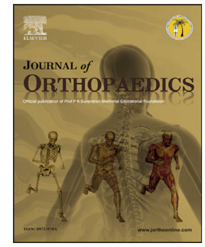
Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/jor




Original Article

# Braided tape suture provides superior bone pull-through strength than wire suture in greater tuberosity of the humerus

*Benjamin Leger St-Jean* [a,b], *Jérémie Ménard* [c], *Stéphanie Hinse* [a,b], *Yvan Petit* [d], *Dominique M. Rouleau* [a,b,*], *Marc Beauchamp* [a,b]

[a] *Department of Orthopaedic Surgery, Université de Montréal, Montreal, H3T 1J4, Canada*
[b] *Department of Orthopaedic Surgery, Hôpital du Sacré-Cœur de Montréal, Montreal, H4J 1C5, Canada*
[c] *Research Center, Hôpital du Sacré-Cœur de Montréal, Montreal, H4J 1C5, Canada*
[d] *Department of Mechanical Engineering, École de technologie supérieure, Montreal, Canada*

ARTICLE INFO

*Article history:*
Received 2 December 2014
Accepted 27 January 2015
Available online 19 February 2015

*Keywords:*
Humerus
Rotator cuff
Surgical fixation devices
Reconstructive surgical procedure

ABSTRACT

*Introduction:* The purpose of this study is to compare the pull-through strength of transosseous braided tape suture with wire suture in proximal humeri bones (greater tuberosity).

*Methods:* A biomechanical study on eight cadaveric human specimens where two transosseous sutures were randomly applied on each specimen (anterior and posterior). Force/displacement curves were obtained for each specimen and the maximum pull-through load was noted.

*Results:* There is a significant difference in maximal pull-through strength favoring braided tape suture over wire suture.

*Conclusions:* Transosseous braided tape suture provides almost twice the bone pull-through strength and is slightly correlated to volumetric bone mineral density.



## 1. Introduction

The increase in global life expectancy has led to a growing prevalence of musculoskeletal problems such as osteoarthritis, fractures, degenerative tendon tears, etc.[1] With full thickness rotator cuff tears found in up to 50% of the population, depending on the age group,[1] many elderly patients will become symptomatic and may even develop massive rotator cuff tears, leading to significant functional impairment.

Traditional surgical rotator cuff repair and reconstruction techniques using wire suture have been a mainstay in patients younger than 60 years of age but are now expanded for use in patients over 70 years of age.[2] The main challenge in

* *Corresponding author*. C2095-5400 Boul. Gouin Ouest, Montreal, Quebec, Canada. Tel.: +1 514 338 2222x3427.
E-mail address: dominique.rouleau@yahoo.ca (D.M. Rouleau).
http://dx.doi.org/10.1016/j.jor.2015.01.025

older patients is to achieve an adequate tendon to bone contact in a hypovascular and osteoporotic environment.

Bone density is a major factor on the pullout strength of anchors and therefore influences the overall strength of the repair.[3] In some studies, the failure rate of rotator cuff repairs by pullout can reach 9%–30%[4,5] and is likely underestimated.[6] In addition, up to 90% of massive rotator cuff repairs show signs of new tears at 1 year follow-up.[7] This high complication rate has led the community of shoulder surgeons to reconsider current surgical techniques. New suture material and techniques are now available including the braided tape suture as well as arthroscopic transosseous suture passers in order to improve surgical outcomes. However, no human cadaveric study has ever compared the cut out strength of braided tape suture or of wire suture in proximal humeri bones, which prompted our research.

The purpose of this study is to compare the pull-through strength in proximal humeri bones (greater tuberosity) of transosseous braided tape suture and transosseous #2 wire suture.

## 2. Materials and methods

A biomechanical cadaveric study was undertaken using eight frozen shoulders. The specimens were stored at −22 °C and defrosted at room temperature the day before the procedure. The soft-tissues were dissected and completely removed. The humerus was then placed face down in a custom-made holding box and screwed into place with one diaphyseal and one proximal epiphyseal screw (Fig. 1). Polyester mastic was used to stabilize the bone, taking care to keep the greater tuberosity exposed. To standardize the trials, a curved awl of 22 mm diameter, designed by one of the authors (MB), was used to create the first transosseous tunnel, 1 cm posterior to the bicipital groove, using a minimum starting point 15 mm inferior to the tip of the great tuberosity (GT). The second tunnel was made 1 cm posterior and parallel to the first tunnel. These two tunnels simulate a supraspinatus repair.[8,9] The wire suture (#2 FiberWire®: Arthrex, Naples, FL, USA) was then randomly attributed to either the anterior or posterior tunnel adding up to four trials in each position. The curved suture passer, using a similar design to the curved awl, was then used to slip the wire suture from the distal orifice to the proximal orifice of the selected bone tunnel. The holding box was fixed to the base of a biomechanical testing unit (858 Bionix II, MTS Corp., Eden Prairie, MN, USA). A surgeon's knot followed by six half-hitches were used to secure the suture loop to the eyebolt fixed to an axial load cell (load capacity 2500 N; MTS Corp, Eden Prairie, MN, USA) calibrated by the manufacturer. To stabilize the assembly construct, a 10 N tension preload was applied and, subsequently, load to failure was applied at a rate of 1 mm/s.[10] The primary outcome measure was the bone pull-through maximum load. Secondary outcome measures included comparison of the bone pull-through maximum load between anterior and posterior tunnels and mode of failure. Secondly, a braided tape suture (FiberTape®: Arthrex, Naples, FL, USA) was passed in the other tunnel position and the load-to-failure procedure was repeated. The wire was tested first in all specimens to minimise the effect on the overall resistance strength of the GT.

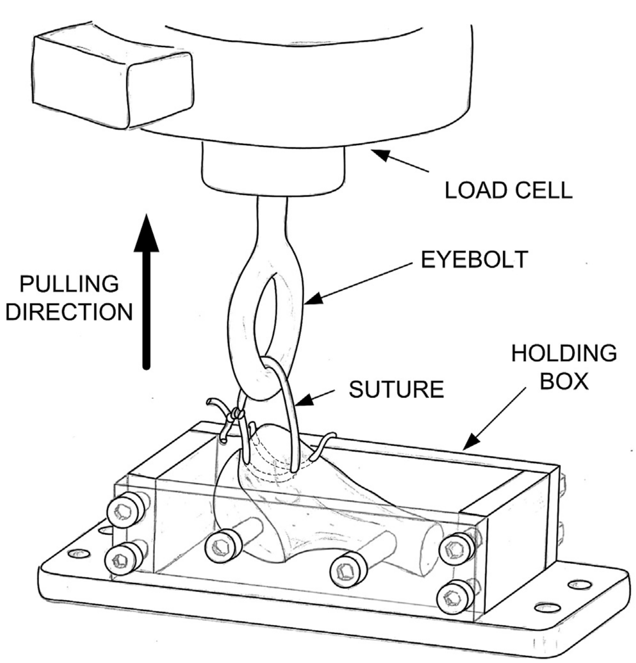



**Fig. 1 – Experimental setup.**

All proximal humeri were imaged with a LightSpeed VCT (GE Medical System, Milwaukee, WI, USA) CT scanner (1.25 mm slice thickness and 0.27 mm pixel resolution) along with four calcium hydroxyapatite calibration bars[11] prior to the experimental testing. The volumetric bone mineral density (vBMD) of the 4 bars used were 100, 400, 1000 and 1750 mg/cc covering the common density range of cortical and trabecular bone. The linear relation between mineral density and Hounsfield units was obtained using linear regression analysis. CT images were analyzed with a semi-automated segmentation software (sliceOmatic, TomoVision Inc., Montreal, QC, Canada) to identify the global vBMD (cortical and trabecular) of each proximal humerus (up to the surgical neck).

Because two tests were performed on each specimen, a paired nonparametric Wilcoxon test applied to the difference between tape and wire pull-through strengths was used for statistical analysis using STATISTICA v7.1 software (StatSoft Inc., Tulsa, OK, USA). A general linear model as well as repeated measures of analysis of variance (ANOVA) were used to verify the effect of the suture position (anterior or posterior) for each type of suture. Pearson's correlation coefficient was also used to verify the correlation between the pull-through strength and the vBMD. The significance level was set at $p \leq 0.05$.

## 3. Results

Three pairs of shoulders and two left shoulders were used. The ages of the specimens ranged from 24 to 78 years with a median of 66 years (2 × 24, 1 × 57, 2 × 66, 2 × 72 and 1 × 78 years). In all but one specimen (#5), bone pull-through maximal load was superior in the braided tape suture group (Table 1). Overall, there was a significant difference in bone pull-through maximum load in favor of braided tape suture

**Table 1 – Summary of the Bone Pull-Through maximum load results.**

| Bone pull-through maximum load (N) | | | | |
|---|---|---|---|---|
| Specimen | Wire | | Tape | |
| | Load (N) | Position (A – P) | Load (N) | Position (A – P) |
| 1 | 296 | A | 331 | P |
| 2 | 326 | P | 373 | A |
| 3 | 140 | A | 341 | P |
| 4 | 184 | A | 406 | P |
| 5 | 201 | P | 192 | A |
| 6 | 338 | A | 517 | P |
| 7 | 281 | P | 840 | A |
| 8 | 163 | P | 244 | A |
| Average | 241 | | 406 | |
| [minimum; maximum] | [140; 338] | | [192; 840] | |

(406 N [192; 840]; 241 N [140; 338]) over wire suture ($p = 0.017$). There was no statistical difference between anterior and posterior placement of the sutures in the GT ($p = 0.929$). The mode of failure for five wire sutures was the cut out through bone and wire failure for the other three specimens (adjacent to the knot). The mode of failure of six of the braided tape sutures was influenced by the cut out of the wire suture. These six specimens had a GT fracture that extended through the cut out section of the wire (Fig. 2). The mode of failure of the other two braided tape suture specimens was cut out through bone.

The range of vBMD was 138–254 mg/cc with an average of 185 mg/cc. A high correlation between vBMD and pull-through strength was found for the braided tape suture group ($r = 0.77$; $p = 0.027$) and a low correlation was found for the wire suture group ($r = 0.36$; $p = 0.380$) (Fig. 3).

## 4. Discussion

As expected, there is a significant difference in overall cut out strength in favor of transosseous tape compared to transosseous wire. The tape design seems to allow stress to be distributed over a greater surface area at the bone-tape interface, thus creating a stronger construct more resistant to cutting out. Similar results have been demonstrated in a study comparing the contact area and the pull-through force in tendons for FiberTape® and #2 FiberWire®.[12] Even though previous studies have suggested that the anterior cortex of the great tuberosity has denser bone, this has not proven to be a significant factor in this study.[3]

There are several limitations to this study. Its main weakness is the small number of cadavers which may have affected the trends established. Another, is the wire pull-through initially performed in all the cadavers, negatively influencing the braided tape suture pull-through strength with fracture lines extending into the wire cut out in six of eight cadavers. Nonetheless, this study demonstrates favorable results for the braided tape suture over the wire construct even if the bone was weakened by the first test. One could anticipate that the difference would have been even more significant if the tape had been tested first.

Even considering that the results of most of the braided tape sutures have been negatively influenced by the previous wire bone cut out, our study still proves that the use of tape reduces the risk of bone cut out. The two highest braided tape suture strength results (specimens #6 and #7) were the trials where no wire bone cut out had occurred. Therefore, we can infer that the pull-through strength of braided tape suture would have been better and more representative if no wire pull-through trial had been done before.

Fig. 3 illustrates the relationship between maximal pull-through strength and volumetric bone mineral density. With a weak correlation coefficient of 0.38, it seems that the wire/bone construct is slightly influenced by bone density, with the wire cutting through both osteoporotic and normal bone at the same rate. However, with a strong correlation coefficient of 0.77, it does appear that the braided suture-tape/bone construct is influenced by bone mineral density. Indeed, the construct strengthens as volumetric bone mineral density increases, to values strongly exceeding other parts of the rotator cuff repair, namely the suture/tendon junction and the tendon itself.

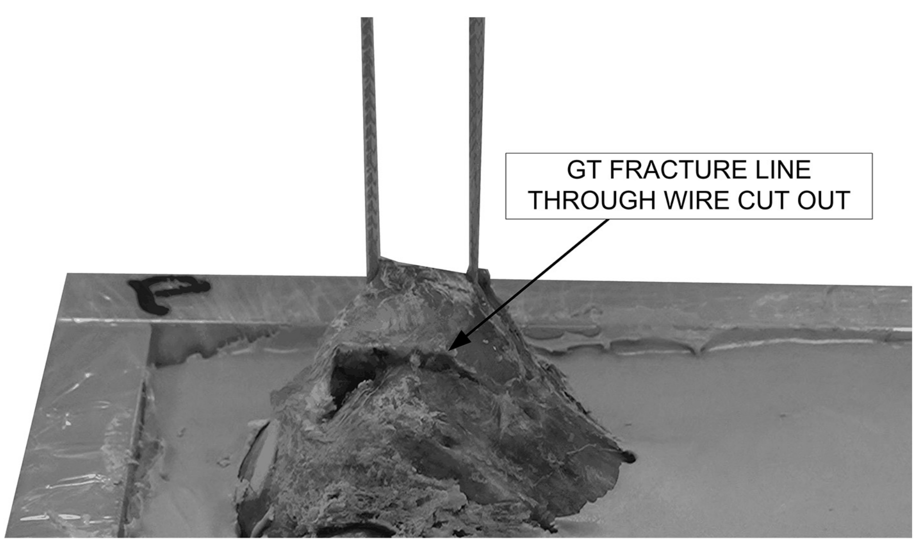



**Fig. 2 – Greater tuberosity fracture line through wire cut out.**

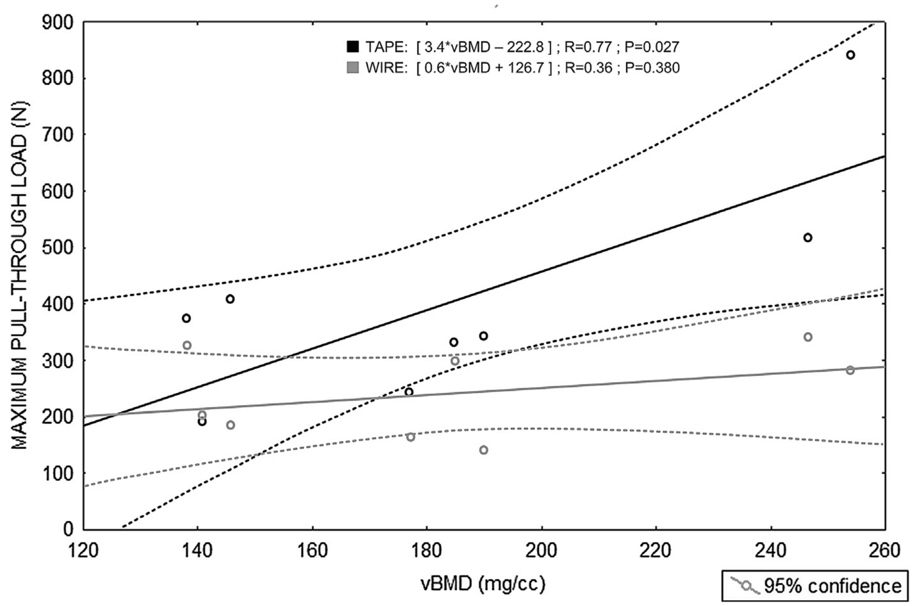



**Fig. 3 – Correlation between volumetric bone mineral density (vBMD) and the maximum pull-through strength.**

Wieser et al[13] published a study where the central tendon–tendon junction of a cuff repair had an average pull-through strength of 191 N [20; 263]. Considering that the average pull-through strength of the braided tape construct in this study was 406 N [192; 840], we can establish that the tendon, rather than the bone, appears to be the weakest link within the braided tape suture transosseous construct.

In conclusion, transosseous braided tape suture provides significantly superior bone pull-through strength than transosseous wire suture. Secondly, the wire/bone construct seems to be weakly influenced by the vBMD compared to the tape/bone construct, which suggests that wire cuts at the same rate through osteoporotic and normal bone. Opposition to transosseous fixation underlines the risk of bone sawing by the wire under tension, especially with the use of modern woven wires, advocating rather the use of suture anchors for rotator cuff fixation. The present study demonstrates that such sawing effect is significantly reduced by the use of braided tape instead of wire. Further research should focus on strengthening the suture/tendon junction. This study is one of the first steps in the validation of rotator cuff repair materials and favors the use of braided tape suture for transosseous repair.

## Conflicts of interest

All authors have none to declare.

## REFERENCES


1. Yamamoto A, Takagishi K, Osawa T, et al. Prevalence and risk factors of a rotator cuff tear in the general population. *J Shoulder Elbow Surg*. 2010;19:116–120.
2. Rebuzzi E, Coletti N, Schiavetti S, et al. Arthroscopic rotator cuff repair in patients older than 60 years. *Arthroscopy*. 2005;21:48–54.
3. Tingart MJ, Apreleva M, Lehtinen J, et al. Anchor design and bone mineral density affect the pull-out strength of suture anchors in rotator cuff repair: which anchors are best to use in patients with low bone quality? *Am J Sports Med*. 2004;32:1466–1473.
4. Cho NS, Lee BG, Rhee YG. Arthroscopic rotator cuff repair using a suture bridge technique: is the repair integrity actually maintained? *Am J Sports Med*. 2011;39:2108–2116.
5. Duquin TR, Buyea C, Bisson LJ. Which method of rotator cuff repair leads to the highest rate of structural healing? A systematic review. *Am J Sports Med*. 2010;38:835–841.
6. Benson EC, MacDermid JC, Drosdowech DS, et al. The incidence of early metallic suture anchor pullout after arthroscopic rotator cuff repair. *Arthroscopy*. 2010;26:310–315.
7. Galatz LM, Ball CM, Teefey SA, et al. The outcome and repair integrity of completely arthroscopically repaired large and massive rotator cuff tears. *J Bone Joint Surg Am*. 2004;86-A:219–224.
8. Boileau P. *Shoulder Concepts 2010: Arthroscopy & Arthroplasty: Sauramps Médical*. 2010.
9. Park MC, Cadet ER, Levine WN, et al. Tendon-to-bone pressure distributions at a repaired rotator cuff footprint using transosseous suture and suture anchor fixation techniques. *Am J Sports Med*. 2005;33:1154–1159.
10. Lorbach O, Anagnostakos K, Vees J, et al. Three-dimensional evaluation of the cyclic loading behavior of different rotator cuff reconstructions. *Arthroscopy*. 2010;26:S95–s105 [Epub 2010 Aug 2015].
11. Levasseur A, Ploeg HL, Petit Y. Comparison of the influences of structural characteristics on bulk mechanical behaviour: experimental study using a bone surrogate. *Med Biol Eng Comput*. 2012;50:61–67.
12. Arthrex. *Contact Area and Tendon Pull-through Force of FiberTape and #2 FiberWire*. 1370 Creekside Blvd., Naples, FL 34108: Arthrex Research and Development; 2008:1.
13. Wieser K, Rahm S, Farshad M, et al. Stitch positioning influences the suture hold in supraspinatus tendon repair. *Knee Surg Sports Traumatol Arthrosc*. 2013;21:1587–1592.