Published online: 2020-01-08

Free full text on www.ijps.org

DOI: 10.4103/0970-0358.63944

Original Article

Two-stage reconstruction for flexor tendon injuries in zone II using a silicone rod and pedicled sublimis tendon graft

Mohammed Heshmat Abdul-Kader, Mahmound A. M. Amin[1]

Departments of Orthopedic Surgery and [1]Surgery (Plastic Surgery Unit), Faculty of Medicine, Al-Azhar University, New Damietta, Egypt

Address for correspondence: Prof. Mohammed Heshmat Abdul-Kader, Department of Orthopedic Surgery, Faculty of Medicine, Al-Azhar University, New Damietta, Egypt. E-mail: m.heshmat51@yahoo.com

ABSTRACT

We report the results of staged flexor tendon reconstruction in 12 patients (12 fingers) with neglected or failed primary repair of flexor tendon injuries in zone II. Injuries involved both flexor digitorum profundus (FDP) and flexor digitorum sublimis (FDS), with poor prognosis (Boyes grades II–IV). The procedure included placing a silicone rod and creating a loop between the FDP and FDS in the first stage and reflecting the latter as a pedicled graft through the pseudosheath created around the silicone rod in the second stage. At a mean follow-up of 18 months (range 12–30 months), results were assessed by clinical examination and questionnaire. The mean total active motion of these fingers was 188°. The mean power grip was 80.0% and pinch grip was 76% of the contralateral hand. The rate of excellent and good results was 75% according to the Buck-Gramcko scale. These results were better than the subjective scores given by the patients. Complications included postoperative hematoma in two, infection in one, silicone synovitis in one (after stage I) and three flexion contractures after stage II. This study confirmed the usefulness of two-stage flexor tendon reconstruction using the combined technique as a salvage procedure to restore flexor tendon function with a few complications.

KEY WORDS

Flexor tendon; pedicled sublimis tendon graft; staged reconstruction

INTRODUCTION

The reconstruction of a scarred flexor tendon system in zone II of the hand remains a challenge for the hand surgeon. In 1965, Paneva-Holevich[1] described a method for reconstructing flexor tendons, both in acute and neglected injuries, which involved creating a loop between the flexor digitorum profundus (FDP) and the flexor digitorum sublimis (FDS) proximal stumps and reflecting the latter after 2–3 months as a pedicled graft. Two-stage flexor tendon reconstructions using a silicone rod (flexible silicone–Dacron-reinforced gliding implant) in the first stage and a free tendon graft through the pseudosheath formed around the silicone in the second stage was described by Hunter and Salisbury in 1971.[2]

A combination of the Hunter and Paneva-Holevich techniques was first published by Kessler.[3] Since then, several studies of this combined method have been reported.[4-9] The aim of this study is to present our results with the combined use of silicone implant in the first stage and pedicled FDS tendon as a graft in 12 patients who suffered zone II injuries of both flexor tendons with scarring and nonfunctioning flexor apparatus.

MATERIALS AND METHODS

Twelve patients underwent staged flexor tendon reconstruction between 2002 and 2006 at the Health Insurance Hospital and the Al-Azhar University Hospital. There were eight males and four females, ranging in age, at time of first stage, from 12 to 45 years (mean 26 years). All patients had suffered injuries of both flexor tendons in zone II with considerable scarring and nonfunctioning flexor apparatus. All patients had only single digit involvement: the index finger in five patients, the long finger in two, the ring finger in three and the little finger in two. The initial injury was the result of clean laceration in seven patients and crushing injury in five.

The previous status of the finger was evaluated using Boyes and Stark[10] grading modified by Wehbe *et al*[11] [Table 1]. The distribution of digits was as follows: grade I, none; grade II, 6; grade III, 2; grade IV; 1 and grade V, 3 fingers. The mean interval between initial injury and first stage was 8 months, (range 4 months to 26 months). In 10 patients, the primary tendon lesion had been missed. Only two patients had failed primary repair. Six patients were labourers, two did sedentary work and four were students. Ten patients were right-handed and in, eight cases, the injury affected the dominant hand.

Surgical technique

The surgical technique includes two stages. It is important that an aggressive physiotherapy program precedes the first stage to overcome stiffness and achieve maximum range of passive motion.

Stage I

In the first stage, the flexor tendons are exposed through a Bruner zigzag incision extending into the palm.[12] The scar tissues and the distal tendon remnants are excised. The proximal stumps of the FDS and FDP of the injured finger are retrieved, freed of adhesions and sutured end-to-end in a coaptation loop using a modified Kessler technique at the level of the lumbrical origin. The A-2 and A-4 pullies are preserved or reconstructed using tendon graft from the excised tendons or from the palmaris longus tendon. A silicone rod with a size corresponding to the FDS diameter is passed through the pulley system and sutured distally to the distal FDP stump. The proximal end of the implant is left free in the palm at the level of the lumbrical origin and its uninhibited movement is checked. Pulley reconstruction (in three patients), digital nerve repair using magnifying loops (in two) and release of flexion contractures (in four patients) were also carried out in this stage. Immobilization in the dorsal splint for 1 week is followed by passive range of motion (ROM) exercises; the goal is to achieve full passive flexion after the first stage and to preserve it until the second stage is performed [Figures 1 and 2].

Stage II

The second stage is performed 8–12 weeks after the first stage, provided the patient has regained the maximal passive motion of the finger joints. The palm is opened and the proximal end of the silicone rod is identified. The site of FDP–FDS junction is located. All the loops in this series were found to be well healed and strong. Adhesions are dissected carefully to free the repair site; trimming of a bulky loop was necessary in two patients. The FDS tendon of the involved finger is exposed through an incision on the volar aspect of the distal forearm and divided at its musculotendinous junction. The tendon is then delivered into the palmar incision and sutured to the proximal end of the silicone implant.

Through a separate incision, the distal end of the implant is identified and freed from its distal attachment. By gentle distal traction on the implant, the FDS tendon graft is threaded through the new sheath and delivered into the distal wound. The free distal end of the tendon is attached to the distal profundus stump as well as to the periosteal soft tissue of the distal phalanx after adjusting proper tension. The desired tension is so adjusted that the injured finger is kept in slightly more flexion as compared to the adjacent fingers throughout the range of motion of the wrist. The tension is adjusted so that when the wrist is in extension, the finger will

Table 1: Boyes and Stark grading, modified by Wehbe *et al.*

Grade I (good)	Tendon injury only, good soft tissues, supple joints and no significant scarring
Grade II (scar)	Injury to tendon and soft tissue, deep cicatrix, resulting from injury or previous surgery
Grade III (joint)	Injury to tendon and contractures of more than 10° at any joint
Grade IV (nerve or artery)	Injury to tendon and one or both neurovascular bundles
Grade V (multiple)	More than one of the aforementioned injuries and, in addition, involvement of the palm or more than one finger injured

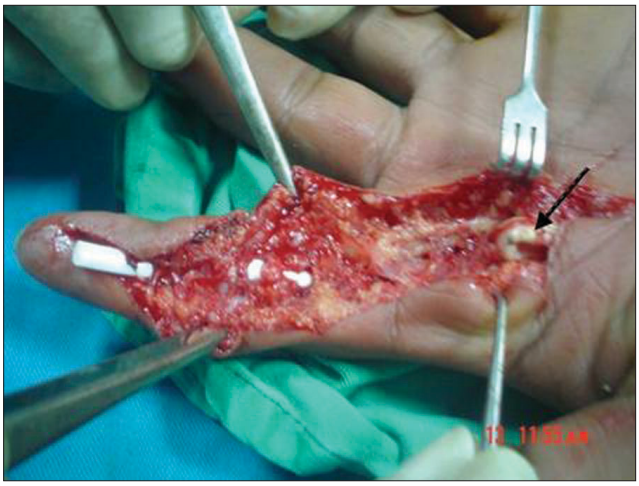

Figure 1: Stage I: Scars and flexor tendons were excised, the proximal stumps of the flexor digitorum profundus and the flexor digitorum sublimis were sutured in a coaptation loop (arrow) and the silicone rod was inserted through the preserved pullies

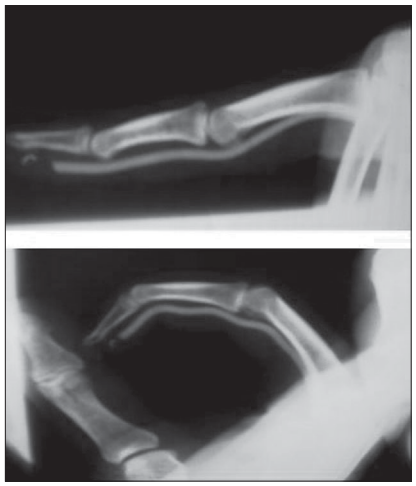

Figure 2: X-ray demonstrating the amplitude of excursion of the silicone implant

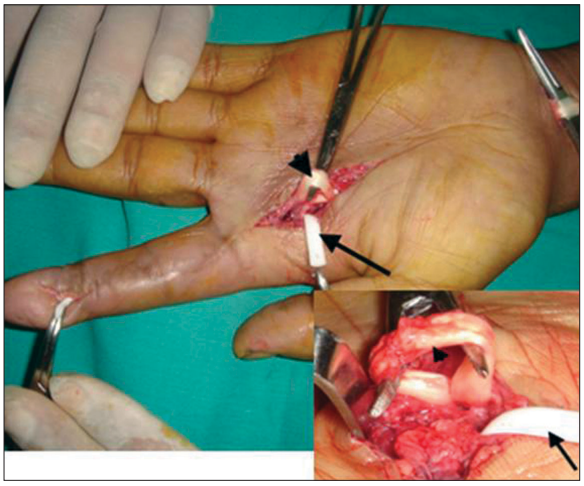

Figure 3a: Stage II: The flexor digitorum sublimis–flexor digitorum profundus loop (head arrow) and proximal end of the silicone rod (arrow) are retrieved through a midpalmer incision

Figure 3b: The flexor digitorum sublimis tendon is cut proximally at the musculotendinous level and brought to the midpalmer incision

Figure 3c: The flexor digitorum sublimis tendon is sutured to the proximal end of the silicone rod and is delivered to the distal wound by gentle distal traction on the implant

automatically be brought in to about the same amount or slightly more flexion in relation to the adjoining digits; flexion is to be increased a little in the more ulnar digits. A separate suture is placed through the distal end of the nail to be used for dynamic traction. A dorsal splint is applied to hold the wrist in about 40° flexion and the finger in intrinsic-plus position and rubber band traction is set up. One week after surgery, patients are started on a controlled mobilization program (passive flexion, active extension).[13] Active ROM exercise is started at 3 weeks and unprotected digital motion is allowed at 6 weeks [Figure 3].

Follow-up evaluation

Assessment of the patients included measurement

Table 2: Assessment method of Buck-Gramcko *et al.

		Score
PTP distance TAF	0–2.5 cm ≥200°	6
	2.5–4 cm ≥180°	4
	4–6 cm ≥150°	2
	>6 cm <150°	0
Extension deficit	0–30°	3
	31–50°	2
	51–70°	1
	>70°	0
TAM	≥160°	6
	≥140°	4
	≥120°	2
	<120°	0
Grade	Excellent	14–15
	Good	11–13
	Fair	7–10
	Poor	0–6

*PTP, palm-to-pulp distance in centimeters; TAF, composite flexion of MCP, PIP and DIP joints; TAM, total active motion (TAM = TAF - TAED); TAED, total active extension deficit[14]

Table 3: Questionnaire (Subjective grading by patient)

Problems work/daily life: (Yes/No)
Complaints
Decrease of grip strength, power loss
Difficulties with fine movements
Pain
Cold intolerance
Cosmetic complaints
No complaints
Patients grading of the end result
Excellent
Good
Satisfactory
Poor
Considering further operation: (Yes/No)

Table 4: Comparison of results according to the Buck-Gramcko score and those according to the Questionnaire

	Buck-Gramcko rating	*Results of questionnaire*
	Finger	
Excellent	6	2
Good	3	5
Satisfactory	2	3
Poor	1	2

of active and passive motion of each joint and palm-to-pulp distance (the distance from the fingertip to the distal palmar crease in maximal flexion). Pinch grip (pulp-to-pulp pinch) and power grip strength of the hand were measured using a pinch gauge and hydraulic dynamometer. Measurements of the injured side were compared with the uninjured hand and expressed as a percentage of it.[14] The functional results were classified according to the Buck-Gramcko rating [Table 2]. The patients were then asked to complete a questionnaire [Table 3].

RESULTS

The mean follow-up of the patients from the stage II procedure was 18 months (range 12–30 months).

The mean total active motion (TAM) achieved was 188°. The mean total active flexion was 227°. The mean total active extension deficit was 39°. The mean strength (in Kg f) of pinch grip and power grip were 76% and 80%, respectively, compared to the unaffected side.

The pulp to distal flexion crease distance was 0 cm in five fingers, 0.5 cm in three, 1–2 cm in two and more than 2 cm in two fingers.

Overall, a good and excellent Buck-Gramcko score was achieved in nine fingers (75.0%); there were two satisfactory and one poor results. Table 4 shows the comparison of results according to the Buck-Gramcko score and those perceived by the patients according to the questionnaire [Figures 4a–c].

The patient with poor result according to the Buck-Gramcko score was male (labourer) with Boyes grade V, presenting with a stiff pre-stage I finger that improved slightly after soft tissue release at this stage. At last follow-up, the patient had a functioning graft, with most of the motion at the MCP joint and little PIP and DIP joint motion.

Additional surgery was considered in two patients after stage II, one with slack graft (needing tension readjustment) and one with severe DIP joint flexion contracture (needing arthrodesis). Both were satisfied with the functional results gained and refused additional surgery.

Complications

After stage I, no skin necrosis, rod buckling, rod migration or proximal tenorrhaphy ruptures were encountered in this series.

Although this is considered a potential complication, no skin necrosis was observed in the present series. This was achieved by careful planning of the Bruner incision.[12] In particular, care was taken to always have zigzag angles of more than 45°. Two patients developed

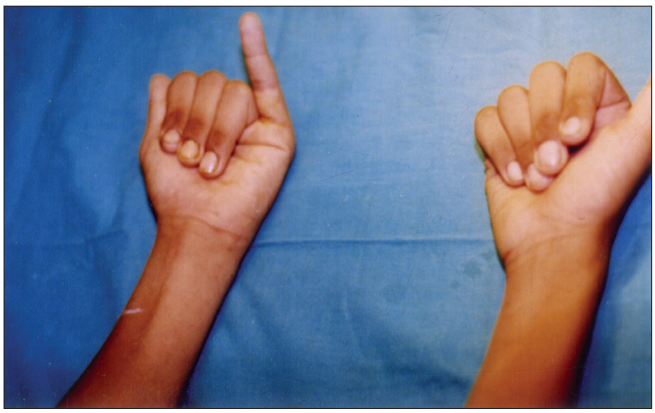

Figure 4a: A 25-year-old male patient in whom both flexor digitorum sublimis and flexor digitorum profundus were injured in zone II of the left little finger (6 months after injury)

Figure 4b: After stage II: Full flexion was restored

Figure 4c: Extension was maintained

postoperative haematoma (after stage I); surgical drainage was performed in one case. One patient had mild infection that was treated conservatively. There was only one complication of synovitis, which was diagnosed by swelling of the finger, loss of passive motion and relative pain, and it was treated by administration antibiotics, splinting of the digit in the resting position and avoidance of any passive motion.

After stage II, we recorded no distal disruption of the graft and no patients had tenolysis. Flexion deformity of the PIP and/or DIP joints of 20-55° were noted postoperatively in six patients. This was successfully treated with night splint in three cases. At last follow-up, only three cases with pre-operative flexion contracture still had flexion deformity; at the DIP joint in two and at the PIP joint in one.

DISCUSSION

Restoration of a flexor tendon function in a badly scarred finger is a challenge and much effort is required from both the surgeon and the patient to achieve a good result. The rationale of tendon grafting is to create tenorrhaphy sites outside zone II, where adhesions do not interfere with function. Two-stage flexor tendon reconstruction using silicone rod in the first stage and a free tendon graft through the pseudosheath formed around the silicone in the second stage, as described by Hunter,[2] is the most widely accepted treatment in poor prognosis patients (Boyes grades II–IV).[11,14-17] Nevertheless, this method presents some problems. An intrasynovial tendon is replaced by an extrasynovial graft (palmaris longus, plantaris, toe extensors) of varying size. Because the graft is harvested in the second stage, it is difficult to determine the size of the silicone rod that should be used and the width of the pulleys to be reconstructed during the first stage. In addition, the proximal stump of the profundus tendon is usually difficult to retrieve in the second stage. The proximal and distal tenorrhaphies to the graft must heal simultaneously and be able to withstand the loads of the rehabilitation programme.[18]

Results of the combined techniques in the current study are equally good or better than those achieved by the Hunter technique.[11,14] In the Wehbe *et al.*[11] report (with 81% of the injuries in zone II), the mean TAM was 176° and the mean grip strength was 79% of normal. In the Frakking *et al*.[14] series, excellent to good results were obtained in 70% of 30 finger reconstructions according to the Buck-Gramcko score (zone II injuries in 23 fingers). In this study, the mean TAM was 188°, the mean power grip was 80.0% and the mean pinch grip was 76% of the normal side.

We found a significant disagreement between the examiners and patients as to the quality of the results [Table 4]. This has also been reported by others.[14,16]

The Buck-Gramcko score is very useful in evaluating finger motion, but it is unable to express the patient's subjective assessment of the end results, which ultimately determines the success of the procedure.

The combined technique has the advantage of using local tendon and allowing early active movements of the fingers without risk of rupture of the proximal juncture.[9] It uses an intrasynovial FDS graft, which has better morphologic and functional characteristics than extrasynovial grafts such as palmaris longus or plantaris.

Gelberman *et al*.[19] studied the morphologic and functional tendon grafts in dogs. They found that the intrasynovial tendon grafts healed with minimal adhesions with normal cellularity and collagen organization, which provided a smooth, adhesion-free gliding surface, while the extrasynovial graft healed with ingrowths of peripheral adhesions that became larger and more dense over time. The procedure has further advantages. The FDS graft has a more appropriate size, with a mean cross-sectional area of 10.6 mm^2 compared with the 3.1 mm^2, 1.6 mm^2 and 3.2 mm^2 of PL, plantaris, and toe extensors, respectively.[20] It is a stable anatomic structure compared with plantaris and PL, which are reported to be absent in 20% and 25% of healthy individuals, respectively.[21] Donor site morbidity is also minimised with this procedure. The proximal tenorrhaphy has healed by the time the second stage is performed, which nullifies the incidence of proximal rupture that is reported in 7% of Hunter reconstructions.[11] These advantages may explain the improved results in the present series. No tendon rupture and no tenolysis were performed in this series, whereas in Hunter reconstructions, it has been reported in 12–47%.[11,15,16] An overall 75% excellent to good results achieved in this series are comparable to findings in two more recent studies using the combined techniques for zone II injuries[18,22] and the Buck-Gramcko score for rating the results.

Technically, with the combined technique, the size of the silicone rod and, as a consequence, the size of the reconstructed pulleys, can be assessed precisely according to the FDS size during stage I. In addition, the bulky loop at the lumbrical level is easier to identify during stage II than FDP alone with the Hunter method. Should abandoning the technique during stage II or regrafting be needed, conversion to the classic free-grafting technique of Hunter can be carried out. A potential technical disadvantage is that tensioning of the graft must be performed at the distal anchoring point.[18]

Pulley preservation and reconstruction is thought to be crucial for a good functional result, and attempts should be made to preserve not only the A2 and A4 pulleys but as much of the flexor sheath as possible. The pulley system is not only important to prevent bowstringing and improve the effective excursion of the tendon but also to decrease the degree of flexion contractures.[2,11,23] Wehbe *et al*.[11] identified a clear association between the number of intact pulleys and the final flexion contractures.

Four patients in our series were <20 years of age at the time of surgery. Their results were: two excellent, one good and one satisfactory according to the Buck-Gramcko scale. Both with Hunter and with the combined techniques, with comparison of the two techniques, better results were achieved in young age.[9,11,18,22] Comparison of the two techniques in children showed better results following the combined technique in one study.[24]

The pre-operative status of the finger according to the Boyes grading system is a better determinant of the final result.[9,11,18] In our group of patients, the three postoperative contractures found at last follow-up occurred in the four patients with pre-operative contractures. This confirms the importance of correcting any flexion contracture either by physiotherapy and/or surgery prior to the second stage. Maximum passive motion before stage II is the goal of the hand therapy programme.

Paneva-Holevich has recommended starting active motion of the involved finger in the first postoperative week, and reported no increase in incidence of rupture of the distal insertion with the very early active motion.[25] In our series, a controlled mobilization program was used for the first 3 weeks. The results that we obtained may suggest that a well-executed, controlled mobilization program is perhaps effective as very early active motion. Another possible benefit is reduction of the potential of graft rupture.

In conclusion, this two-stage technique is a useful, effective method of reconstruction of a scarred flexor tendon system in zone II of the hand, yielding a high rate of excellent and good results with a few complications.

REFERENCES

1. Paneva-Holevich E. Two-stage plasty in flexor tendon injuries of fingers within the digital synovial sheath. Acta Chir Plast 1965;7:112-24.
2. Hunter JM, Salisbury RE. Flexor tendon reconstruction in severely damaged hands: A two-stage procedure using a slincone-dacron reinforced gliding prosthesis prior to tendon grafting. J Bone Joint Surg Am 1971;53:829-58.
3. Kessler FB. Use of a pedicled tendon transfer with a silicone rod in complicated secondary flexor tendon repairs. Plast Reconstr Srug 1972;49:439-43.
4. Chong JK, Cramer LM, Culf NK. Combined two-stage tenoplasty with silicone rods for multiple flexor tendon injuries in "no-man's-land". J Trauma 1972;12:104-21.
5. Alms M. Pedicled tendon graft for flexor tendon injuries of the fingers. J Bone Joint Surg Br 1973;55:881-2.
6. Winspur I, Phelps DB, Boswick JA Jr. Staged reconstruction of flexor tendons with a silicone rod and a "pedicled" sublimis transfer. Plast Reconstr Surg 1978;61:756-61.
7. Brug E, Stedtfeld HW. Experience with a two-staged pedicled flexor tendon graft. Hand 1979;11:198-205.
8. Chuinard RG, Dabezies EJ, Mathews RE. Two-stage superficialis tendon reconstruction in severely damaged fingers. J Hand Surg Am 1980;5:135-43.
9. Naam NH. Staged flexor tendon reconstruction using pedicled tendon graft from flexor digitorum superficialis. J Hand Surg Am 1997;22:323-7.
10. Boyes JH, Stark HH. Flexor tendon grafts in the fingers and thumb: A study of factors influencing results in 1000 cases. J Bone Joint Surg Am 1971;53:1332–42.
11. Wehbe MA, Mawr B, Hunter JM, Schneider LH, Goodwyn BL. Two stage flexor tendon reconstruction: Ten-year experience. J Bone Joint Surg Am 1986;68:752-63.
12. Bruner JM. The zig-zag volar digital incision for flexor tendon surgery. Plast Reconstr Surg 1967;40:571-4.
13. Lister GD, Kleinert HE, Kutz JE, Atasoy E. Primary flexor tendon repair followed by immediate controlled mobilization. J Hand Surg Am 1977;2:441-51.
14. Frakking TG, Depuydt KP, Kon M, Werker PM. Retrospective outcome analysis of staged flexor tendon reconstruction. J Hand Surg Br 2000;25:168-74.
15. LaSalle WB, Strickland JW. An evaluation of the two-stage flexor tendon reconstruction technique. J Hand Surg Am 1983;8:263-7.
16. Amadio PC, Wood MB, Cooney WP 3rd, Bogard SD. Staged flexor tendon reconstruction in the fingers and hand. J Hand Surg Am 1988;13:559-62.
17. Strickland JW. Development of flexor tendon surgery: Twenty-five years of progress. J Hand Surg Am 2000;25:214-35.
18. Beris AE, Darlis NA, Korompilias AV, Vekris MD, Mitsionis GI, Soucacos PN. Two-stage flexor tendon reconstruction in zone II using a silicone rod and a pedicled intrasynovial graft. J Hand Surg Am 2003;28:652-60.
19. Gelberman RH, Vande Berg JS, Lundborg GN, Akeson WH. Flexor tendon healing and restoration of the gliding surface: An ultrastructural study in dogs. J Bone Joint Surg Am 1983;65: 70-80.
20. Carlson GD, Botte MJ, Josephs MS, Newton PO, Davis JL, Woo SL. Morphological and biomechanical comparison of tendons used as free grafts. J Hand Surg Am 1993;18:76-82.
21. Wehbe MA. Tendon graft anatomy and harvesting. Orthop Rev 1994;23:253-6.
22. Darlis NA, Beris AE, Koromphilias AV, Vekris MD, Mitsionis GI, Soucacos PN. Two-stage flexor tendon reconstruction in zone 2 of the hand in children. J Pediatr Orthop 2005;25:382-6.
23. Soucacos PN, Beris AE, Malizos KN, Zenakis T, Touliatos A, Soucacos PK. Two-stage treatment of flexor tendon ruptures: Silicone rod complications analyzed in 109 digits. Acta Orthop Scand 1997;68:48-51.
24. Valenti P, Gilbert A. Two-stage flexor tendon grafting in children. Hand Clin 2000;16:573-8.
25. Paneva-Holevich E. Two stage tenoplasty results. Tendon surgery in the hand. In: Hunter JM, Schneider LH, Mackin EJ, editors. St. Louis: CV Mosby; 1987. p. 272-81.

Source of Support: Nil, **Conflict of Interest:** None declared.