Flexor Tendon Repairs: Techniques, Eponyms, and Evidence

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The evolution in surgical technique and suture technology has provided an abundance of options for flexor tendon repairs. Multiple biomechanical studies have attempted to identify the best surgical technique based on suture properties, technical modifications, and repair configurations. However, the burgeoning amount of research on flexor tendon repairs has made it difficult to follow, and no gold standard has been determined for the optimal repair algorithm. Therefore, it seems that repairs are usually chosen based on a combination of familiarity from training, popularity, and technical difficulty. We will discuss the advantages, disadvantages, and technical aspects of some of the most common core flexor tendon repairs in the literature. We will also highlight the nomenclature carried through the years, drawings of the repairs referred to by that nomenclature, and the data that support those repairs. *(J Hand Surg Am. 2014;39(9):1846–1853. Copyright © 2014 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Flexor tendon injuries, repair, zone II, load to failure, repair site gapping, surgical technique.

Although there are multiple surgical techniques for zone II flexor tendon repairs, no consensus has been achieved on what is the gold standard. Strickland described the *ideal* repair as having the following characteristics: (1) easy suture placement, (2) secured knots, (3) smooth end-to-end tendon apposition, (4) minimal to no gapping at the repair site, (5) avoiding injury to tendon vasculature, and (6) having enough strength for early active postoperative motion.[1] In reality, no technique has completely filled these criteria.

What has been established is that with current suture technology, multiple core suture strands (≥ 4) crossing the repair site result in a stronger repair that is able to tolerate early postoperative active motion rehabilitation protocols. Repair strength is further increased by the use of higher suture caliber and stiffer suture materials. The addition of an epitendinous stitch improves biomechanical strength of repairs, minimizes gapping, and helps reduce cross-sectional area, which in turn decreases gliding friction. Knots are also the weakest component of the repair, and their location matters. Pruitt et al showed in an *in vivo* canine study that placement of internal knots was inferior to outside knot placement in terms of overall biomechanical strength at day 0. However, internal knots demonstrated equivalent tensile strength at 6 weeks compared to external knots.[2] In terms of gliding friction from external knot placement, Momose et al also demonstrated that 2 lateral sided knots had more friction than 1 volar-sided or 1 lateral-sided knot.[3]

However, there is great variability among the repair configurations, and it is easy to confuse different eponyms for the classic (eg, Kirchmayr, Kessler, etc), modified classic (eg, Pennington, Tajima, etc), and modern repairs (eg, Winters-Gelberman, Lim-Tsai, etc). Various repairs over time have assumed multiple eponyms and descriptions, creating confusion

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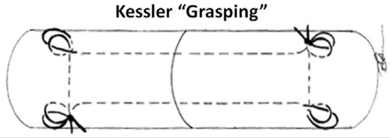
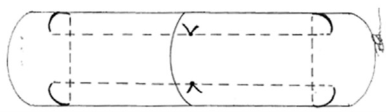
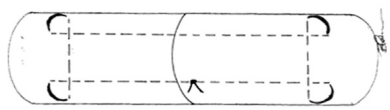
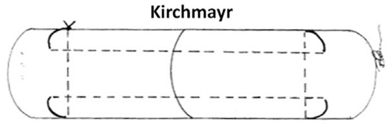
Technique 2-Stranded Core Repairs	# Core Strands # Knots & Location # Sutures	Suture Size/Type	2 mm Gapping Load (N) (unless otherwise stated)	Failure Load (N)	Epitendinous Suture
Kessler "Grasping" 	• 2 • 2 External Knots • 2 Sutures	No recent articles discussing the original form of the Kessler "Grasping" Repair			
Tajima "Modified Kessler" 	• 2 • 2 Internal Knots • 2 Sutures	4-0 Braided Nylon	30 (initial)	32	Yes
Pennington "Modified Kessler" Single Repair 	• 2, 4 • 1-2 Internal Knots • 1 Suture • Modification: Double repair using 1-2 sutures or double stranded suture	3-0 FiberWire® Single	54	65	Yes
		4-0 Ethibond® a)Single b)Doubled	a)14 b)26	a)39 b)66	Yes
		3-0 Ticron™ a)Single b)Doubled	a)21 b)57	a)35 b)68	Yes
Kirchmayr 	• 2 • 1 External Knot • 1 Suture	No recent articles discussing the original form of the Kirchmayr repair			

FIGURE 1: Two-stranded flexor tendon repairs. The repair and biomechanical data for common 2-stranded repairs depicted above include the original Kessler repair, Tajima modified Kessler, Kirchmayr repair, and Pennington repair. The Pennington has historically and erroneously been called a *modified Kessler* in many studies and is likely a modification of the Kirchmayr repair.[4–8]

in the literature. A recent historical review article by Sebastin et al describes this dilemma and proposes a conventional naming system based on core suture strands, number of knots, and type of repair.[4] In their article, they astutely highlight the confusion associated with the term *modified Kessler*, which actually refers to repairs that modify the 2-strand Kirchmayr repair, not the Kessler repair as originally described.[4]

More recently, improvements in suture design and technology have renewed interest in barbed suture and stainless steel wire in flexor tendon repairs.

2-STRAND REPAIRS

We present the biomechanical data for common 2-strand repairs, such as the Pennington and Tajima *modified Kessler* repairs, in Figure 1.[4–8] As discussed by Sebastin et al, these modifications are likely alterations of the Kirchmayr repair, not the original Kessler grasping repair.[4] The major differences in technique deal with knot placement and type of loop used to pass the suture through the tendon, which are outlined in the figures. The Pennington stitch has been commonly referred to as the *modified Kessler* and is doubled to create 4-core stranded repairs with either double-stranded suture, separate placement of 2 separate Pennington repairs leading to 2 knots, or continuous passage of suture to stack repairs adjacent to each other with 1 knot.

4-STRAND REPAIRS

With current suture technology, 4-strand repairs are the "minimum" number of core strands necessary for early motion exercises. We will discuss variations of the cruciate repair; Massachusetts General Hospital (MGH) repair, otherwise referred to as the augmented Becker repair; and the Strickland repair (Fig. 2).[6,7,9–17]

Cruciate repairs

Cruciate repairs are one of the most commonly performed repairs in flexor tendon surgery and are commonly the control repair in numerous studies evaluating different repair configurations. The original cruciate repair designed by McLarney et al was a grasping (nonlocking) repair technique. However, locking configurations have been shown to be biomechanically superior to grasping (nonlocking) configurations.[9]

Croog et al compared the biomechanics of different locking cruciate configurations: simple lock, circle