Braided tape is equivalent to modified Mason-Allen multi-strand #2 suture in subscapularis muscle repair: results of a biomechanical study

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Abstract

Background: To help determine the optimal fixation method for subscapularis tendon repair in arthroplasty, the present study compares single-passage transosseous tape (BT) and modified Mason-Allen #2 suture (MA).

Methods: Eighteen human cadaveric shoulders were randomized to two repair constructs after arthroplasty preparation. Both techniques included two transosseous passages through the bicipital groove and then through the tendon at the level of the anatomical neck. Construct was tested using a traction machine, measuring cyclic loading and ultimate load to failure.

Results: The mean age of our specimens was 71 years. No significant difference was observed between the repair techniques in both mean ultimate load and cyclic loading. The mean (SD) ultimate load (UL) for BT was 293 (84) N and 342 (117) N for MA, which was not statistically significant ($p = 0.374$). The majority of repairs failed in the tendon. Bone cut-out was observed with the MA but not for the BT repair. No correlation was found between bone density and UL for BT ($r = -0.09$) but there was strong correlation for MA ($r = 0.63$).

Conclusions: The MA repair appears to be more dependant on bone mineral density for ultimate load, indicating that braided-tape might be better suited for osteoporotic patients to avoid bone cut-out.

Keywords

biomechanical, braided tape, fixation, Mason-Allen, repair techniques, shoulder, subscapularis tendon

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Introduction

Subscapularis tendon repair during shoulder arthroplasty is still a source of controversy among shoulder surgeons. Indeed, when performing a resurfacing, anatomic or reverse total shoulder arthroplasty, the tendon must be tenotomized to give access to the shoulder joint and multiple techniques have been described for both tenotomy and repair. The joint can be accessed through a lesser tuberosity osteotomy,¹ a peel of the tendon from the tuberosity² or a tenotomy 10 mm medial to the lesser tuberosity.³ With respect to tendon repair, this can be performed either with transosseous sutures or bone anchors, with or without the addition of a plate. The reason why it is a subject of interest is that a subscapularis postoperative rupture is a major issue for patients, causing secondary prosthesis instability and poor function.⁴ It has been shown that, after repair, the subscapularis recovers only about 70% of

the patient's strength on the contralateral side.⁵ In previous studies, the lift-off test demonstrated a weakness in 25% of patients and the Belly press demonstrated a weakness in 40% of cases.^{1,6} Lesser tuberosity osteotomies have been reported to have a non-union rate as high as 13%, which is why this technique is not always utilized.⁷ Regarding the subscapularis peel and repair technique with sutures, this is associated with a 12.5%

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risk of postoperative rupture.⁸ In a large randomized study, the lesser tuberosity osteotomy and the peel technique both gave similar clinical outcomes at 24 months in terms of both strength and function.⁹ In a recent biomechanical study, both subscapularis tenotomy and lesser tuberosity osteotomy gave similar results in terms of repair strength.³

To improve shoulder function after shoulder arthroplasty, we are looking to improve the strength of the subscapularis repair. In a previous study, braided tape has demonstrated stronger bone pull-through strength than #2 sutures in the greater tuberosity and is a potential solution for increasing the strength of shoulder tendon repairs.¹⁰ The aim of the present study is to compare the strength of a subscapularis peel repair using #2 sutures in a modified Mason Allen configuration with that of a repair using braided tape in a simple suture configuration.

Materials and Methods

The present study was conducted with the institution's ethics committee approval and used eighteen frozen cadaveric shoulders from nine specimens selected for the study. The specimens were stored at -22°C and were defrosted at room temperature on the day of the procedure. Before preparation, all proximal humeri were imaged with a Lightspeed VCT (GE Medical System, Milwaukee, WI, USA) computed tomography (CT) scanner (1.25-mm slice thickness and 0.27-mm pixel resolution) along with four calcium hydroxyapatite calibration bars. The volumetric bone mineral density (vBMD) of the four bars used were 100 mg/cm^3 , 400 mg/cm^3 , 1000 mg/cm^3 and 1750 mg/cm^3 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, Canada) to identify the global vBMD of each proximal humerus (up to the surgical neck). Volumetric bone mineral density and the WHO osteoporosis equivalent relation are presented in Table 1.¹¹

The soft tissues were dissected from the specimens, with the exception of the subscapularis, and the tendon was then carefully peeled off the humerus, with the footprint being outlined with a hot soldering iron. The humerus was cut with a bone saw along the anatomical neck. The humeral canal was then prepared using Tornier's anatomical system rasps (Aequalis®; Tornier, Bloomington, MN, USA). A 2.5-mm drill bit was used to drill two holes in the bicipital groove 10mm apart starting 7mm distally from the cut surface of the humerus; the sutures run medially from the humeral canal through the holes (Figure 1). For the transosseous

Table 1. Volumetric bone mineral density (vBMD) and WHO osteoporosis equivalent¹⁰

QCT trabecular spine BMD range	Equivalent WHO diagnostic category
$\text{vBMD} > 120\text{ mg/cm}^3$	Normal
$80\text{ mg/cm}^3 \geq \text{vBMD} \geq 120\text{ mg/cm}^3$	Osteopenia
$\text{vBMD} < 80\text{ mg/cm}^3$	Osteoporosis

tape repair, two simple sutures using ULTRATAPE® braided tape (Smith & Nephew, Mississauga, Canada) were passed through the bone and then through the subscapularis 15mm from the tendon insertion. A surgeon's knot followed by four half-hitches were used to secure the suture loop. For the transosseous suture repair, each #2 Ultrabrade® (Smith&Nephew) suture was first inserted through the bone and then through the tendon using a modified Mason-Allen technique where an anatomical trial humeral stem was impacted.¹² The humeral shaft was then potted in an ABS (acrylonitrile-butadiene-styrene) tube and fixed to a biomechanical testing unit (858 Bionix II; MTS Corp., Eden Prairie, MN, USA). The subscapularis muscle belly was fixed to an axial load cell (load capacity 2500 N; MTS Corp) using a thermoelectric cooling soft-tissue clamp.¹³ The axial load cell was then fixed to the actuator of the biomechanical testing unit. A pre-load of 10 N was applied and then cyclic loading was applied at a rate of 1 mm/s with increasing tension (Table 2). A total of 100 cycles were applied on the repaired tendon (25 cycles between 10 and 40 N; 25 cycles between 10 and 60 N; 25 cycles between 10 and 80 N; and 25 cycles between 10 and 100 N). A maximum of 100 N was chosen because this is the expected tension applied on the subscapularis during postoperative physiotherapy for shoulder arthroplasty.^{2-4,14,15} Finally, if the reconstruction was still intact, load to failure was applied at a rate of 33 mm/s until rupture. A 3D video extensometer (PONTOS; GOM, Braunschweig, Germany) set at a frame rate of 15 Hz was used to record tendon displacement. Optical images were then analyzed using segmentation software (SliceOmatic, Tomovision Inc., Montreal, Canada) to measure the coverage of the footprint by the repaired tendon throughout the test (Figure 1). The primary outcome measures included percentage of footprint coverage after each cyclic traction loading condition. Secondary outcome measure was the ultimate load to failure. Because two tests were performed on shoulder pairs, a paired nonparametric Wilcoxon test was used for statistical analysis in STATISTICA, version 7.1 (StatSoft Inc, Tulsa, OK, USA). A nonparametric Mann-Whitney *U*-test was used to compare density of the two groups. A Pearson coefficient was used to

Figure 1. Experimental testing unit and different constructs. The potted specimen is fixed in the ABS tube holder, and the subscapularis tendon is placed in the thermoelectrically cooled clamp. The thermoelectrically cooled clamp is attached to the actuator with the load cell between. Load is applied to the construct through the actuator.

Table 2. Loading Conditions

	Type of load	Number of cycles	Load	Rate	Coronal loading angle	Rotation
1	Preload	NA	10 N	1 mm/s	0°	Neutral
2	Cyclic	25	10 N to 40 N	1 mm/s	0°	Neutral
3	Cyclic	25	10 N to 60 N	1 mm/s	0°	Neutral
4	Cyclic	25	10 N to 80 N	1 mm/s	0°	Neutral
5	Cyclic	25	10 N to 100 N	1 mm/s	0°	Neutral
6	Load to failure	NA	Variable	33 mm/s	0°	Neutral

NA, not available.

correlate ultimate load of the constructs with vBMD. The strength of the correlation was characterized as:¹⁶ 0.0–0.19 very weak; 0.20–0.39 weak; 0.40–0.59 moderate; 0.60–0.79 strong; and 0.8–1.0 very strong.

Results

The mean age of the 18 specimens was 71 years (range 58 years to 87 years) with six males and three females. The mean volumetric bone mineral density was 130 mg/cm³ (ranging from 76 mg/cm³ to 172 mg/cm³) for the Mason-Allen repair specimens and 138 mg/cm³ (ranging from 92 mg/cm³ to 180 mg/cm³) for the braided tape repair specimens ($p = 0.596$). There was one specimen with bilateral glenohumeral osteoarthritis. No significant pathology was identified in the subscapularis tendons.

The mean (SD) ultimate load for the Mason-Allen repair was 342 N [range 135 N to 497 N (117 N)] and 293 N [range 130 N to 393 N (84 N)] for the simple suture braided tape repair (Table 3). This difference of 49 N was not statistically significant ($p = 0.374$). In the cyclic loading phase, the displacement of the tendon

was measured using the percentage of exposed footprint (Figure 2 and Table 4). At pre-load, there was a mean (SD) of 16% (20%) of the footprint exposed for the Mason-Allen repair and 18% (11%) for the braided tape repair. The mean (SD) footprint exposed increased to 30% (31%) for the first cyclic load (10 N to 40 N); 36% (31%) for the second cyclic load (10 N to 60 N); 43% (31%) for the third cyclic load (10 N to 80 N); and 49% (33%) for the final cyclic load (10 N to 100 N) for the Mason-Allen repair. For the simple suture braided tape repair, the footprint exposed increased to 30% (11%) for the first cyclic load (10 N to 40 N); 43% (16%) for the second cyclic load; 55% (20%) for the third cyclic load (10 N to 80 N); and 62% (22%) for the final cyclic load (10 N to 100 N). No statistically significant difference was observed during the entire cyclic loading (Table 4). The majority of repairs failed in the tendon at the suture junction (Table 3). The other modes of failure for Mason-Allen repair were bone cut-out, suture failure and knot failure. For the braided tape repair, the only other mode of failure was knot failure.

Table 3. Ultimate load to failure, density and mode of failure

Specimen number	Mason-Allen (N)	Density (mg/cm ³)	Mode of failure	Braided tape (N)	Density (mg/cm ³)	Mode of failure
SP01	184	76	Bone cut-out Suture failure	255	92	Tendon cut-out
SP02	379	160	Tendon cut-out Suture failure	249	169	Tendon cut-out
SP03	354	102	Suture failure	393	111	Tendon cut-out Knot failure
SP04	419	131	Tendon cut-out	260	131	Tendon cut-out
SP05	135	118	Suture failure	376	114	Tendon cut-out
SP06	497	141	Suture failure	130	148	Knot failure
SP07	304	138	Bone cut-out Knot failure	309	154	Knot failure
SP08	436	172	Suture failure	383	180	Tendon cut-out
SP09	367	130	Knot failure	287	140	Tendon cut-out
Mean	342	130		293	138	
Minimum	135	76		130	92	
Maximum	497	172		393	180	
SD	117	29		84	29	
Difference	abs (mean of Mason-Allen – mean of braided tape)			49		
Wilcoxon (paired t-test)			p = 0.37426

Figure 2. Mean percentage of footprint loss of both constructs through progressive cyclic loading.

Table 4. Footprint loss

Loading Conditions	Mason-Allen mean (SD)	Braided tape mean (SD)	Wilcoxon (paired t-test)
Preload (10 N)	16% (20%)	18% (11%)	$p = 0.26039$
Cyclic load (10 N to 40 N)	30% (31%)	30% (12%)	$p = 0.67840$
Cyclic load (10 N to 60 N)	36% (31%)	43% (16%)	$p = 0.31394$
Cyclic load (10 N to 80 N)	43% (31%)	55% (20%)	$p = 0.26039$
Cyclic load (10 N to 100 N)	49% (33%)	62% (22%)	$p = 0.31394$

There was no correlation between the volumetric bone density and the ultimate load for the braided tape repair ($r = -0.09$) (Figure 3). However, there was a strong positive trend for the Mason-Allen repair ($r = 0.63$) (Figure 4).

Discussion

In the present study, no statistically significant difference was found between transosseous tape repair and the modified Mason-Allen #2 suture repair with respect to both footprint coverage during cyclic loading and mean ultimate load. There was a positive correlation between bone mineral density and ultimate load to failure for the Mason-Allen repair ($r = 0.63$) but not for the tape repair ($r = 0.09$). Although only two specimens from the suture group ultimately failed from bone cut-out, on video analysis, all suture specimens showed signs of the wire

sawing through the bone, which was not the case for the tape group. This suggests that bone density might be more of an issue with suture than with braided tape. This is why some surgeons choose to use a plate or an endobutton as a means of decreasing cut-out. Moreover, a previous biomechanical study comparing the bone pull-through strength of suture versus tape in the greater tuberosity has also demonstrated the potential of the braided tape suture to minimize bone cut-out.¹⁰ Thus, braided tape might be better suited for more osteoporotic patients. It should also be noted that, in the suture group, six out of nine cases were suture failures, whereas the primary mode of failure in the tape group was tearing at the suture tendon junction in addition to three knot failures. Therefore, we should investigate on different suture configurations using braided tape suture material to strengthen the suture/tendon junction.

When compared with other biomechanical studies on subscapularis repair, our ultimate loads of 342 N and 293 N appear to be lower or similar to other reports. Both Giusseffi et al.³ and Krishnan et al.¹⁷ report failure at pullout over 400 N for lesser tuberosity osteotomy repair, and Krishnan showed 252 N load to failure for his tenotomy repair group. The loss of footprint coverage is worrisome in the present study because it does appear significant at relatively small loads. It is hard to interpret these data because we do not know what is the minimal coverage needed to obtain tendon healing. Healing in an elongated position could also decrease subscapularis strength.

When considering all these factors, it is suggested that, when using suture repairs, it is preferable to use multiple sutures rather than only two to distribute stress over a greater number of fixation points. Regarding the tape group, we might have increased the strength of the suture/tendon junction by also

Figure 3. Correlation between volumetric bone density and ultimate load for the braided tape repair.

Figure 4. Correlation between volumetric bone density and ultimate load for the Mason-Allen repair.

doing a Mason-Allen stitch in the subscapularis. In addition, failure at the knot in the tape group was not surprising because these implants have been designed primarily for knotless repairs.

Limitations

There are some limitations to the present study in addition to the low number of specimens. Comparing two

different types of suture techniques as well as two different materials does not allow us to determine which factor is more important in overall strength. In testing cyclic loading, the present study has allowed us to understand that significant displacement of the tendon occurs at loading rates far less significant than maximal strength, suggesting that load to failure may not be the best way to represent overall construct strength. Although the number of cycles performed was fewer

than in previously published studies, we found that the maximum displacement occurred within the first few cycles of a new applied load and thus, a fewer number of cycles would still allow us to get a reliable estimation of the displacement for an applied load.

Although our repair ultimate load to failure was similar or inferior than in other studies, it still exceeded the maximum subscapularis physiological load of 250 N reported previously.¹⁸ It was also greater than subscapularis load of 100 N expected during total shoulder arthroplasty rehabilitation.⁴

In conclusion, we were not able to detect a statistically significant difference between Mason-Allen #2 suture subscapularis repair and simple-passage tape repair for the peel technique. However, the Mason-Allen suture repair appears to be more dependant on bone mineral density for ultimate load, indicating that braided-tape might be better suited for osteoporotic patients to avoid bone cut-out.

Declaration of Conflicting Interests

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Ethical Review and Patient Consent

Research Ethics committee approval was granted by the HSCM # 2013-923.

Level of evidence

Level III

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