

**Acellular Dermal Matrices for Tendon Sheath Reconstruction:
A Novel Method for Pulley Reconstruction and Adhesion Prevention**

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ABSTRACT

BACKGROUND: Tendon and pulley reconstruction after tenolysis is a complex task often complicated by adhesion formation and delayed range of motion. Various autologous (e.g. fascia lata, free tendon, grafts, and extensor retinaculum) and synthetic materials (e.g. Teflon, silicon, Dacron, nylon, and PTFE) have been described for pulley and sheath reconstruction with limited success. Animal models have reported successful A2 pulley reconstruction with acellular dermal matrices versus autologous grafts. This case series describes a novel method of using acellular dermal matrices for flexor tendon sheath and pulley reconstruction after tenolysis with the goal of preventing adhesion formation and allowing earlier range of motion.

METHODS: From 2011 to 2015 the senior author reconstructed a total of 12 zone 2 pulleys in five consecutive patients using acellular dermal matrix (Flex HD, Ethicon, Musculoskeletal Tissue Foundation).

RESULTS: Three of the five patients had suffered crush/laceration injuries to A2 and A4 in the past and had previously undergone bone and tendon repair, resulting in significant loss of motion and flexion contractures. After extensive tenolysis, the pulleys were reconstructed with Flex HD anchored subperiosteally. One patient was reconstructed acutely at the time of nerve and tendon repair to prevent adhesion formation. Another patient had a flexion contracture with extensive A2 and A4 scarring with rupture secondary to a Jersey finger. With early active therapy, all patients had significantly improved range of motion and strength after an average of 10.2 months. No infections or foreign body reactions occurred in this series.

CONCLUSION: In theory, the use of acellular dermal matrices in tendon sheath and pulley reconstruction allows for biologic incorporation and decreased adhesion formation. These advantages allow for earlier range of motion, better functional outcomes and no donor site morbidity. Our case studies demonstrate that acellular dermal matrices are a viable option for tendon sheath and pulley reconstruction after tenolysis.

INTRODUCTION

The fibroosseous pulley system keeps flexor tendons adjacent to the phalanges to prevent bowstringing during finger flexion and to maximize the arc of flexion, which are essential for normal grasping power.¹⁻³ Given the intricate anatomy and complicated function, repair of the pulley system is replete with challenges such as adhesion formation and delayed range of motion.¹ Although flexor pulley injuries requiring surgical management are relatively infrequent,¹ hand surgeons must be facile with flexor pulley reconstructions because of the potential disability from these injuries.

The pulleys are comprised of 3 distinct layers, each with a unique function: the inner-most layer facilitates tendon gliding by secreting hyaluronic acid; the middle layer is rich in collagen and provides constitutional support and the outer-most layer provides nutrition to the tendons.^{1,4}

Proposed methods of reconstruction have varied from various autologous (e.g. fascia lata, free tendon, grafts, and extensor retinaculum⁵⁻⁷ and synthetic materials (e.g. Teflon, silicon,⁸ Dacron, nylon, and PTFE^{6,9,10} with limited success.² Ideally, materials used for pulley reconstruction should be biocompatible, strong enough for early motion and adequately smooth for tendon gliding. Acellular dermal matrices have been employed in various areas of hand reconstruction including burns,¹¹⁻¹³ Dupuytren contracture,¹¹ and ligament reconstruction in basal joint arthritis.^{11,14} Basic science literature suggests that acellular dermal matrices prevent adhesion formation and support migration and proliferation of tendon progenitor cells.¹⁵ Recent rabbit models report successful A2 pulley reconstruction with acellular dermal matrices with no foreign body reactions and no differences in tendon excursion and work of flexion versus controls that underwent autologous grafting.² Acellular dermal matrices have been shown to have a low complication profile when used in hand reconstruction, and when they do occur, they are in the setting of active infection.

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This case series describes a novel method of using acellular dermal matrices for flexor tendon sheath and pulley reconstruction after tenolysis with the goal of preventing adhesion formation and allowing earlier range of motion without donor site morbidity.

PATIENTS AND METHODS

This study was reviewed and approved by The Cedars Sinai Medical Center Institutional Review Board (ID: Pro00037830). This is retrospective chart review of a total of **twelve** zone **2** pulley

reconstructions, which were performed by the senior author (D.A. K.) on five consecutive patients using Flex HD (Ethicon Inc, Someville, NJ), a non-cross-linked acellular dermal matrix. Data were collected from 2012 to 2015 from a single institution (Cedar Sinai Medical Center). Patient demographic, pre-operative, operative and post-operative data were recorded and analyzed.

SURGICAL TECHNIQUE

CASE SERIES

Three of the five patients had suffered crush/laceration injuries in the past and had previously undergone bone and tendon repair, resulting in motion and strength limiting contractures. The third patient suffered a zone 2 pulley laceration with obliteration and was reconstructed in the acute setting, and the last patient developed a contracture after sustaining a FDP avulsion injury, which was repaired several times prior to presentation. Patient demographic, pre-operative, and operative data are summarized in Table 1.

Table 1

Case #	Age	Sex	Chronicity	Mechanism of injury	Injury	Pulleys Reconstructed	Adjunctive Surgery	Follow up (months)
1 JT	44	M	Chronic	Crush	RF & SF open fx and lacerations of FDS, FDP Obliteration of A2, A4	RF A2, A4 SF A2, A4	Tenolysis	38
2 DD	20	F	Chronic	Crush	Fx Obliteration of A2 pulleys	MF A2 RF A2	Intrinsic release Tenolysis	1

3	TY	20	M	Acute	Laceration	Thumb zone 2 laceration	Thumb A2, A4	Radial digital nerve repair Tenolysis FPL repair	4
4	KL	39	F	Chronic	Jersey finger	Obliteration of A2, A4 pulleys	RF A2, A4		5
5	RS	31	M	Chronic	Laceration	FDP laceration, repair	Long finger A2, A4	Tenolysis	3

Case 1 (JT)

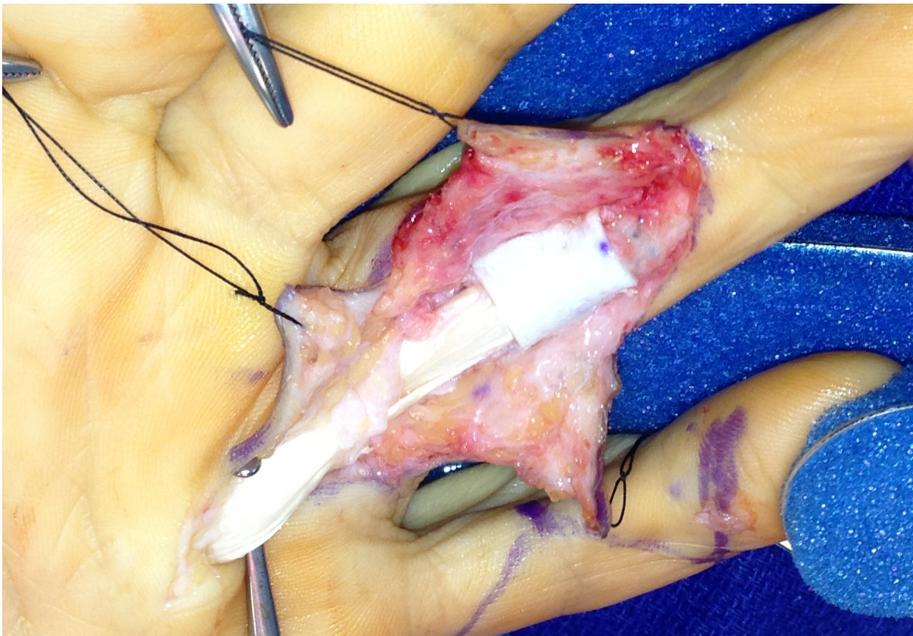
Patient 1, a 44 year-old right hand dominant man, who previously sustained a crush injury that resulted in open fractures and lacerations of the flexor digitorum profundus and superficialis tendons to the fourth and fifth digits. Two years after the initial repair, he presented with persistent flexion contractures and rupture of the A2 and A4 pulleys of the fourth and fifth digits. (Figure 1)

After extensive tenolysis, the A2 and A4 pulleys to the fourth and fifth digits were reconstructed by anchoring Flex HD (Ethicon Inc, Someville, NJ) subperiostially. (Figure 2) After reconstruction, there was no bowstringing of the flexor tendons and there was sufficient tension on the flexor tendons in order to facilitate full range of motion.

Figure 1: Extensive scar tissue and obliteration of A2 pulley in fourth digit



Figure 2: Acellular dermal matrix anchored in place for A2 pulley reconstruction



CASE 2 (DD)

The second patient was 20 year-old right hand dominant female who sustained a crush injury resulting in fractures of her left third, fourth and fifth proximal phalanges. Initially, the fractures were treated with open reduction internal fixation and subsequent zone 2 flexor tenolysis, as well as IP

contracture release of these fingers. She presented to our institution 6 months after the tenolysis with a chief complaint of inability to make a fist with her left third and fourth fingers. Intrinsic tightness on exam suggested there was extensive A2 scarring and rupture.

After performing an intrinsic release and tenolysis, it was observed that both A2 pulleys were obliterated, resulting in bowstringing. The pulleys were reconstructed by suturing Flex HD it to the periosteum extending from the proximal phalanx to the palm of the third and fourth digits and ensuring that there was complete tendon coverage. After repair, there was no bowstringing of the tendons with proximal pulling and the tendons glided easily back and forth.

CASE 3 (TY)

A right-hand dominant 20 year-old male sustained a right thumb zone 2 laceration from a fall onto glass while skateboarding two weeks prior to presentation. On exam, there was a laceration at the base of the right thumb, loss of sensation on the radial side of the thumb and inability to flex the thumb interphalangeal joint.

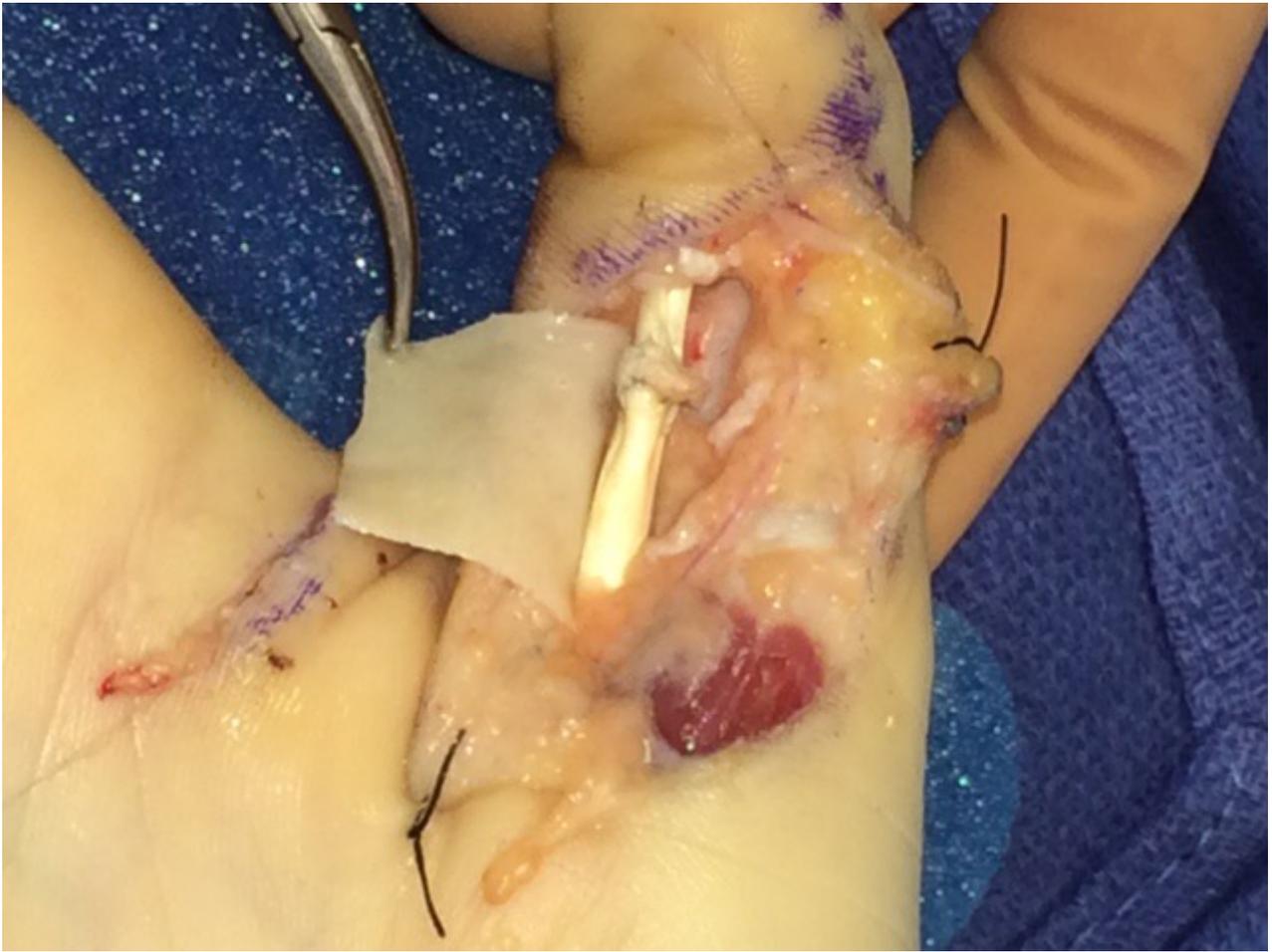
Intraoperatively, a lacerated radial digital nerve, extensive scarring of the flexor tendons (Figure 3), laceration of flexor pollicis longus and complete lacerations of the A2 and A4 pulleys were found. After extensive tenolysis, the flexor pollicis longus was repaired with modified Kessler and circumferential epitendinous sutures. The A2 pulley system was repaired by suturing acellular dermal matrix to the remainder of the pulley from the periosteum of the proximal phalanx, extending from the IP joint to the proximal phalanx, with 4-0 Mersilene suture. Following the reconstruction, the tendons passed easily underneath the new pulley system without bowstringing, clicking or obstruction.

Figure 3. Extensive scarring of the flexor tendons



Figure 4. Acellular dermal matrix was used to reconstruct the pulley system

a.



b.



CASE 4

This patient was a right-hand dominant 39 year-old female pianist who presented with a right ring finger flexion contracture of the DIP joint following a previous FDP avulsion injury five years prior. Following the initial injury, the patient subsequently underwent three surgeries, which included open reduction internal fixation of the DIP with screw placement and eventual tenolysis with hardware removal, followed by capsulotomy and tenolysis. On exam, she had a 45 degree flexion contracture of the DIP joint. The flexor digitorum profundus and superficialis tendons were intact and functional, however she was unable to actively extend her finger beyond 45 degrees and had approximately 20 degrees of flexion at the DIP. There was full range of motion at the PIP joint. Radiographs reveal an intact DIP joint space and a

healed fracture without other bony abnormalities. MRI demonstrated rupture of the pulley system, as well as significant scar contracture.

Significant scar tissue was noted to be enveloping the flexor digitorum superficialis and profundus(Figure 5a), thus extensive tenolysis from the proximal phalanx to the distal phalanx of the fourth digit was performed. The pulley system was obliterated from the A2 to the A4 pulley (Figure 5b) and proximal to this, the flexor tendons were significantly adherent. Thus, a proximal incision was made over the distal palmar crease of the fourth digit and a tenovagotomy at the A1 pulley was performed. Next, capsulotomy of the PIP joint was performed to bring the digit into full extension. This was followed by reconstruction of the A2 and A4 pulleys with acellular dermal matrix by suturing it to the periosteum extending from the middle phalanx to the proximal phalanx (Figure 6). There was no bowstringing observed after the reconstruction, and both the FDS and FDP tendons were noted to be gliding independently with finger flexion and extension. Intra-operative cultures grew out *Enterococcus* and she was given ampicillin-sulbactam peri-operatively. She did not develop a subsequent surgical site infection.

Figure 5. Extensive scarring (a) and bowstringing of the flexor tendons at the obliterated A2 pulley of the ring finger.

a.



b.



Figure 6. A2 pulley reconstruction with acellular dermal matrix



CASE 5 2 pulleys

The last patient is a right hand dominant 31 year-old male who previously sustained a laceration of the left middle finger flexor digitorum profundus which was repaired at an outside hospital. Despite aggressive hand therapy, he presented with a fixed flexion contracture of the PIP joint. Thus, he was taken to the operating room for extensive tenolysis and reconstruction of the A2 and A4 pulleys; the FDP was noted to be intact. Occupational therapy was initiated 2 weeks post-operatively, however, 2 years after this repair, he presented with a recurrent flexion contracture of 110 degrees at the PIP.

He was taken to the operating theatre once again and we performed an extensive tenolysis, FDS tenotomy, and FDS to FDP tendon transfer. The A4 pulley was reconstructed with a remnant of a slip of the FDS while the A2 pulley was reconstructed with acellular dermal matrix, by suturing it to the fibrous

canal. Next, a piece of acellular dermal matrix was sutured from the A4 pulley to the A2 pulley in order to protect the tendon repair. It was sutured into the periosteum of the middle phalanx with multiple interrupted 4-0 mersilene sutures, and intra-operatively, the patient exhibited full passive extension and an active extension lag of 20 degrees.

Hand therapy was initiated one week after surgery and after therapy, he demonstrated a passive and active extension lag of 5 and 50 degrees, respectively.

All patients began early active therapy at 1 to 2 weeks post-operatively. At 3 weeks post-operatively all patients noted significantly improved range of motion and strength, which was sustained over the length of follow up (range: two to twelve months). Follow up ranged from 1 to 38 months (mean 10.2 months). There were no infections or foreign body reactions.

DISCUSSION

Given the unique challenges that plague flexor pulley reconstruction,¹ there has been a myriad of proposed yet imperfect solutions to this problem⁵⁻¹⁰ Biologic materials such as free tendon grafts^{16, 17} and fascia lata⁶ have been described in pulley reconstruction, however, postoperative immobilization results in stiffness. Other drawbacks of utilizing autologous tissues for pulley reconstruction include donor site morbidity and the tendency to form adhesions at the site of tendon repairs.² Thus, others have studied pulley reconstruction using synthetic materials, including Teflon,¹⁸ polyethylene tubes,¹⁰ and silicon,⁸ however, these materials are fraught with complications such as foreign body reactions, adhesions, and breakage.

In the past decade, acellular dermal matrices have become a mainstay in various areas of reconstruction, ranging from breast reconstruction,^{19, 20} ventral hernia repair,^{21, 22} to rotator cuff repair.^{23, 24} Acellular dermal matrices have also been utilized in hand reconstruction,¹¹⁻¹⁴ and basic science literature suggests that they prevent adhesion formation and support migration and proliferation of tendon progenitor cells,¹⁵ making it an attractive material for flexor pulley reconstruction. In this series, we have demonstrated the feasibility of using acellular dermal matrix in pulley reconstruction in both the acute and chronic setting. There were no complications such as infection, foreign body reactions, or adhesions.

As a retrospective case series, this article is limited by its small cohort size and lack of long term follow up. Nonetheless, this data sets the stage for further prospective studies to be conducted in order to elucidate the long-term results of flexor tendon pulley reconstruction with acellular dermal matrices.

CONCLUSION

In theory, the use of acellular dermal matrices in tendon sheath and pulley reconstruction allows for biologic incorporation and decreased adhesion formation. These advantages allow for earlier range of motion, better functional outcomes without donor site morbidity. Our case series demonstrates that acellular dermal matrices are a viable option for tendon sheath and pulley reconstruction after tenolysis in both the acute and chronic setting.

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