I and zone II were surgically treated using tumescent infiltration for flexor tendon repair without using general anesthesia or tourniquet. At the end of the follow-up period (6 months) our results were excellent according to the Boyes outcome scale, regarding the range of movement, (figures 10, 11, and 2). No patients experienced tendon rupture.

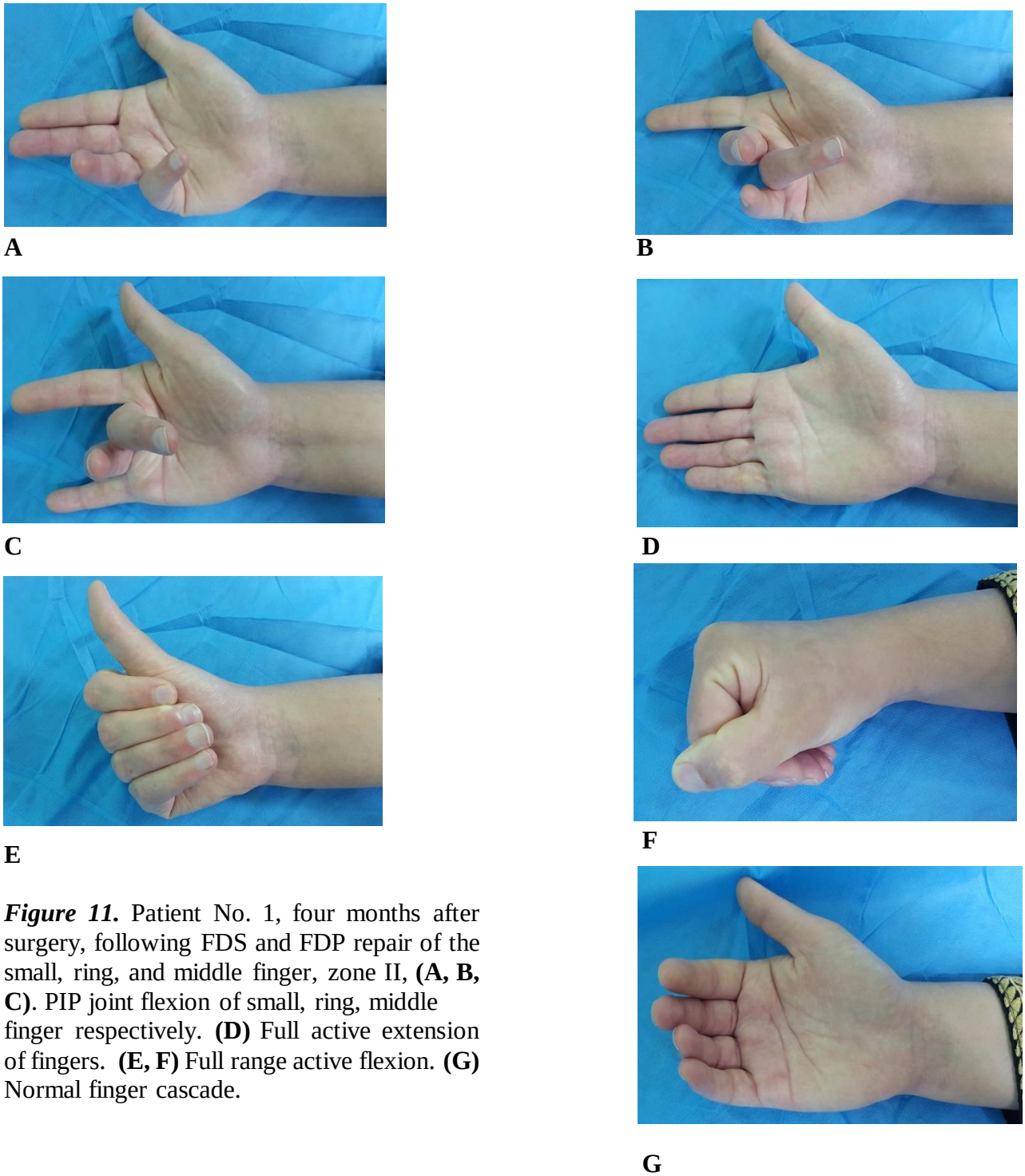


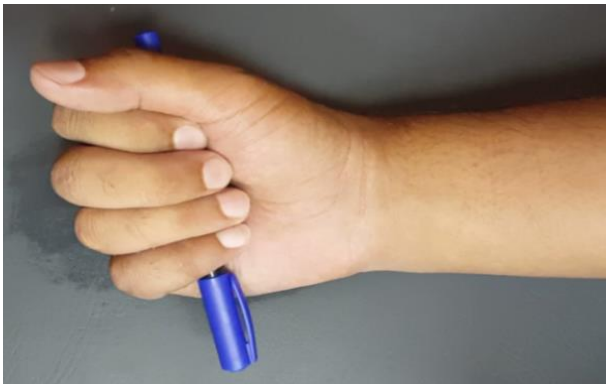
Figure 11. Patient No. 1, four months after surgery, following FDS and FDP repair of the small, ring, and middle finger, zone II, **(A, B, C)**. PIP joint flexion of small, ring, middle finger respectively. **(D)** Full active extension of fingers. **(E, F)** Full range active flexion. **(G)** Normal finger cascade.

A

B

BB

Figure 12. Patient No. 6, eight weeks after surgery, following FDP repair of the small finger, zone II. **(A)** Full range active extension. **(B, C)** Full range active flexion.



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A

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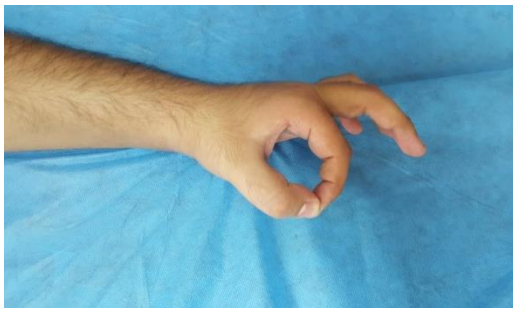

E

F

G

Figure 13. Patient No. 7, three months following flexor pollicis longus repair of the left hand, zone II. **(A)** Active extension of thumb and digits. **(B, C, D, E)** Range of active flexion of FPL. **(F, G)** FPL flexion of both hands.

One of our patients (No. 8, zone II small finger) had not achieved a full range of motion, and full extension of his involved digits was still restricted two months after surgery. This patient was not compliant to physiotherapy, and he was diagnosed to have tendon adhesion. He was scheduled for a further course of hand physiotherapy, which involved active tendon-gliding exercises, done by performing a sequence of three fists: hook fist, straight fist, and composite fist. There was an improvement in the range of movement.

Another patient (No. 5) had developed flexion lag six weeks after surgery, with some restriction of the full range of motion for the involved digit (FDP repair of the ring finger in zone II). This patient had an A4 pulley collapse and poor postoperative compliance with the hand therapist. He was kept on physiotherapy, and the range of movement improved within two months.

Complications

None of our patients developed joint contracture. No major postoperative complications occurred, such as flap necrosis, wound infection, or wound dehiscence. The resultant scar was aesthetically acceptable; no hypertrophic or keloid scar was observed in any of our patients. Intraoperatively, no lidocaine systemic toxicity (such as convulsion or cardiac arrhythmias) was observed. Similarly, with regard to adrenaline, there were neither systemic side effects (such as hypertension or tachycardia) nor local side effects (such as vasospasm or tissue necrosis).

DISCUSSION

Even though flexor tendon repair is one of the earliest training skills in plastic and orthopedic surgery, the topic of flexor tendon injuries remains one of the most published subjects in hand surgery, and the outcomes continue to evade our expectations. New modalities of flexor tendon repair and hand therapy regimen are regularly reported. [5]

The main goal of flexor tendon repair is to achieve a normal range of finger motion, which will be gained through accurate coaptation of the lacerated tendon ends in a way that restores tendon gliding after a postoperative rehabilitation regime that enhances the

tendon healing process and decreases peritendinous adhesions. [6]

Previously, it had been standard practice for flexor tendon surgery to be done under regional or general anesthesia, due to the need for a tourniquet. Nowadays, however, tendon repair can be performed under local anesthesia, without the need for a tourniquet, by injection of adrenaline mixed with lidocaine, to achieve a bloodless field for surgery. [7] Patients are kept awake during the procedure and they are instructed to flex and extend their fingers to ensure that no gap exists between the stumps of the repaired tendon, to examine for the strength of the repair, and to ensure that there is no rupture or adhesion and that good tendon gliding is obtained.

In a retrospective chart review study for flexor tendon repair conducted by Amanda Higgins et al., the wide-awake technique was carried out with 68 patients (122 flexor tendons repairs) in two Canadian cities, by two surgeons, between 1998 and 2008. In this study, intraoperative gap formation was detected with active movement testing in seven patients. The repair was redone, resulting in the elimination of the gap after active movement testing. None of these patients experienced a postoperative rupture. In the same study, the overall rupture rate was 3.3% (i.e., 3 patients, 4 tendons), due to accidental forced movements. [8]

In our study, 9 patients (17 injured flexor tendons in zone I and zone II), were surgically repaired by using tumescent infiltration. After six months of follow-up, all patients had achieved nearly normal range of motion, without any adhesion or tendon rupture.

During surgery, we observed 2 patients (3 tendons) that had gap formations with active flexion and active extension movement of their digits. We repeated the repair with slightly more tension, again asking the patients for active flexion and active extension of their digits to confirm that there was no gapping. There were no tendon ruptures during the follow-up period.

The rupture rate of flexor tendon repairs under general or regional anesthesia has been reported in several published articles by Tang (4–10 % of repaired fingers, and 3–17 % in flexor pollicis longus of thumbs);[9] Peck et al. (4–17 %);[10] and Boyer et al. (9%).[11]

In addition to the obvious clinical advantages of terminating the need for general anesthesia and its potential complications, this method also decreases the cost of treatment, which adds additional advantages for the wide-awake technique beyond avoiding the possibility of postoperative tendon rupture and adhesions. [12]

The myth that epinephrine is contraindicated in the finger has clearly become past history. [13] In 2005, Lalonde et al. demonstrated their use of

epinephrine in hand and finger surgery in a multicenter study that involved 3,110 cases, with no complications related to ischemia and infarction secondary to epinephrine use.

Lalande et al. described their findings with the use of epinephrine in hand and finger surgery (with the majority in the hand). Tissue ischemia and sloughing have been described with a concentration of epinephrine of 1:20,000. Current recommendations support a concentration in the range of 1:100,000 to 1:800,000, with a maximum dose not exceeding 1mg. [(3)]

The use of adrenaline in hand surgery for hemostasis has eliminated the need for a tourniquet, [(14)] and this is regarded as a unique advantage since possible complications of tourniquet use in limb surgery are thereby avoided.

A tourniquet can damage any tissue of a limb; the most common problem is damage to the nerve. Middleton and Varian investigated the number of neurological complications after the use of a tourniquet, and the incidence of peripheral nerve lesions was 1:5,000 for the arm and 1:13,000 for the leg. [(15)]

By contrast, wide-awake flexor tendon repair allows intraoperative testing of the integrity of tendon repair. By instructing the patient to move his fingers through full flexion and extension, the surgeon can ensure that there is no gapping. This, in turn, encourages the surgeon to begin the postoperative active movement protocol. [(8)] In our study, however, we used a passive-active protocol early on, due to our use of 2-strand core sutures. In the future, we may use 4-strand core sutures and begin an active flexion protocol early.

CONCLUSION AND RECOMMENDATIONS

The wide-awake approach for flexor tendon repair enables the surgeon to undertake the operation without sedation or tourniquet. This simplifies the operation, eliminates the need for general anesthesia, and reduces the time and the cost involved. In addition, it allows intraoperative monitoring of the tendon repair site and tendon gliding, thus minimizing the possibility of postoperative tendon rupture and adhesion. However, this procedure is not applicable to children, persons who have experienced major trauma, or those who are mentally challenged.

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