Barbed Sutures and Tendon Repair—a Review

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Abstract

Introduction Traumatic tendon lacerations are a common problem encountered by hand surgeons worldwide. Although the use of barbed suture to repair tendon lacerations has gained theoretical popularity in recent years, there is little information available regarding the safety, efficacy, longevity, or complications encountered when used in tenorrhaphy. In this study, we review the available literature on the use of barbed suture in tendon repair.

Methods Studies conducted between 1980 and 2014 were identified using several databases, including EMBASE, SCOPUS, MEDLINE, and Web of Science. Keywords used to search for appropriate studies included the following: barbed, v loc, quill, tendon, tendon injuries, suture, tenorrhaphy, injury, and laceration, in various combinations.

Results Our initial literature search identified 47 articles, and 8 were deemed appropriate for review after applying our exclusion criteria. The data from each of the articles is reviewed for the following major categories:

1. Maximum load to failure
2. Mode of failure
3. Load to 2-mm gap
4. Change in cross-sectional area
5. Type of repair

Conclusions Barbed suture tenorrhaphy has a myriad of theoretical advantages, supported by varying ex vivo studies, as compared to traditional techniques. However, due to the non-uniformity in current studies and the lack of available data in a live model, we are unable to argue for or against barbed suture

tenorrhaphy. We believe our review provides the most in-depth analysis of barbed suture tenorrhaphy to date, illuminates the potential advantages of using barbed sutures, and highlights the need for further investigation into this technique.

Keywords Tendon · Tenorrhaphy · Barbed suture · V-Loc · Quill · Tendon repair · Tendon laceration

Introduction

Traumatic tendon lacerations are a common problem encountered by hand surgeons worldwide. The prevalence of these injuries has lead to a large volume of research dedicated to finding the appropriate suture material for repair, the ideal suture technique, and the appropriate protocol for post-operative rehabilitation [4, 7, 12, 14, 19, 24, 26, 33, 38].

In most modern day tendon repairs, the surgical material used requires knots in order to secure the suture. Advances in repair techniques, including increasing the number of crossing strands at the repair site and the evolution of the epitendinous repair, demonstrate an increase in the strength of the tenorrhaphy [15, 24, 33, 38]. However, the increased bulk caused by fraying, excess suture material, knots, and bunching during repair can inhibit passage through the sheath [23, 29, 37]. To combat these issues, while also maintaining the suture strength necessary for proper healing, barbed sutures present a possible solution.

Barbed sutures are permanent sutures that have directional projections (or barbs) along their entire length. The suture is passed into the tissue in the opposite direction of the splay of the barb, allowing the suture to pass easily. When a force is applied in the opposite direction, the barb of the suture grasps the surrounding tissue and secures the tissue in place. These barbs provide multiple anchoring points when the suture is used in wound closure or for the apposition of tissues,

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allowing a more uniform distribution of force along the length of the suture [11]. The new generation of barbed suture has been shown to be comparable to an unbarbed wound closure technique with regard to appearance, resistance to wound gapping, and rate of dehiscence, and is thought to result in improvements in distribution of tension across the repair site [27]. Barbed sutures, while not a new phenomena in tendon repair [12], have seen a recent resurgence due to these favorable characteristics [8–10].

Although the use of barbed suture to repair tendon lacerations has gained theoretical popularity in recent years, there is little information available regarding the safety, efficacy, longevity, or complications encountered when used in tenorrhaphy. In this study, we review the available literature on the use of barbed suture in tendon repair.

Methods

Studies conducted between 1980 and 2014 were identified using several databases, including EMBASE, SCOPUS, MEDLINE, and Web of Science. Keywords used to search for appropriate studies included the following: barbed, v loc, quill, tendon, tendon injuries, suture, tenorrhaphy, injury, and laceration, in various combinations. Articles were excluded based on the following criteria:

1. Studies of tendons that were not located either in the hands of human models or the equivalent in animal models (i.e., Achilles repair, patellar tendon repair, etc.)
2. Studies of barbed suture repair that did not involve tendon repair (i.e., fascial repair, skin repair, meniscal repair, etc.)
3. Studies that did not have data comparing barbed suture to traditional suture repair of tendons
4. Studies where the primary focus was evaluating a new barbed suture device
5. Studies that did not provide objective data

Results

Our initial literature search identified 47 articles, and 8 were deemed appropriate for review after applying our exclusion criteria. The data from each of the articles is reviewed for the following major categories:

1. Maximum load to failure
2. Mode of failure
3. Load to 2-mm gap
4. Change in cross-sectional area
5. Type of repair

The multitude of variables within each study with regard to methodology and the type of repair performed requires that the articles be presented individually, rather than as an assimilation of data.

Maximum Load to Failure

All articles report data on the maximum tensile load to failure. The method of testing was significantly variable between the articles. See Table 1 for numerical details.

Positive Results

McClellan et al. reported results for a comparison of 3 groups of cadaveric porcine tendons: 22 repairs using 3-0 Ethibond Modified Kessler 2-strand repair, 22 repairs using 3-0 Ethibond Modified Savage repair, and 22 repairs using a knotless 4-0 novel barbed suture (Quill) repair. The tensiometer (Instron) was preloaded with 1.5 N and advanced at a rate of 20 mm/min. Their results demonstrate a statistically significant higher load to failure for the Savage and Knotless repair as compared to the Modified Kessler repair. There was no significant difference between the modified Savage repair and the barbed suture repair [21].

Parikh et al. compared five groups of human cadaveric tendons, with eight tendon repairs in each. Tendons repaired using a novel 2-0 barbed suture (Quill) 3 strand or a novel 2-0 barbed suture 6-strand repair were compared to tendons repaired with a cruciate 4-0 prolene, a 4-0 ethibond, or a 4-0 fiberwire. The tensiometer (Mini Bionix) was preloaded to 2 N and distracted at a rate of 50 mm/min. Their results demonstrate a statistically significant higher load to failure for the 6-strand 2-0 Quill barbed suture repair as compared to the remaining groups and no statistically significant difference between the three-strand barbed suture repair as compared to the unbarbed repairs [29].

Lin et al. compared 2 groups of human cadaveric tendons consisting of 11 tendons each: one group repaired using a modified four-strand Kirchmayr-Kessler 3-0 braided polyester, the other using a modified four strand Kirchmayr-Kessler 0 V-Loc as described by Zeplin [39], with the tensiometer (Instron) preloaded to 1 N and distracting at a rate of 20 mm/min. Their results demonstrate a statistically significant higher load to failure for the barbed suture group as compared to the unbarbed group [18].

Peltz et al. compared 3 groups of cadaveric sheep tendons—15 four-strand Adelaide 3-0 Ticron traditional repairs, 15 novel 3D four-strand 3-0 V-Loc barbed suture repairs, and 10 novel 3D four-strand 3-0 Ticron traditional suture repairs—after preloading the tensiometer (Mini Bionix) to 3 N and distracting at a rate of 20 mm/min. Their results reveal a statistically significant higher load to failure for the

Table 1 Load to failure

Publication	Year	Groups	Load to failure (N)	<i>p</i> value
McClellan et al.	2011	A=Modified Kessler 3-0 Ethibond B=Savage 3-0 Ethibond C=Knotless Repair 0 Quill	32.03±5.36 69.18±8.96 72.39±15.16	<i>p</i> <0.05: knotless and Savage had significantly greater ultimate strength than Kessler
Parikh et al.	2009	2-0 Quill 6 strand 2-0 Quill 3 strand 4-0 Prolene (polypropylene) 4-0 Ethibond (braided polyester) 4-0 Fiberwire	88±4 36±7 29±7 30±8 40±11	b3str vs ub, <i>p</i> =0.32; b6str vs ub, <i>p</i> <0.001; b3str vs b6str, <i>p</i> <0.001
Lin et al.	2013	A=Modified 4 strand Kirchmayr- Kessler 3-0 Ethibond B=Knotless 4 strand repair 0 V-Loc	42.3±12.7 52.3±12.5	<i>p</i> =0.01
Zeplin et al.	2011	2-strand 3-0 Polydioxane Knot (A) 3-0 Glycoliccarbonate Knotless (B) 4-strand 3-0 Polydioxane Knot C 3-0 Glycoliccarbonate Knotless (D)	94±10.5 38±6.1 149.5±7.0 145.6±16.1	2str knot vs knotless, <i>p</i> <0.001; 4str vs 2str, <i>p</i> <0.001; 4str knot vs knotless, <i>p</i> =0.0737
Marrero- Amadeo et al.	2011	A=Tajima w/Horiz Mattress 4 strand 4-0 surgilon B=Mod Kirsch Kess 4 strand with 3 tranverse passes 2-0 Quill	48±12 50±14	<i>p</i> =0.48
	2013	A=Traditional 4 strand Adelaide Repair 3-0 Prolene B=Knotless 4 strand Adelaide Repair 2-0 V-Loc	52.0±11.3 55.5±4.7	<i>p</i> >0.05
Peltz et al.	2013	A=4 strand Adelaide 3-0 Ticron B=V Loc 3D repair C=3-0 Ticron 3D repair	48.6±5.9 61.5±9.3 47.2±6.3	barb vs Ade, <i>p</i> =0.002; barb vs conv sutur, <i>p</i> <0.001; Ade vs Conv, <i>p</i> =0.623
Trocchia et al.	2009	A=3-0 Ethibond Kessler B=2-0 Quill Kessler-Bunnel	34.7±5.4 29.6±3.6	<i>p</i> =0.001

barbed suture repair as compared to both the traditional Adelaide repair and the 3D traditional suture repair [30].

Equivalent Results

Joyce et al. compared 2 groups of porcine cadaveric tendons: 20 tendons repaired by a four-strand Adelaide 3-0 Prolene traditional suture repair and 20 tendons repaired by a modified Adelaide 2-0 V-Loc barbed suture repair. The tensiometer (Zwick) was preloaded to 1.5 N and distracted at a rate 20 mm/min. Their results demonstrate no significant difference between the barbed suture and traditional repairs [13].

Marrero-Amadeo et al. compared 2 groups of human cadaveric tendons—21 novel 2-0 Quill suture repairs versus 20 four-strand 3-0 surgilon Tajima and horizontal mattress with a 6-0 nylon epitendinous suture—after preloading the tensiometer (Alliance RT/S Materials Testing System) to 1 N and distracting at a rate of 100 mm/min. Their results demonstrate no significant difference between the barbed suture and traditional repairs [20].

Zeplin et al. compared 4 groups of human cadaveric tendons consisting of 15 tendon repairs in each group—modified Kirchmayr-Kessler 2-strand and 4-strand 3-0 V-Loc barbed suture repair versus modified Kirchmayr-Kessler 2-strand and

4-strand 3-0 PDS traditional suture repair—after preloading the tensiometer (Zwick/Roell) to 1 N and distracting at a rate 20 mm/min. Their results demonstrate a higher load to failure for the four-strand repairs as compared to the two-strand repairs, but no difference between the four-strand unbarbed and barbed suture repair [39].

Negative Results

Trocchia et al. compared 2 groups of human cadaveric tendons consisting of 20 tendon repairs—Kessler-Bunnel 2-0 Quill barbed suture repair to Kessler 3-0 Ethibond traditional suture repair—after preloading the tensiometer (858 Bionix; MTS) to 2 N and distracting at a rate of 50 mm/min. Their results revealed a statistically significant higher load to failure for the traditional repair as compared to the barbed suture repair [35].

Mode of Failure

Of the eight articles, four comment on the mode of failure during the application of maximum tensile load. See Table 2 for further details.

Table 2 Mode of failure

Publication	Year	Groups	Mode of failure						p value
			Suture breakage		Knot rupture		Pullout		
			Frequency	Load (N)	Frequency	Load (N)	Frequency	Load (N)	
Parikh et al.	2009	2-0 Quill 6 strand	6/6 (100 %)	Not reported	N/A	Not reported	0/6	Not reported	b vs ub, $p<0.001$
		2-0 Quill 3 strand	7/8 (88 %)		N/A		1/8 (12 %)		
		4-0 Prolene (polypropylene)	0/8		5/8 (63 %)		3/8 (37 %)		
		4-0 Ethibond (braided polyester)	0/8		7/8 (88 %)		1/8 (12 %)		
Marrero-Amadeo et al.	2011	4-0 Fibervire	0/8		6/8 (75 %)		2/8 (25 %)		Max load and suture rup - trad vs. barb, $p=0.90$
		A=Tajima w/Horiz Mattress 4 strand 4-0 surgilon	13/20 (65 %)	52±13	7/20 (35 %)	43±11	N/A	N/A	
		B=Mod Kirsch Kess 4 strand with 3 transverse passes 2-0 Quill	7/21 (33 %)	63±16	N/A	N/A	14/21 (67 %)	43±8	
Peltz et al.	2013	A=4 strand Adelaide 3-0 Ticron	14/29 (48 %)	Not reported	13/29 (45 %)	Not reported	1/29 (3 %)	Not reported	Not reported
		B=V Loc 3D repair	10/15 (67 %)		N/A		5/15 (33 %)	N/A	
		C=3-0 Ticron 3D repair	0/10		6/10 (60 %)		4/10 (40 %)	0/10	
Trocchia et al.	2009	A=3-0 Ethibond Kessler	Not reported		18/20 (90 %)	Not reported	2/20 (10 %)	Not reported	Not reported
		B=2-0 Quill Kessler- Bunnel			0/20		20/20 (100 %)		

Table 3 Load to 2-mm gap

Publication	Year	Groups	Load to 2-mm gap	<i>p</i> value
McClellan et al.	2011	A=Modified Kessler 3-0 Ethibond B=Savage 3-0 Ethibond C=Knotless Repair 0 Quill	23.45±5.32 59.22±15.12 62.84±17.30	<i>p</i> <0.05: knotless and Savage had significantly greater 2-mm gap formation force than Kessler
Lin et al.	2013	A=Modified 4 strand Kirchmayr- Kessler 3-0 Ethibond B=Knotless 4 strand repair 0 V-Loc	11.7±4.5 10.9±3.8	<i>p</i> =0.62
Marrero-Amadeo et al.	2011	A=Tajima w/Horiz Mattress 4 strand 4-0 surgilon B=Mod Kirsch Kess 4 strand with 3 tranverse passes 2-0 Quill	42±12 32±9	<i>p</i> =0.90
Joyce et al.	2013	A=Traditional 4 strand Adelaide Repair 3-0 Prolene B=Knotless 4 strand Adelaide Repair 2-0 V-Loc	41.5±10.9 46.5±5.5	<i>p</i> <0.05
Trocchia et al.	2009	A=3-0 Ethibond Kessler B=2-0 Quill Kessler-Bunnel	22.8±6.3 22.2±4.0	<i>p</i> =0.723

In the study by Parikh et al., the majority of the barbed suture repairs failed through suture breakage, and the majority of the traditional repairs failed through knot rupture—this difference was statistically significant [29].

In the study performed by Marrero-Amadeo et al., the majority of the traditional repairs failed through suture breakage and a minority failed through knot rupture—none failed through suture pull out. The majority of the barbed suture repairs failed through suture pullout, and the minority failed through suture breakage [20].

In the study performed by Peltz et al., the Adelaide traditional suture repair mode of failure was split nearly evenly among suture breakage and knot rupture. However, the novel 3D unbarbed suture repair mode of failure was split nearly evenly among knot rupture and suture pullout. The majority of failures in the barbed suture repair were due to suture breakage, with a minority due to suture pull out [30].

In the study performed by Trocchia et al., the majority of failures in the group of traditional suture repairs were due to knot rupture, whereas all failures in the group of barbed suture repairs were due to suture pull out [35].

Load to 2-mm Gap

Five of the eight studies reported data on the load required to create a 2-mm gap within the repair site. See Table 3 for further details.

Positive Results

McClellan et al. found that barbed suture repair and the Savage traditional suture repair had a statistically higher load to 2-mm gap than the Modified Kessler traditional suture repair. However, there were no significant differences between the barbed suture repair and the Savage repair [21].

Joyce et al. found that the barbed suture repair had a statistically higher load to 2-mm gap than the Adelaide traditional suture repair [13].

Equivalent Results

Trocchia et al., Lin et al., and Marrero-Amadeo et al. found no statistically significant differences in load to 2-mm gap

Table 4 Change in cross-sectional area

Publication	Year	Groups	Cross-sectional area (mm ²)	Change in cross-sectional area	Cross-sectional area ratio	<i>p</i> value
McClellan et al.	2011	A=Modified Kessler 3-0 Ethibond B=Savage 3-0 Ethibond C=Knotless Repair 0 Quill	32.3* 31.9* 24.4*	+14.3±5.55 +13.6±3.35 +7.10±4.58	Not reported	* <i>p</i> <0.01
Joyce et al.	2013	A=Traditional 4 strand Adelaide Repair 3-0 Prolene B=Knotless 4 strand Adelaide Repair 2-0 V-Loc		+7.7±6.7 % +2.8±0.4 %		<i>p</i> <0.001
Parikh et al.	2009	2-0 Quill 6 strand 2-0 Quill 3 strand 4-0 Prolene 4-0 Ethibond 4-0 Fiberwire			1.2±0.1 1.2±0.2 1.6±0.2 1.3±0.3 1.2±0.2	b3str vs ub, <i>p</i> =0.009; b6str vs ub, <i>p</i> =0.005, b3str vs b6str, <i>p</i> =0.62

**p*<0.01

Fig. 1 Novel barbed suture repair using modified four-strand Kirschmayr-Kessler. Figure taken from Lin et al. [18]

between the barbed suture repair and the traditional suture repair (Kessler and Tajima) [35, 18, 20].

Change in Cross-Sectional Area

Three of the eight studies reported data on the change in cross-sectional area after tenorrhaphy. All studies with data reported a smaller change in cross-sectional area with barbed suture repairs as compared to traditional repairs. See Table 4 for further detail.

McClellan et al. found that the change in tendon size with the knotless technique was significantly less than with the Savage and Kessler techniques [21].

Joyce et al. reported that change in tendon size with the knotless technique was significantly less than with the traditional Adelaide repair [13].

Parikh et al. measured the ratio of the cross-sectional area of repaired tendon to that of uninjured tendon, and reported the data as such. A significant decrease in repair-site bunching

was observed between both barbed repair groups and all control cruciate groups. No significant difference was observed between barbed suture groups [29].

Type of Repair

All eight studies reported data on how the barbed suture tenorrhaphy was performed. Most developed a novel method of barbed suture repair based upon previously known traditional suture techniques.

The most frequently encountered barbed suture repair was a modified four-strand Kirschmayr-Kessler [18, 20, 39] (see Fig. 1). Marrero-Amadeo, while performing a version of the modified four-strand Kirschmayr-Kessler, makes an alteration at the end of the repair in which there are multiple passes through the tendon to lock it in place (see Fig. 2) (Table 5).

McClellan et al. performed a novel barbed suture repair technique that incorporates elements of both the modified Kessler and the Savage method [21] (see Fig. 3), Parikh

Fig. 2 Novel barbed suture repair using modified four-strand Kirschmayr-Kessler with alteration. Figure taken from Marrero-Amadeo et al. [20]

Table 5 Type of repair

Publication	Year	Groups	Uni or bi directional?	Number of throws of knots	Epitendinous?	Technique for knotless
McClellan et al.	2011	A=Modified Kessler 3-0 Ethibond B=Savage 3-0 Ethibond C=Knotless Repair 0 Quill	Bi	6 6 N/A	No	Novel
Parikh et al.	2009	2-0 Quill 6 strand 2-0 Quill 3 strand 4-0 Prolene (polypropylene) 4-0 Ethibond (braided polyester) 4-0 Fiberwire	Bi	Not divulged	No	Novel
Lin et al.	2013	A=Modified 4 strand Kirchmayr- Kessler 3-0 Ethibond B=Knotless 4 strand repair 0 V-Loc	Uni	4	No	Modified 4 strand Kirchmayr- Kessler
Zeplin et al.	2011	2-strand 3-0 Polydioxane Knot (A) 4-strand 3-0 Glycoliccarbonate knotless (B)	Uni	Not divulged	No	Modified 4 strand Kirchmayr- Kessler
Marrero-Amadeo et al.	2011	A=Tajima w/Horiz Mattress 4 strand 4-0 surgilon B=Mod Kirsch Kess 4 strand with 3 tranverse passes 2-0 Quill	Bi	5	Yes 6-0 Ethilon locking For only the traditional	Modified 4 strand Kirchmayr- Kessler With extra suture passes at end
Joyce et al.	2013	A=Traditional 4 strand Adelaide Repair 3-0 Prolene B=Knotless 4 strand Adelaide Repair 2-0 V-Loc	Bi	Not divulged	No	Novel Adelaide
Peltz et al.	2013	A=4 strand Adelaide 3-0 Ticron B=V Loc 3D repair C=3-0 Ticron 3D repair	Bi	5	No	3D method
Trocchia et al.	2009	A=3-0 Ethibond Kessler B=2-0 Quill Kessler-Bunnell	Uni	Not Divulged	No	Kessler-Bunnell

et al. performed a novel repair that resembles a multi-stranded cruciate repair [29] (see Fig. 4), and Joyce et al. created a technique that is best described as a variation of the traditional Adelaide repair [13] (see Fig. 5). Peltz et al. performed a novel 3D barbed suture repair [30] (see Fig. 6), and Trocchia performed a variation of the Kessler-Bunnell technique [35] (see Fig. 7).

Of note, five studies used a bi-directional barbed suture (Quill) and three studies used a unidirectional barbed suture (V-Loc). Only one of eight studies used an epitendinous suture, and this was only performed for the control (traditional) group.

Fig. 3 Novel barbed suture repair technique that incorporates elements of both the modified Kessler and the Savage method. Figure taken from McClellan et al. [21]

Discussion

The concept of using barbed suture for repair of skin and other tissue is not new. The first patent for barbed suture was filed in 1964, and in 1967, Mackenize described a barbed suture to repair lacerated tendons in hands [22]. In comparison to regular suture repair, barbs provide multiple anchoring points, allowing a more uniform distribution of tissue-holding forces [11]. Barbed suture, due to this theoretically favorable characteristic, has seen a recent resurgence in use in wound repair.

The search for an ideal method of tendon repair with the ideal suture material is ongoing. Absorbable suture, as demonstrated by several authors, can be used safely for flexor tendon repair [5, 28]. Research focusing on the method of repair has shown that an increased number of strands [3, 36], as well as epitendinous sutures [1, 17], will lead to improved outcomes.

The presence of knots in tendon repair is an interesting point of contention. There are several arguments that support the use of a knotless suture. First, knots add bulk to the repair site, which increases the cross-sectional area of the tendon. If the cross-sectional area is increased, the gliding resistance through the pulley system is also increased [2, 6, 25].

Fig. 4 Novel repair resembling a multi stranded cruciate repair. Figure taken from Parikh et al. [29]

Therefore, if a robust knot is created (five throws) [34], gliding will be impeded. Second, it is possible that the knot is the weak point of the tendon repair because of decreased tensile strength of the suture [16, 34]. Third, if the knot is located between the tendon ends, the apposition of the repair may be decreased [32].

In light of the previously mentioned issues with conventional tendon repair, the advantages to barbed suture tenorrhaphy become self-evident. Because the suture has barbs, the potential surface area of interaction between the suture and the tendon is increased. This increased interaction between the suture and the tendon in turn theoretically increases the force needed to separate a tendon repair. Furthermore, the use of unidirectional barbs could obviate the need for knots, thereby overcoming the issues caused by knots in traditional repair techniques.

Fig. 5 Variation of the traditional Adelaide repair. Figure taken from Joyce et al. [13]

Fig. 6 Novel 3D barbed suture repair. Figure taken from Peltz et al. [30]

The data assimilated in this review largely support the theoretical advantages attributed to barbed suture repair as compared to traditional suture tenorrhaphy. In all but one study reviewed, the maximum load to failure of the barbed suture repair was either greater than or statistically equivalent to the traditional suture tenorrhaphy. This includes one study in which the barbed suture was compared to a traditional suture repair with an epitendinous repair. These results support the notion that barbed suture repair is stronger than or at least as strong as traditional suture repair, while avoiding the detriments associated with placing knots. Furthermore, the one study in which the traditional repair was found to have a statistically significant advantage over the barbed suture repair demonstrated an absolute difference of only 5 N in terms of load to failure, underscoring the apparently minimal difference between the two methods of repair. All studies with reportable data regarding the load to 2-mm gap reiterate these results, demonstrating either a higher load to 2-mm gap for the barbed suture repair or at least statistically equivalent loads. Perhaps, most important is the data regarding the change in cross-sectional area—all studies with data reported a smaller change in cross-sectional area with barbed suture repairs as compared to traditional repairs. This data implies that the tendon repaired with a barbed suture technique will glide with less impedance through its respective pulley than the tendon repaired in a traditional fashion (which would require knots).

There are, however, problems with using this data to exclusively support the notion that barbed suture repair should

Fig. 7 Novel barbed suture repair variation of the Kessler-Bunnell technique. Figure taken from Trocchia et al. [35]

replace traditional tenorrhaphy techniques. It is important to note that the details of repairs performed in both the barbed suture and the traditional repair groups varied greatly from study to study. In addition, the methodology of measuring strength/loads to failure differs depending on the study. Without some consistency between reports, it is difficult to make definitive statements regarding the absolute usefulness of the varying techniques. Due to these variances, the data itself cannot be assimilated as would be done in a true meta-analysis. Furthermore, only one of the included studies used an epitendinous repair to augment the strength of either the traditional or barbed suture repair, as would almost certainly be performed in a “gold-standard” tendon repair. To put it simply, the current literature is mixed.

Still, the most striking concern is that in spite of the overwhelming theoretical support for barbed suture repair throughout hand, orthopedic, and plastic surgery literature, the support remains only “theoretical” in nature. All studies regarding barbed suture tenorrhaphy at this point in time are *ex vivo* studies, performed in either cadaveric human or animal models. There are no studies of barbed suture tenorrhaphy in either a live animal or human model, and therefore, no available data regarding the ability of a repair to withstand *in vivo* forces. There is no data regarding how well a tendon repaired with a barbed suture technique is able to glide through a pulley, no data demonstrating a barbed suture repaired tendon can maintain the same range of motion as compared to a traditional repair over time, and no data assessing whether a tendon repaired with a barbed suture is prone to develop more (or less) adhesions than a traditional repair. It should be noted that one *in vivo* study in turkeys was identified in our initial literature search, and that it showed more tendon repair failures in a barbed suture group compared with the conventional knotted repair group. It also showed that biomechanical testing after 6 weeks was more stable in the conventional repair group compared with the barbed suture group [31]. However, this study was excluded from our review based on the presentation of data in an only qualitative fashion. Without more quantitative data, no true conclusions can be drawn.

A study to address the variations of the current literature could be designed. The design should compare groups of tendon repairs with unidirectional barbed suture, bidirectional barbed suture, and 4-0 fiberwire suture. The barbed suture repairs should all be done in the same fashion, whether it is a novel repair or a variation of a currently performed repair. The traditional suture repair should be one of the standard time-tested repairs with an epitendinous suture, in order to simulate a gold standard repair. All tendon repairs should be subjected to the same tensiometer settings. However, the most important aspect of the new study is the use of an *in vivo* animal model. After this study is performed, future authors can consider the same comparison of repairs in a live human model.

Conclusion

Barbed suture tenorrhaphy has a myriad of theoretical advantages, supported by varying *ex vivo* studies, as compared to the multitude of time-tested traditional tenorrhaphy techniques. However, due to the non-uniformity in current studies and the lack of available data in a live model that can simulate the true biologic forces acting upon the tendon repair and its subsequent function, we are unable to argue for or against barbed suture tenorrhaphy. We believe our review provides the most in-depth analysis of barbed suture tenorrhaphy to date, illuminates the potential advantages of using barbed sutures, and highlights the need for further investigation into this technique.

Conflict of Interest AS declares that he has no conflict of interest.

MR declares that she has no conflict of interest.

AA declares that he has no conflict of interest.

Statement of Human and Animal Rights This article does not contain any studies with human or animal subjects.

Statement of Informed Consent Informed consent is not necessary in this study as it is a review of the available literature on the topic.

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