Biomechanical Properties of Various Surgical Suture Needles in a Cadaveric Quadriceps Tendon Model

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Background

Quadriceps tendon autografts have experienced a rapid rise in popularity for anterior cruciate ligament (ACL) reconstruction due to advantages in graft sizing and potential improvement in biomechanics.

However, investigation into the biomechanical properties of stitch techniques in a quad tendon has been limited.

Sample Preparation

24 matched pair cadaveric knees were dissected, and a combined 48 quadriceps tendon grafts were harvested and standardized to the same size. Grafts were randomized into 3 groups (16 tendons per group), representing products from three different manufacturers (W, A, B). Matched pairs were categorized into subgroups for two different stitch methods (whip stitch (8) or locking stitch (8)). Graft preparation was completed by two fellowship-trained orthopaedic surgeons.

Table 1. Experimental test groupings

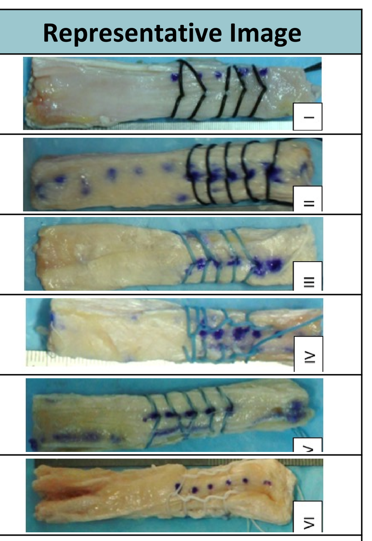
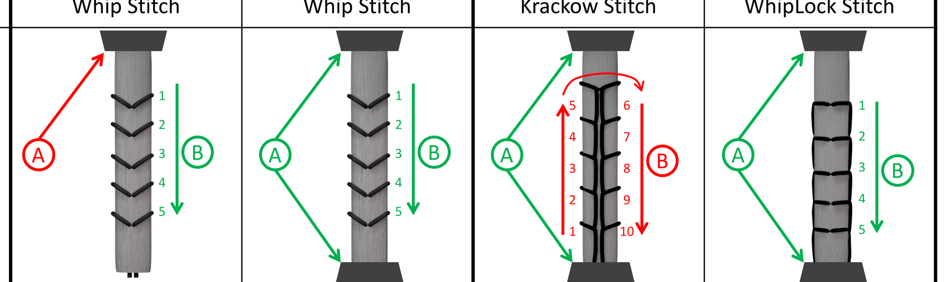
Group	Sample Size	Method	Representative Image
1 (Manufacturer W)	8	Whip Stitch	
	8	WhipLock	
2 (Manufacturer A)	8	Whip Stitch	
	8	Krackow	
3 (Manufacturer B)	8	Whip Stitch	
	8	Krackow	
Total	**48**		

Figure 1. Illustration of stitch methods and products

Needle Type	Loop Suture Needle	2-Part Needle	Curved Needle	2-Part Needle
Manufacturer (s)	A, B	W	A, B	W
Needle Illustration				
Stitch Method	Whip Stitch	Whip Stitch	Krackow Stitch	WhipLock Stitch
Stitch Method Illustration				
(A) Tissue Fixation on Stand	One end	Both ends	Both ends	Both ends
(B) Needle Passes Through Tissue (for a 5-stitch series)	5	5	10	5

Methods

Biomechanical Testing
A standardized length of tendon, 7 cm, was coupled to the MTS actuator by passing it through a cryoclamp cooled by dry ice to a temperature of -5°C (Figure 2). Samples were pre-conditioned to normalize viscoelastic effects and testing variability.

Pre-Conditioning
- 25-100 N for three cycles
- 89 N hold for 15 minutes

Cyclic Loading
- 50-200 N for 500 cycles at 1 Hz

Failure Loading
- 20 mm/min ramp to failure

Metrics of Interest
- Total elongation (mm)
- Stiffness (N/mm)
- Ultimate failure load (N)
- Failure mode

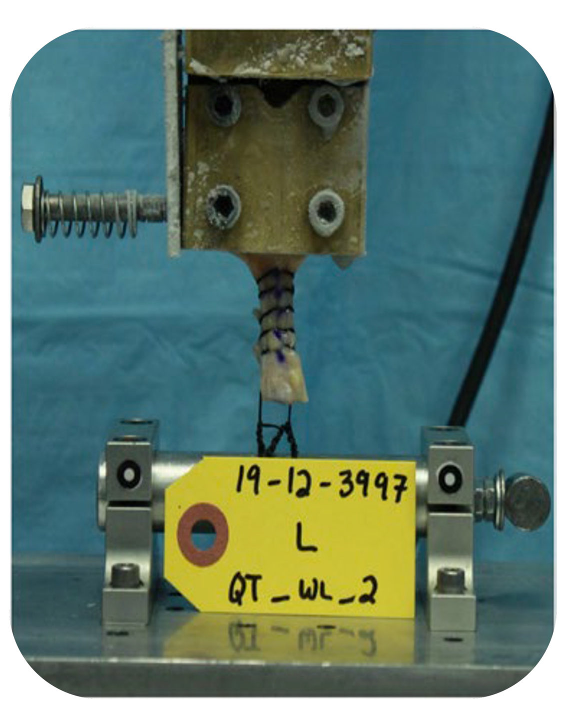


Figure 2. Biomechanical test setup

Statistical Analysis
Data are presented as averages and standard deviations. A one-way analysis of variance (ANOVA) test was used to evaluate the biomechanical performance. Statistical significance was set at P = .05.

Objective

Evaluate a novel suture needle design against conventional suture needles by comparing the biomechanical properties of two commonly used stitch methods (whip & locking) in a quadriceps tendon.

Results

Total Elongation

Whip stitch: Elongation was equivalent across all groups (Group 1: 36 ± 10mm; Group 2: 32 ± 18 mm; Group 3: 33 ± 8mm).

Locking stitch: Elongation (Group 1: 26 ± 10 mm; Group 2: 14 ± 2 mm; Group 3: 29 ± 5 mm), was equivalent across all groups.

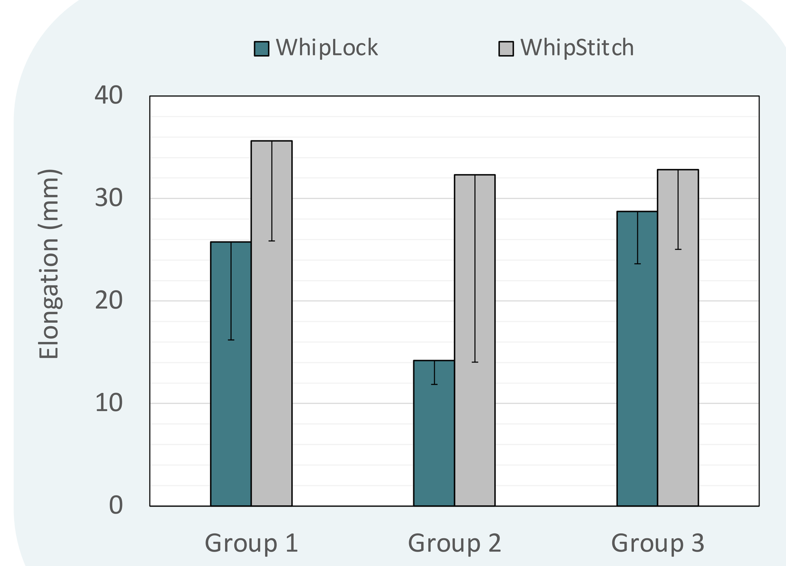


Figure 3. Elongation results

Stiffness

Whip stitch: Stiffness of Group 2 (103 ± 11 N/mm) method was significantly larger than Group 1 (64 ± 8 N/mm; p=.0016).

Stiffness of method by Group 1 was equivalent to Group 3 (80 ± 32 N/mm; p=.985).

Locking stitch: Stiffness (Group 1: 75 ± 11 N/mm; Group 2: 104 ± 23 N/mm; Group 3: 79 ± 10 N/mm) was equivalent across all groups.

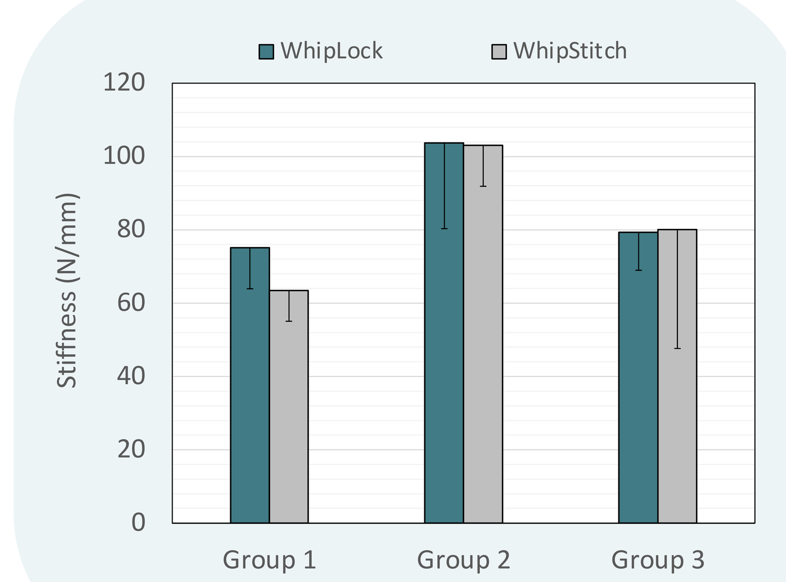


Figure 4. Stiffness results

Ultimate Load

Whip stitch: Ultimate load was equivalent across all whip stitch methods (Group 1: 379 ± 31 mm; Group 2: 412 ± 103 mm; Group 3: 438 ± 63 mm).

Locking stitch: Ultimate load (Group 1: 343 ± 22 N; Group 2: 369 ± 30 N; Group 3: 438 ± 63 N) was equivalent across all groups.

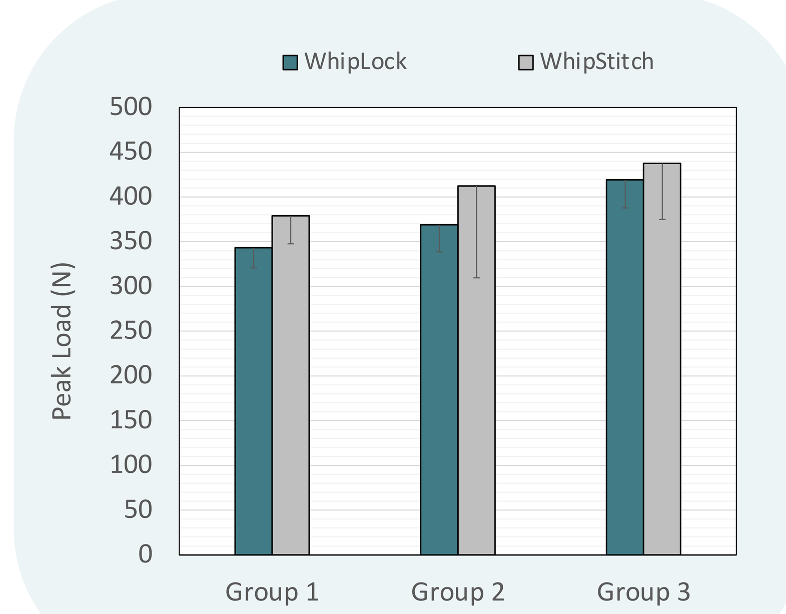


Figure 5. Ultimate load results

Results (Continued)

Failure Mode

The common mode of failure across study groups and stitch configuration was suture breakage. However, the whip stitch from Group 2 and Group 3 had varied failure modes. The failure mode for all groups is in Table 2.

Table 2. Failure Modes by Test Group

		Failure Modes		
Study Group	**Configuration**	***Suture Pull Through***	***Suture Breaking***	***Tendon Tear then Suture Breaking***
Group 1	WhipLock	-	100%	-
	Whip Stitch	-	100%	-
Group 2	Krackow	-	100%	-
	Whip Stitch	13%	75%	13%
Group 3	Krackow	-	100%	-
	Whip Stitch	-	75%	25%

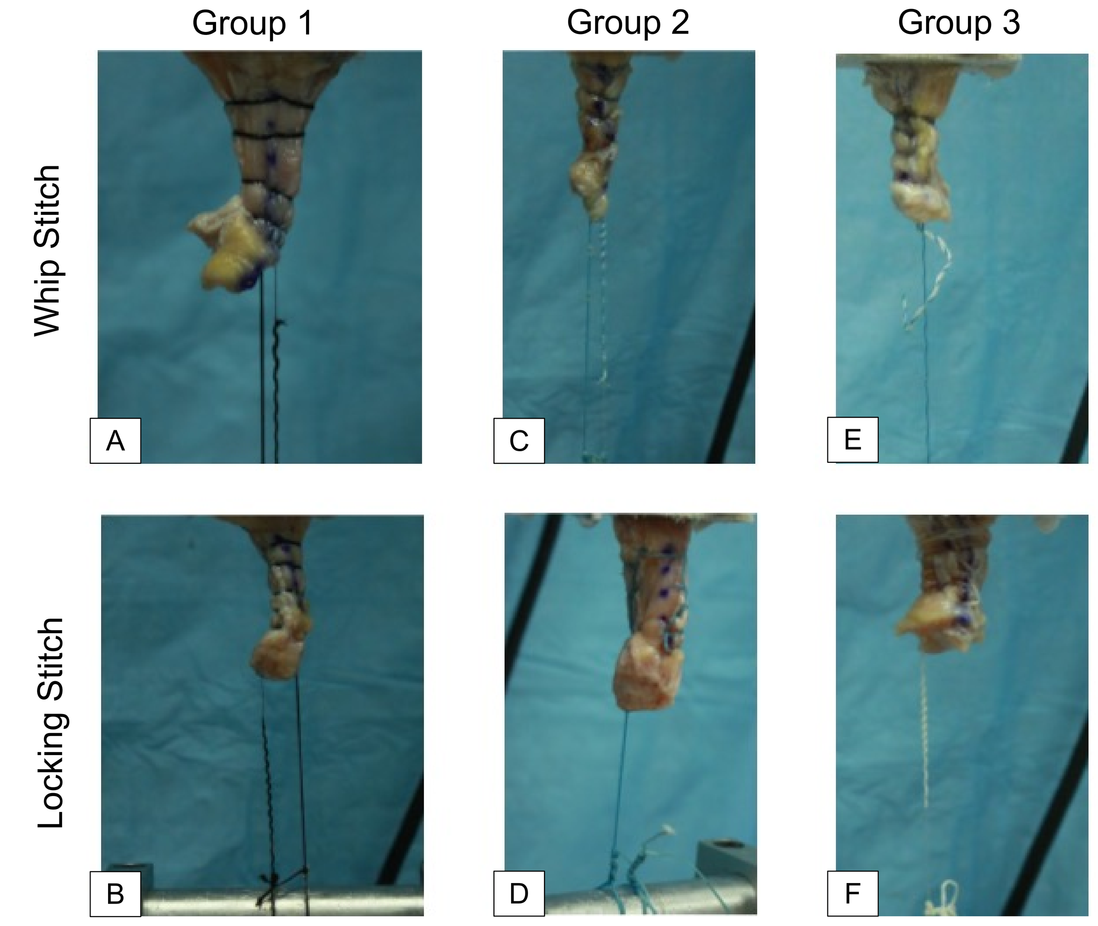


Figure 6. Representative failure mode images for Group 1 Whip Stitch (8a), WhipLock (8b); Group 2 Whip Stitch (8c), Krackow (8d); Group 3 Whip Stitch (8e), Krackow (8f)

Conclusion

- **Clinically relevant biomechanics metrics** of *total elongation* and *ultimate failure load*, **no significant differences were found across Groups 1-3** for both whip stitch and locking stitch methods.
- Group 1 stitches all failed by suture breakage, whereas Group 2 & 3 had a range of failure modes.
- **All locking stitch methods** failed in **suture breakage** across all three groups, whereas **whip stitches** had **varied failure modes**.
- **Novel two-part suture needle** demonstrated the capabilities of whip stitches and locking stitches **achieving equivalent biomechanical performance** compared to conventional needle products
  - The **versatility** to easily create different stitch methods with a single device may provided **clinical advantages**

Future Work

- Expand comparative testing between the stitching methods and resultant biomechanical properties of quadriceps and semitendinosus tendon grafts
- Understanding stitch method biomechanics in other tissue types and anatomical sites (Achilles, biceps, etc.)

References

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