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Endoscopic retrieval of retracted flexor tendons: An atraumatic technique☆

Arda Kucukguven*, Hakan Uzun, Fethiye D. Menku, Gokhan Sert, Ali E. Aksu

Faculty of Medicine, Department of Plastic, Reconstructive and Aesthetic Surgery, Hacettepe University, Sihhiye, 06080 Ankara, Turkey

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Abstract *Background:* The repair of retracted flexor tendons is a challenging problem for hand surgeons. The tendon stump should be handled in an atraumatic manner because any microtrauma to the sheath and tendon can lead to poor functional outcomes.
Methods: Twenty-three patients with flexor zone 2 injuries and intraoperative finding of retracted tendons were randomly divided into two groups: endoscopic retrieval group and proximal incision group. A flexible endoscope and a flexible grasping forceps were used for endoscopic retrieval of the retracted flexor tendons. The groups were compared in terms of infection rate, neurovascular complications, regional pain, total range of active motion (TAM) and functional outcomes.
Results: Age, gender, average preoperative pain and general pain perception scores were similar between the two groups. We found a significantly shorter duration of operation and better pain scores at 1-2 weeks in the endoscopic group than in the other group ($p = 0.002$ and $p = 0.020$, respectively). A significant difference in TAM was demonstrated between the groups at 3 to 5 weeks ($p = 0.003$).
Conclusion: The surgical procedure presented here has the advantages of direct visibility of the proximal tendon end and retrieval in an atraumatic manner, with better results and decreased morbidity. It is a promising approach and can be used as a routine procedure in retracted tendon cases.

Background

Flexor tendon injuries are frequently encountered events, as the tendons lie just beneath the skin and can be affected by lacerations and crush injuries. The repair of flexor tendons is a challenging problem for hand surgeons and requires a carefully planned management for effective results. One

☆ Our study has not been presented previously in any congress or symposium.

* Corresponding author.
E-mail address: ardakucukguven@gmail.com (A. Kucukguven).

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of the major technical aspects of flexor tendon repair is the retraction of the proximal segment towards the palm. If the vincula are damaged, tendons retract with muscle contraction, and retrieval of these ends can be demanding.[1] The tendon stump should be handled in an atraumatic manner because any microtrauma to the sheath and tendon can lead to poor functional outcomes and induce scarring and adhesions.[2,3]

Various retrieval techniques have been described in the literature for the delivery of the proximal end to the tenorrhaphy site.[4-14] When standard manoeuvres fail, the retracted tendon is externalised through a proximal palmar incision to place sutures between the tendon stump and a catheter, which is inserted in a retrograde manner through the tendon sheath. The primary objective of all these techniques is making the whole procedure as atraumatic as possible to minimise complications related to surgery and to achieve better functional outcomes.

Li et al. described the use of a flexible ureteroscope in retracted flexor tendon retrieval in three cadaveric hands and in three patients with flexor pollicis longus (FPL) injuries.[15] Hill et al. also used the endoscopic approach in four cadaveric hands. These studies were limited to tendon injury simulations on cadaveric hands and a very small number of cases (3 FPL injuries).[16] Moreover, they lacked a comprehensive assessment of the functional outcomes and a follow-up period. Except for these two studies, we have not been able to find other reports of the clinical use of this technique in the literature. In this study, we would like to present this atraumatic technique as a routine procedure in retracted tendon retrieval and highlight its reliability and advantages over the existing procedures.

Patients and methods

Twenty-three patients with flexor zone 2 injuries and intraoperative finding of retracted flexor digitorum profundus (FDP) or FPL tendons were treated between June 1, 2016, and January 1, 2018. Patients with complex hand injuries (e.g. neurovascular injury, phalanx fracture, skin or soft tissue defect, multiple finger trauma and partial or multilevel tendon lacerations) were not included in our study. Additionally, patients under 18 years of age were also excluded from the study owing to the relatively small size of their tendon sheaths. All patients provided written informed consent for the procedures performed and their data to be used for research purposes. All repairs were performed under local anaesthesia by the same surgeon (A.K.), and the injury sites were explored and extended with Brunner incisions. The proximal flexor tendon segments, which cannot be brought to the injury site by standard mosquito forceps manoeuvre, were considered as retracted tendons. The diagnosis was established according to operative findings. These patients were randomly divided into two groups: endoscopic retrieval group (Group 1, $n = 11$) and proximal incision group (Group 2, $n = 11$). If any endoscopic approach failed to retrieve the retracted tendons, then a proximal incision was made and the tendons were brought to the injury site by standard manoeuvres.[12]

A 2.5 mm (7 French) diameter and 67 cm long flexible FLEX-X[2] Uretero-Renoscope (Model No.: 11278 A; Karl Storz, Tuttlingen, Germany) with a 1.2 mm instrumentation channel and a 1 mm (3 French) diameter flexible grasping forceps (Model No.: 11275 ZE; Karl Storz, Tuttlingen, Germany) (Figure 1) with double action jaws were used for endoscopic retrieval of the retracted flexor tendons (Figure 2, Supplementary Video 1). The endoscope was connected to a standard fibre optic light source and a video camera. Saline irrigation of any blood in the tendon sheath through the instrumentation channel, using a Y connector, enhanced the visualisation of the proximal tendon end.

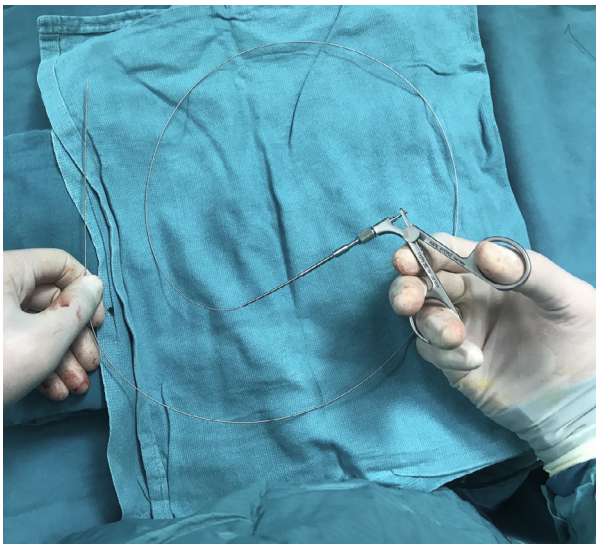
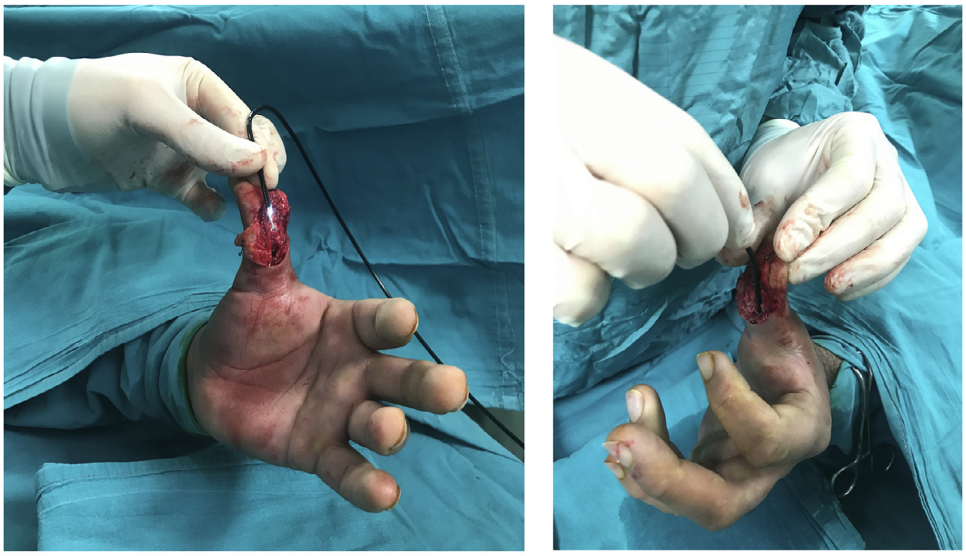


Figure 1 A 1 mm diameter flexible grasping forceps.

Tendon repairs were performed using a double-modified Kessler core suture technique with 3-0 braided polyester coated with polybutilate (Ethibond; Ethicon, Somerville, NJ). Circumferential epitendinous sutures with 6-0 polypropylene (Prolene; Ethicon Somerville, NJ) were also used for additional strength and to make the repair tidier. If both the flexor digitorum superficialis (FDS) and FDP tendons were injured, then those repairs were performed to avoid increasing the bulkiness of the tendon for unrestricted gliding through the sheath.[17] The FDS was excised in cases with restricted gliding after tendon repair for better functional outcomes. In selected cases, an A2 pulley (non-thumb digits) or an oblique pulley (thumb) was partially released to facilitate tendon repair.[18] After surgical repair, patients were referred for early physical therapy and rehabilitation described by Tang.[19] In our rehabilitation programme, the hand is protected in a dorsal thermoplastic splint after the operation. Both passive and active exercises start at 3-5 days after repair. The splint is removed after 5 weeks, and patients can return to normal use of their finger from 8 weeks.

The two groups were compared in terms of need for tenolysis, infection rate, neurovascular complications, regional pain after tendon surgery (pain at rest, while moving and while placing the hand on a surface) and the TAM[20] using the sum of the active ranges of the proximal interphalangeal (PIP), distal interphalangeal (DIP) and metacarpophalangeal (MCP) joints of the non-thumb fingers or the TAM of the interphalangeal joint (IF) and the MCP joint of the thumb at



(a) (b)

Figure 2 Retrieval of a retracted flexor tendon with a flexible endoscope.

postoperative 3–5 weeks and then for more than 8 weeks (mean, 11 weeks; range, 9–18 weeks). The functional outcomes were graded with the Strickland-Glogovac criteria for non-thumb digits and the thumb assessments were graded according to the Buck-Gramcko scoring system at the final follow-up.[21,22] The visual analogue scale (VAS; 0 = no pain, 10 = maximum pain) was used to measure the severity of the pain before surgery and then at post-operative day 1, 1–2 weeks, 3–5 weeks and more than 8 weeks (mean, 11 weeks; range, 9–18 weeks). The patients were asked to rate their surgical site pain after surgery with reference to pain at rest, while moving and while placing the hand on a surface. The general perceptions of the pain from common experiences were also assessed by general pain questions (pain from sprained ankle/wrist) to determine any potential differences in pain tolerance.[23] Such standardisation for pain perception is necessary and suggested in other studies using VAS scoring.[24] Furthermore, the intraoperative duration of tendon repair, the timing of the surgery and patients' demographics such as gender and age were recorded.

Statistical analysis

The numerical variables were tested for normality using the Shapiro–Wilk test. The Mann–Whitney U test was used to analyse the VAS scores, which were not normally distributed, whereas the independent samples Student's *t*-test was used to evaluate the duration of surgeries and the age of the patients, which were normally distributed. The VAS scores of patients and the duration of surgeries were compared between the two groups. Gender was evaluated between the groups using the chi-square test with continuity correction. Categorical variables such as the patients' functional outcomes, according to Strickland-Glogovac and Buck-Gramcko scoring systems, were compared between the groups using the Fisher exact test. One-way ANOVA was used to compare the TAM results between the groups, considering the thumb and non-thumb subgroups. Quantitative data were presented in tables as mean and standard deviation (SD). Statistical significance was considered at *p*-values less than 0.05.

Results

There were no significant differences regarding age, sex, preoperative pain score and pain perceptions from experiences (sprained ankle/wrist) between Groups 1 and 2 (Table 1). Thus, no corrective factor was used in analysing the post-operative regional pain scores based on those pain perception scores. The mean time from injury to surgery was 2.8 days (range 0–16 days). No ruptures occurred in the repaired tendons. Because of the poor functional outcomes and low TAM degrees, tenolysis was performed in two patients, one in Group 1 and the other in Group 2. Tenolyses were performed at least 6 months after primary surgery. After tenolyses, these two patients achieved excellent and good outcomes according to Strickland-Glogovac scale. In this study, the results presented for these two patients are those before tenolysis. The last assessments of the TAM degrees, VAS scores and the functional outcomes according to the Strickland–Glogovac and Buck–Gramcko scoring systems of the patients were performed at more than 8 weeks post-operation (mean, 11 weeks; range, 9–18 weeks). Except for the two patients who required tenolysis, all patients could return to normal use of their finger from 8 weeks (range 9–18 weeks). After that period, the routine physical examination of the hand was performed during the follow-up period (mean, 6 months; range, 4–12 months). Four out of 23 patients had minor infections, which were resolved with antibiotics without any need for hospitalisation, two of whom were in Group 1 and the other two in Group 2. Furthermore, no iatrogenic neurovascular damage was seen in any patient. In Group 1, five FDS tendons were damaged, one partially and four completely. In Group 2, four FDS tendons

Table 1 Preoperative data on the two groups of patients.

	Group 1 ($n=11$)	Group 2 ($n=11$)	p
Age (SD)	34.2 (14.4)	36.1 (16.4)	0.774
Male:female	7:4	5:6	0.669
Average preoperative pain (SD)	2.4 (1.6)	2.3 (1.3)	0.891
Average pain: sprained ankle-wrist (SD)	5.5 (0.5)	5.4 (0.8)	0.971

SD: Standard deviation.

Table 2 Average duration of surgeries and post-operative TAM degrees.

	Group 1 (SD)	Group 2 (SD)	p
TAM degrees			
3-5 weeks	57.7° (16.6)	37.3° (12.5)	**0.003**
>8 weeks	161.8° (70.4)	158.1° (69.0)	0.703
Average duration of surgery (minutes)	58.2 (10.1)	73.6 (10.7)	**0.002**

Statistically significant values are indicated in bold.
TAM: Total range of active motion.
SD: Standard deviation.

were damaged, one partially and three completely. All FDS injuries were repaired; however, a FDS tendon of a little finger was excised due to the restricted gliding after tendon repair in Group 2.

Eleven patients with retracted tendons were treated with the endoscopic approach in Group 1 and 11 patients were treated with the conventional proximal incision approach in Group 2. However, in one patient with a thumb injury (who was not included in any group), the endoscopic approach failed, and retrieval of the retracted tendon was achieved by the proximal incision approach. There were six thumbs (three in Group 1 and two in Group 2), seven index fingers (three in Group 1 and four in Group 2), three middle fingers (two in Group 1 and one in Group 2), three ring fingers (one in Group 1 and two in Group 2) and four little fingers (two in Group 1 and two in Group 2) in this series.

The mean TAM degrees of the fingers at 3-5 weeks and more than 8 weeks after operation are presented in Table 2. Table 2 also provides the difference between the two groups in terms of the average duration of surgery. A significantly short duration of operation was found in the endoscopic group ($p=0.002$). Regarding the comparison of the functional outcomes of 22 fingers, according to the Strickland-Glogovac and Buck-Gramcko scoring systems, results were excellent in five, good in four, fair in one and poor in one in Group 1 and excellent in two, good in six, fair in two and poor in one in Group 2. Additionally, grading of the thumb and non-thumb subgroups was analysed together because both the scoring systems have the same parameters (excellent, good, fair and poor) and there were a small number of patients in each subgroup. Nevertheless, no statistically significant difference was found between the two groups ($p=0.725$).

In both the groups, the average VAS scores of post-operative regional tenderness were evaluated at each post-operative visit (at first day, 1-2, 3-5 and >8 weeks; Table 3). The endoscopic approach resulted in significantly better VAS scores at 1-2 weeks than the proximal incision approach ($p=0.020$). No significant difference was found between the groups at first day, 3 to 5 weeks and more than 8 weeks after operation ($p=0.097$, $p=0.372$ and $p=0.689$, respectively).

Discussion

Retrieval of retracted flexor tendons has always been demanding for hand surgeons. Therefore, many techniques have been described, such as grasping of the severed ends with mosquito forceps, reverse milking of the forearm muscles with Esmarch bandage,[4] rigid-semi-rigid tendon retrievers, suction catheter and sheath dilatators,[5,6] skin hooks and hypodermic needles,[7] steel wires,[8] aneurismal needle,[9] suturing tendons to various materials like plastic catheters for retrieval,[10] Seldinger catheter,[11] feeding tubes,[12] Silastic tubes,[13] red rubber catheter[14] and silicon rods.[11] Although the principle of proximodistal milking using an Esmarch bandage and the use of a suction catheter are atraumatic procedures, they have high failure rates. Repetitive grasping manoeuvres and techniques using hypodermic needles, skin hooks, steel wires and rigid retrievers can cause damage to the tendon sheath, the proximal stump and the surrounding neurovascular structures.[25] This damage may enhance adhesion formation and compromise functional outcomes. The repetitive trauma also frays the proximal tendon end, hence trimming before tendon repair becomes inevitable resulting in the shortening of the tendon and a repair with tension. Based on our experience, these techniques, without the proximal incision, are tedious and have low success rates.

Another substantial aspect of the retracted tendon retrieval techniques is the flexible intraluminal materials. Various retrieval devices have been described, but the principle underlying it remains the same.[10-14] Following a proximal incision, the proximal tendon is found and externalised. The tendon end is sutured to the catheter, which is inserted in

Table 3 VAS scores for regional pain after surgery.

Time	Group 1 (SD)	Group 2 (SD)	*p*
1st day	3.1 (0.7)	3.6 (0.7)	0.097
1-2 weeks	2.5 (0.5)	3.0 (0.4)	**0.020**
3-5 weeks	1.8 (0.8)	2.1 (0.7)	0.372
>8 weeks	1.4 (0.7)	1.5 (0.7)	0.689

Statistically significant values are indicated in bold.
VAS: Visual analogue scale.
SD: Standard deviation.

a retrograde manner through the tendon sheath. In these procedures, the tendon frequently gets stuck in the tendon sheath. In that situation, any attempt forcing its withdrawal causes additional damage to the tendon end and abrades the delicate tendon sheath. Moreover, without being related to the way the tendon is held by the retrieval (intraluminal, side-to-side and end-to-end), the sutures placed between the tendon and the catheter are not used for the final repair, which causes additional damage by fraying them.

The endoscopic approach used in our study offers several advantages over these conventional procedures. The direct visibility of the proximal tendon end and the retrieval with a 1 mm diameter flexible forceps in an atraumatic manner, without a proximal incision, shorten the duration of the surgery and make this technique reliable, promising and superior to conventional procedures due to the less traumatic process. We assessed the post-operative periods of the proximal incision approach and the endoscopic approach in terms of regional pain and functional assessments based on the Strickland–Glogovac and Buck–Gramcko scoring systems and the TAM of the fingers. We found significantly better functional scores with less regional pain, which was clinically relevant, especially in the early post-operative period, in the endoscopic approach group, but long-term results did not show difference. According to our interpretation, fewer incisions and a shortened operative duration with less trauma contribute to improved functional outcomes with fewer adhesions. In our study, there was no significant difference between the two groups on the first day after surgery, which might be caused by the sudden increase in pain post-operatively. Moreover, the scores approached each other due to the continuous improvement in pain and function over time, and we had a small number of patients. These reasons might explain the failure to observe significant differences between the groups in terms of the Strickland–Glogovac and Buck–Gramcko scores at the final follow-up, the TAM degrees at more than 8 weeks and the VAS scores at 3–5 weeks and more than 8 weeks after surgery.

There are several limitations in this study that need to be addressed for future research. First, because of the small number of patients, complications such as infection and need for tenolysis could not be assessed properly between the groups. However, we believe that making additional incisions and traumatising the surrounding structures induce scar formation and increase infection rates. Additionally, paediatric endoscopes, smaller in diameter, may extend the use of this technique among the paediatric population. In our study, the relatively large diameter of our endoscope

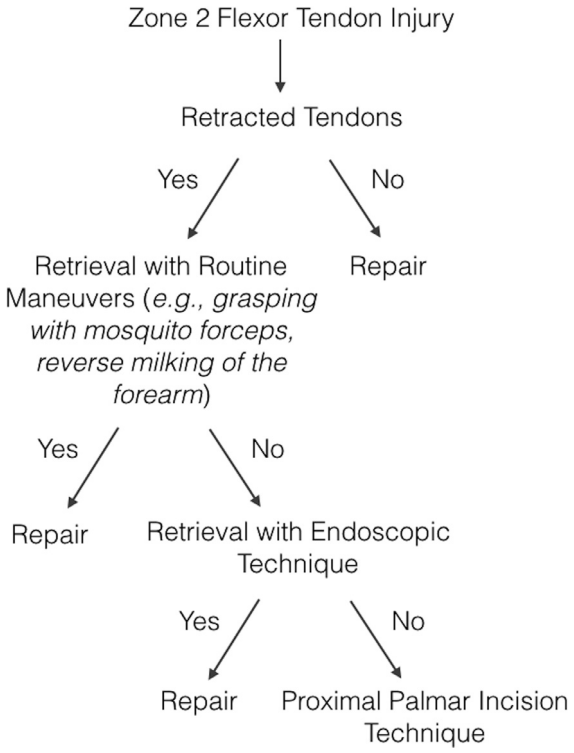


Figure 3 Algorithm for surgical management of zone 2 flexor tendon injuries.

has limited use in children. Despite the high cost of the equipment, it should be noted that the endoscopic devices for retrieval of the retracted tendons are readily available in most of the operating rooms where urological operations are performed. Another point worth mentioning is that the first manoeuvres may damage the proximal tendon end up to a point. However, if tendons cannot be seen at the injury zone, it is inevitable and necessary for surgeons to try to retrieve the proximal tendon end with routine manoeuvres in any case. In the present study, we suggest that the retrieval attempts with mosquito forceps be performed very gently before the endoscopic approach. Thus, the damage to the tendon end can be minimized and the direct visibility by the endoscopic approach makes the procedure less traumatic.

To the best of our knowledge, this is the first comprehensive clinical study on the functional outcomes of the endoscopic retrieval of retracted flexor tendons in the literature except for the first two cadaveric studies.[15,16] Herein, we

demonstrated an atraumatic and reliable technique in the retracted flexor tendon treatment and highlighted its potential benefits over conventional techniques. On the basis of our findings, we propose an algorithm for surgical management of zone 2 flexor tendon injuries (Figure 3).

In conclusion, the endoscopic surgical procedure presented here has the advantage of direct visibility of the proximal tendon end and retrieval in an atraumatic manner with decreased morbidity. It is a promising approach in tendon treatment and can be used as a routine procedure in retracted flexor tendon cases.

Conflict of interest

None.

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Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.bjps.2019.01.007.

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