Two-stage pedicled tenoplasty for the reconstruction of multiple flexor tendons in zone V: case report

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Introduction

The two-stage tenoplasty for zone II flexor tendon injuries in single digits was reported by Paneva-Holevich in 1965 with results comparable to or better than the standard free tendon graft reconstruction [15]. This technique has the advantage of the use of the flexor digitorum superficialis as an intrasynovial “pedicled” tendon graft and allowed healing of the proximal tenorrhaphy site so that mobilization after the second stage procedure can begin immediately to minimize tendon scarring [16]. In 1972, Kessler described the combination of this technique with the use of silicone rods [3] as described by Carroll in 1964 [6] and refined and popularized by Hunter in 1970 [8] as a “space saver” and to create a pseudosheath to facilitate gliding of the tendon graft. Since then, several other series using the pedicled tendon graft technique have been reported in both adults and children for the management of zone II injuries in single or multiple digits with silicone rods and various modifications [3, 5, 20]. In 1997, Naam reported a series of 47 patients using the combined technique as previously described [14]. However his series also included five patients with injuries in zone III and three in zone IV. In these cases as in the others, reconstruction included replacement of the tendon in zone II with attachment of the distal tendon graft to the distal phalanx with a pull-out wire technique. The results for zone III and zone IV injuries were comparable to that for zones I and II.

The pedicled tenoplasty technique has well-described advantages for reconstruction in zone II but offers an alternative technique with other advantages that may be applicable to flexor tendon reconstruction outside of zone II as well [9, 16]. The tendon “loop” that is constructed at the first stage will be healed by the second stage, and as such, there is less concern about the nutrient supply for adequate healing, early disruption at the proximal tenorrhaphy site, and vascular ingrowth leading to scar formation to promote healing but which may limit tendon gliding. The use of intrasynovial tendons such as the flexor digitorum superficialis (FDS) may still provide favorable characteristics for gliding, especially in a scarred wound bed even if used for reconstruction outside of zone II [1, 7, 11, 18]. Our purpose is to present the first report of the use of the two-stage pedicled tenoplasty technique for the reconstruction of multiple flexor tendons in zone V in association with a chronic wound bed, major nerve injury requiring reconstruction, and soft tissue defect requiring flap coverage.

Case Report

The patient is a 22-year-old man who sustained a significant self-inflicted injury to his left wrist in January 2008 that occurred after a severe reaction to a drug overdose of recreational use resulting in self-mutilating behavior and attempted suicide. He inflicted stab wounds to his neck, abdomen, and a deep laceration to his left wrist. There was significant blood loss at the scene and extensive contamination of his wrist wound. He underwent emergent exploratory laparotomy with repair of a liver laceration, management of a pericardial tamponade, and neck exploration with ligation of his internal jugular vein. Once stabilized, he underwent surgery on his wrist the following day still at the outlying

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regional hospital out of state. All wrist and digital flexor tendons, both the radial and ulnar arteries, and the median and ulnar nerves were transected. Primary repair of all flexor tendons, median and ulnar nerves, and ulnar artery were performed, but unfortunately this was complicated by a severe infection and skin flap necrosis with dehiscence of all of his tendon repairs and the median nerve repair. After further incision and drainage, debridements, and washouts, Integra bilayer matrix dressing was applied to the resulting 7×8 cm distal forearm and wrist wound once clean and free of infection, and he was referred to Washington University in St. Louis approximately 1 month after his injury for further management (Fig. 1). Physical examination and an initial exploratory procedure confirmed dehiscence of all of his flexor tendon repairs except for FCU and his median nerve repair, but his ulnar nerve and artery repairs were intact.

Operative Procedure

Definitive management involved a two-stage reconstruction. At the first stage over 2 days of surgery, tendon loops were constructed just proximal to the distal forearm wound to utilize as much tendon length as possible. The FDS tendons were significantly scarred and shortened and therefore were not used. The proximal stump of the flexor pollicis longus (FPL) was sutured directly end-to-end to one of the proximal stumps of the flexor carpi radialis (FCR) which was split longitudinally, and the index finger flexor digitorum profundus (FDP) was sutured similarly to the other proximal stump of the split FCR. The proximal stump of the middle finger FDP was sutured to the proximal stump of the

Fig. 1 Initial appearance of wound upon referral, 1 month post-injury after initial surgery, multiple debridements and washouts, and resolution of infection. There has been dehiscence of all tendon repairs except FCU and median nerve repair

palmaris longus, and the proximal stumps of the FDP to the ring and small fingers were sutured together in the same manner (Fig. 2). The carpal tunnel was released, and the soft tissue defect was covered with a radial forearm flap. The flap was raised in a reversed pedicle fashion and perfusion was noted through distal collateral supply, but because the radial artery was not previously repaired at the wrist, augmentation with microvascular arterial and venous anastomoses was performed as well to the distal stump of the radial artery and venae comitantes which had good back flow from the previously repaired ulnar artery through the palmar vascular arches (Fig. 3).

The second stage of his reconstruction was performed approximately 1.5 months later (Fig. 4). The FCR was divided at its musculotendinous junction in the proximal forearm and the split tendons flipped distally hinged on the healed junctions with the FPL and index FDP to reach across the radial forearm flap to the palm. Similarly, the palmaris longus and the small finger FDP were also divided at their muscle junctions and flipped distally to the palm based on their healed proximal tenorrhaphies. The distal stumps of the FPL and FDP tendons in the hand were all identified and were sutured in the palm to the respective ends of their pedicled tendon grafts. The distal tenorrhaphy sites were kept far enough from the tendon sheath such that at full digit extension they remained outside of zone II and

Fig. 2 **a** Dissection of proximal tendon stumps in preparation for construction of “loop” tenoplasties. **b** Proximal tendon loops constructed: 1 FPL to split FCR. 2 FDP index to other half of split FCR. 3 FDP middle to palmaris longus. 4 FDP ring to FDP small

Fig. 3 Transposition of distally based radial forearm flap turbocharged with microvascular arterial and venous anastomoses as the radial artery was not initially repaired although the distally based flap once elevated was perfused through collaterals to the distal radial artery

did not interfere with tendon excursion. The FDP to the ring and small fingers were sutured together distally such that flexion of these fingers would occur in unison, but thumb, index, and middle finger flexion would remain independent. The median nerve was reconstructed with 10 cm sural nerve grafts in a cabled fashion and an extensor indicis proprius (EIP) opponensplasty was also done at that time. Additional procedures to further improve hand function almost 2 years later included fusion of the thumb MCP joint, EDQ tendon transfer for stronger thumb adduction, and debulking of his radial forearm flap.

Postoperative Course and Functional Outcome

Early motion therapy with passive range of motion was begun within 1 week after his second stage reconstruction but active range of motion was not begun until close to 1 month postoperatively when the distal tenorrhaphy site was felt to be well healed, including the EIP opponensplasty. The potential need

Fig. 4 Second stage surgery 1.5 months later with healed tendon loops and division of FCR, palmaris longus, and FDP to small finger proximally at their musculotendinous junctions for maximal length to extend to the palm for suture to the distal stumps of the FPL and FDP to fingers

for a tenolysis procedure was anticipated, but after several months of aggressive active therapy, we believe he did this on his own when he experienced a painful tearing sensation in his hand and wrist, and thereafter he maintained much better range of motion.

The patient's last follow-up was approximately 4 years after his reconstruction. He has good and individual mobility of his fingers (Fig. 5). His postoperative range of motion is summarized in Table 1. Total active motion for his index, middle, ring, and small fingers were 130°, 175°, 160°, and 195°, respectively. Range of motion for his thumb IP joint was 0–75° and his MP joint again was fused. Wrist flexion and extension were 70° and 60°, respectively. When trying to make a fist, his fingertip to palm distance is 1.5 cm. The average grip strength of the affected left hand was 26 lb and 46 lb on the right. Pinch strength was 13 lb on the left and 16 lb on the right. The deficits that still remain are grip strength, fine motor skills involving his fingers, some residual stiffness, and abnormal fingertip sensation. Examination

Fig. 5 a, b Two-year follow-up after second stage reconstruction with well-healed radial forearm flap and good, useful finger flexion. Individual thumb and finger flexion (except for ring and small fingers which flex together as a unit) was achieved

Table 1 Postoperative range of motion

	Thumb		Index			Middle			Ring			Small		
	MP	IP	MP	PIP	DIP	MP	PIP	DIP	MP	PIP	DIP	MP	PIP	DIP
AROM	Fused	0–75	0–80	60–85	20–45	0–70	55–115	0–45	0–50	50–115	0–45	0–80	45–95	0–65

by Semmes-Weinstein filaments showed fingertip sensation of his thumb, index, and middle fingers of 4.31 (protective sensation), and ring and small fingers was 3.61 (diminished light touch). He had no two-point discrimination in his median nerve distribution and 8 mm in his ulnar nerve distribution. He has sensation along the ulnar aspect of his hand and the first dorsal interosseous muscle is palpable and functioning. Currently he is able to use his hand to pick up certain objects, and he has also been playing sports. Overall pain has improved from 9/10 to 1/10. For regular activities of daily living, his hand remains very useful and he has resumed athletic activities.

Discussion

The two-stage tenoplasty technique was first described by Paneva-Holevich [15] in 1965 and modified by combination with the use of a silicone rod at the first stage by Kessler in 1972 [9]. There have been several publications since then of small series advocating this technique in mostly digital flexor tendon injuries for complete reconstruction and grafting in zone II [3, 5, 14, 20]. The healing of tendon repairs or grafts is dependent upon the blood supply from their attached ends and from the vascular ingrowth of surrounding tissues [4, 12, 17]. However, the resulting fibrous adhesions will limit the excursion of the involved tendon [2, 10, 19]. The advantages of this technique therefore include the use of an intrasynovial tendon (usually FDS) for grafting, a healed proximal tenorrhaphy site at the second stage allowing earlier motion, and potentially less scarring and less inhibition of tendon gliding. Intrasynovial proximal flexor tendon segments contain higher concentrations of proteoglycans and synthesize significantly less collagen and noncollagen protein than extrasynovial tendons, which may reflect the presence of fibrocartilaginous-like tissue within intrasynovial flexor tendons [13]. Despite these advantages and good reported outcomes, it remains a less commonly used alternative to the two-stage free tendon graft technique. To our knowledge, the use of this technique has not been described for tendon repair outside of zone II for the reconstruction of all of the digital flexors.

For our reported case, multiple options for reconstruction were considered and could have been employed. In fact, opinions from several experienced and well-known hand

surgeons were obtained for this case, and all were surprisingly different. Certainly, the conventional free tendon graft technique with or without the use of silicone rods at a first stage could have been done. This would have the advantage of using the proximal motors that still remained intact in the proximal forearm and avoid the need for significant motor reeducation and rehabilitation. Our concern was the chronically scarred wound bed in the distal third of the forearm that may have resulted in delayed tendon healing and/or scarring of the free tendon grafts with compromise of tendon gliding and motion. The use of silicone rods at a first stage could have been considered to minimize such scarring but could have also contributed to additional infectious complications considering the initial heavy wound contamination and severe infection after his first surgery.

Another reasonable option would have been conventional tendon transfers using finger and wrist extensors as donors. This would have had the advantage of mostly avoiding the scarred wound bed and relatively predictable outcomes. The disadvantages would have included wasting the proximal flexor muscles that were otherwise still intact and functional and a more complicated rehabilitation requiring motor reeducation. We were also concerned that because of the extensive volar distal forearm wound of up to 7–8 cm in length and the resulting tendon gap, free tendon grafts would still have been required if using a wrist extensor, pronator teres, or brachioradialis as a donor for tendon transfer. Also because of the size of the wound involving almost the entire width of the volar forearm, it probably would not have been possible for the tendon transfers and additional grafts to completely avoid the scarred wound bed and consequently unfavorable scarring may have still resulted. The use of a finger extensor could have avoided the need for a graft because of its longer available length but would have been antagonistic to finger flexion and would have complicated the rehabilitation and potentially compromised the outcome. Tendon transfers in the standard manner for finger flexion would also have not provided for individual finger movement, which this patient felt was important in his pursuit for a possible career as a dentist.

The two-stage pedicled tenoplasty technique had the advantages of employing the available proximal flexor motors and avoiding any potential donor morbidity from the use of alternative motors. Because of the healed proximal tenorrhaphy site of the pedicled graft constructed at the

first stage, we also had the advantage of being able to mobilize the graft and the proximal tenorrhaphy to maximize tendon gliding with less concern for completely devascularizing the graft segment at the second stage. The distal tenorrhaphy site however did necessitate some caution with early motion for fear of disruption with overly aggressive therapy, but we ensured that there was full range of digital motion and tendon gliding in zone II by keeping the distal tenorrhaphy site far enough away in the proximal palm. Theoretically, complete reconstruction of the tendon system including zone II with the distal tendon juncture at the distal phalanx secured with a pull-out suture/wire or bone anchors may have made a more secure distal juncture with less scarring in the palm. However, because of the large distal volar forearm wound with resulting tendon gap, there was not enough proximal tendon graft length available in the forearm to reach the fingertip. The use of intrasynovial tendon grafts may also have provided some benefit considering the chronically scarred wound bed at the wrist instead of the extrasynovial grafts used (FCR, palmaris longus), but the FDS tendons were not available due to previous repair and disruption, scarring, and shortening at the distal forearm wound.

We are uncertain as to why his sensory reinnervation was not better, both from his reconstructed median nerve and the ulnar nerve which were repaired at the outside facility but left alone as the initial repair remained intact. There was extensive scarring at the site of the wrist wound but the neuromatous stumps of the median nerve were excised until soft and healthy appearing nerve was observed with a good robust fascicular pattern necessitating the use of 10 cm cabled nerve grafts. The nerve coaptations were tension-free throughout the full range of wrist motion so we do not feel that disruption due to early motion had occurred. Although the soft tissue defect was covered with a vascularized radial forearm flap, the wound bed was extensively scarred and devascularized from segmental loss of the radial artery. This may have affected the revascularization of the non-vascularized cabled nerve grafts and diminished the overall quality of nerve regeneration. No other options for further improvement in sensation have been considered. A definitive reconstruction of the gap has been performed and we did not feel that additional grafting would provide any benefit or avoid the same process that limit regeneration through the nerve grafts. Nerve transfer is not an option as his ulnar nerve has been injured and repaired as well and its recovery is only a little better.

Conclusion

Using the two-staged pedicled tenoplasty technique for the extensive reconstruction of multiple tendons, this patient was able to recover good and useful individual finger

flexion and meaningful sensation. Because he lives out of state in Florida, close follow-up and monitoring during his rehabilitation was not possible but assistance with his immediate postoperative follow-up and therapy was provided by his referring surgeon. Current functional deficits include strength and durability of pinch and grip and incomplete recovery of sensation. After flap debulking, he has well-healed scars and a very reasonable contour to his forearm. He is able to perform activities of daily living but has some difficulties with finer and more focused activities requiring a higher degree of dexterity and coordination.

Conflict of Interest The authors have no conflicts of interest, commercial associations, or intent of financial gain regarding this research.

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