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Loop and knot security of a novel arthroscopic sliding-locking knot using high-strength sutures

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ABSTRACT

Objective: We evaluated the loop and knot security of a novel arthroscopic knot, the Wiese knot, using different types of sutures.
Methods: The Wiese knot was tied using four different brands of braided sutures (Ethibond, Orthocord, FiberWire, and UltraBraid) with and without a series of three reversing half-hitches (RHAPs) and tested for loop and knot security.
Results: Orthocord provided the greatest amount of loop security. FiberWire delivered the highest knot security. UltraBraid had the greatest ultimate force. Three half-hitches increased the maximal load to clinical failure.
Conclusion: The biomechanical characteristics of the Wiese knot are affected by suture material qualities.

1. Introduction

The goal of arthroscopic rotator cuff and labral repair is to appose and secure soft-tissue to bone until healing occurs, which often requires the use of arthroscopic knots. Effective knots possess optimal knot and loop security. Loop security describes the knot's propensity to juxtapose soft tissue to bone while the surgeon is tying the knot.[1] Knot security is the ability of the knot to resist slippage, which depends on friction, internal interference, and the slack between throws. Knot security describes the knot's capacity to maintain the apposition of soft-tissue to bone.[1]

Multiple studies have shown that knot and loop security are dependent on knot configuration, suture material, and instrumentation used to tie arthroscopic knots.[1–14] Although numerous arthroscopic knot types and suture material exist, consensus on the best combination has yet to be determined. As new suture material, arthroscopic instrumentation, and knot configurations are developed, biomechanical studies assessing knot and loop security should be performed.

The Wiese knot is an arthroscopic knot that is both sliding and locking.[15] Similar to other knots, it is looped through itself to allow adequate friction. The locking feature sets this knot apart from others in that pulling the contralateral limb allows the knot to change configuration and lock into place.[15] The purpose of this study was to assess the loop and knot security of the Wiese knot, with and without half-hitch configurations, using various commercially available suture materials in order to compare the biomechanical characteristics of this novel knot to other knots already described in literature.

1.1. Methods

The protocol for this study was approved by the institutional review board (IRB).

The knot and loop security were tested using No. 2 size sutures with four brands of braided sutures: FiberWire (Arthrex, Naples, FL), Orthocord (DePuy Synthes Mitek, Raynham, MA), UltraBraid (Smith and Nephew, Andover, MA), and Ethibond (Ethicon US, Somerville, NJ).

Forty total loops were tied; five loops tied with each of the four suture brands using the Wiese knot, and five loops tied in each of the four suture brands using the Wiese knot backed up by 3 reversing half-hitches on alternating posts (RHAPs) (Fig. 1). Although the Wiese knot is a sliding knot with locking capability, loops were tested with three RHAPs because this more closely mirrors clinical practice. All loops were tied by a single, fellowship-trained attending shoulder surgeon who uses the Wiese knot in clinical practice.

Each knot was tied around a 31.4 mm-circumference metal dowel, which is included in the Fundamentals of Arthroscopic Surgery Training (FAST [Sawbones, Vashon Island, WA]) module to ensure a consistent loop circumference of 31.4 mm before locking the knot or throwing the three RHAPs. The 31.4 mm-circumference dowel was chosen because a

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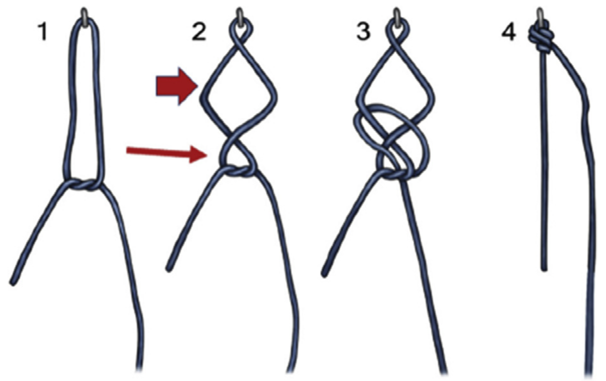

Fig. 1. Depiction of tying the Wiese knot. Image reproduced with approval. Parada SA, Shaw KA, Eichinger JK, Boykin NT, Gloystein DM, Ledford CL, Arrington ED, Wiese PT. The Wiese knot: a sliding-locking arthroscopic knot. Arthroscopy Techniques. 2016:e1-4.

Table 1
Average loop security, knot security, and ultimate force to failure of multiple suture brands with and without three reversing half-hitch on alternating posts (RHAPs). *Italics** = without RHAPs.

Suture Brand	Loop Security (mm)		Knot Security (N)		Ultimate Force (N)	
	Mean	*St.Dev*	*Mean*	*St.Dev*	*Mean*	*St.Dev*
*dEthibond**	31.7	0.5	80.2	16.9	103.6	30.2
*FiberWire**	31.5	0.2	33.2	13.5	38.1	15.7
*Orthocord**	30.7	0.7	28.1	18.9	35.6	19.9
*UltraBraid**	31.5	0.4	29.7	11.4	41.0	8.9
Ethibond	30.5	0.8	119.5	10.4	142.4	8.4
FiberWire	31.3	0.2	230.7	20.3	260.3	22.1
Orthocord	30.4	0.4	180.5	4.1	228.9	27.9
UltraBraid	31.9	0.6	207.7	11.1	274.9	18.2

30 mm loop length has been shown to be a representative length of suture loop used to attach soft tissue to bone in shoulder surgery in previous studies of loop and knot security[9] and the 31.4 mm dowel is easily provided by the FAST module. Each loop was tested on an Instron ElectoPuls E10000 Linear Test Instrument (Instron, Norwood, MA) (Fig. 2).

A 5 N (N) preload was applied to each loop prior to testing to remove slack from the system at a load well below those seen clinically in the shoulder, and has been used in prior studies of loop and knot security.[9,10] The loop circumference was measured at that time using the equation loop circumference = 2 × cross-head displacement + 4 × hook radius + hook circumference as previously described by Lo et al.[9] Each loop was tested to mechanical failure. Maximum tensile load (N) at failure, tensile load at 3 mm elongation (N), and method of mechanical failure (either knot slippage or material breakage) was recorded. Tensile load at 3 mm of elongation was chosen because loop elongation of greater than 3 mm is accepted in the literature as indicative of knot failure.[9] Crosshead speed was set for an elongation rate of 60 mm/min, or two times the length of loop being tested because this is the U.S. Pharmacoeia (USP) standard for suture tensile strength testing.

Data variables collected included loop security, knot security, maximum tensile force, and failure mechanism. Statistical comparison was made with a 1-way analysis of variance (ANOVA) method with $p \leq 0.05$.

2. Results

Loop security was statistically greater (indicated by smaller size) for

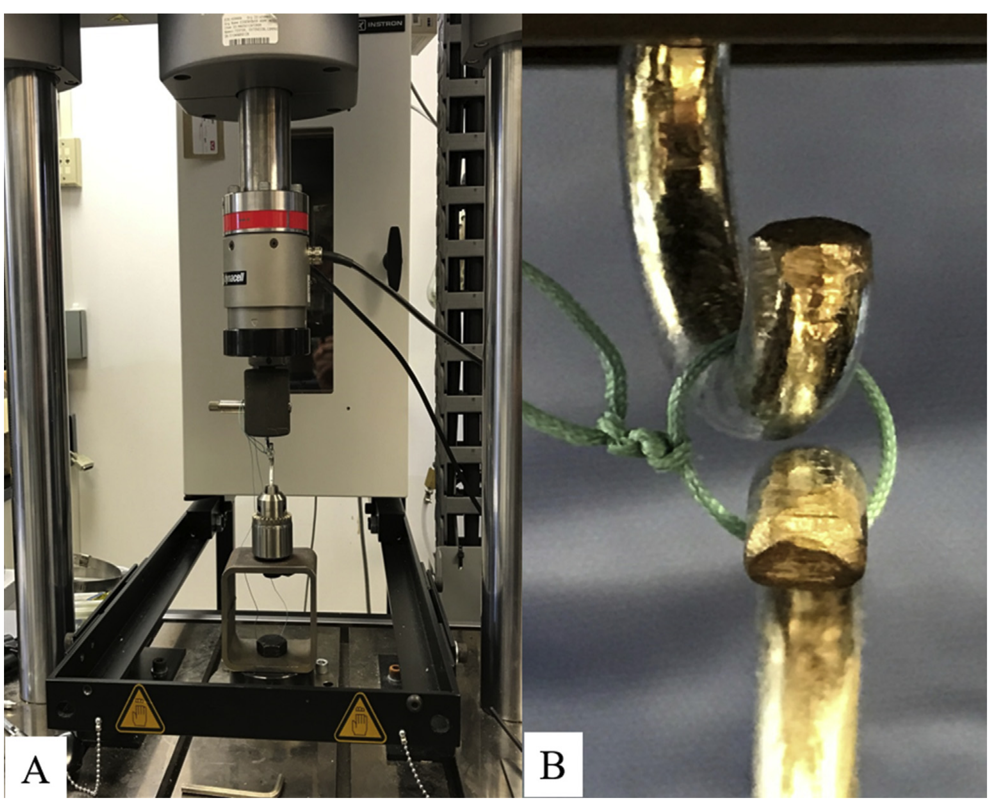

Fig. 2. Set-up for knot testing. A. Instron machine used for testing the biomechanical strength of suture loops. B. The loops were placed so that the knot was half-way between the Instron hooks.