The primary factor for suture configuration at rotator cuff repair: Width of mattress or distance from tear edge

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A B S T R A C T
Objectives: The aims of this study was first to investigate whether the bite size or the bite distance from the tear edge is of primary importance in mattress suture configuration for rotator cuff repair. Secondly, whether the use of a 450 left side bent Arthro-Pierce™ (Smith & Nephew, Andover, USA) during suture passage can be more effective on the strength of the configuration compared to a straight Arthro-Pierce™.

Materials and methods: Twenty-eight bovine infraspinatus muscle tendons were randomized into four groups. Group 1: 5 mm wide ‘bite size’ × 15 mm length ‘distance from the tear edge’s mattress’; Group 2: 7.5 mm × 10 mm; Group 3: 15 mm × 5 mm ‘using straight Arthro-Pierce™’ and Group 4: 5 mm × 15 mm using left sided 450 bent Arthro-Pierce™. The repair specimens underwent cyclic loading prior to loading the failure testing. Cyclic elongation (mm), peak-to-peak displacement (mm), ultimate load (N), stiffness (N/mm) and failure mode were recorded for each specimen.

Results: The mean ultimate load in Group 1 was higher compared to group 3. The peak to peak displacement was higher in Group 4 compared to Group 1 (p<0.05). The predominant failure mode in Groups 1, 2 and 4 was suture rupture. The Group 3 most specimens failed due to suture cut through the tendon.

Conclusion: Bite size from the edge of the tendon seems to be more important than the width of the mattress. The curve of the suture passing device may also have an effect on the strength of the suture tendon interface.

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Introduction

Despite the advances in the arthroscopic repair techniques of rotator cuff tendon tears, the re-tear rates still remain high at 14–25%. Suture-tendon interface is still identified as the weakest link of the repair despite the introduction of newly designed anchors and high strength sutures. Although various suture configurations have been tested in previous biomechanical studies, the most widely used stitch configurations are simple, mattress or a combination of the two, the massive cuff stitch, since the mattress suture is stronger than a simple suture. Recent studies have reported that the medial or lateral distance of the stitch from the tear edge and bite size of the horizontal mattress configuration (distance between the limbs passed through the tendon) has an effect on the strength of the mattress configuration repair. No study has reported the effect of both parameters though.

Recently, it was also proven that arthroscopic devices, used for suture passage, make bigger holes in the cuff, that result in a weaker suture-tendon interface. The purpose of this study was to investigate whether the bite size or bite distance from the tear edge is of primary importance in rotator cuff repair and whether using a 45° left-bent ARTHRO-PIERCE™ (Smith & Nephew Inc., Andover, MA, USA) or a straight ARTHRO-PIERCE™ instrument during suture passage would have a greater effect on the strength of the configuration. The hypothesis was that increasing the bite size of the mattress configuration...
would compensate for the shorter bite distance from the tear edge (that the area of the rectangle covered by the mattress suture ‘bite size times the distance from the tear edge’ is kept constant) and using the 45° bent ARTHRO-PIERCÉ™ instrument would cause the strength of the configuration to weaken.

Materials and methods

Twenty-eight bovine shoulder specimens were obtained from an abattoir for this study. All specimens were harvested from male calves (age: 16 months) and frozen immediately at −20 °C. Before testing, the specimens were thawed, and the infraspinatus muscle with the tendon attached was dissected from its insertion site at the humerus and removed.

For all specimens, tendon thickness was measured using a digital caliper. The three suture configurations were randomly placed in each set of tendon specimens. Seven tendon specimens were tested for each suture configuration.

All procedures were performed by a single investigator. There were four test groups. Groups 1, 2 and 3 used a straight ARTHROPIERCÉ™ instrument with three different suture configurations (Group 1: 5 mm wide ‘bite size’ × 15 mm length ‘distance from the tear edge’; Group 2: 7.5 mm × 10 mm; Group 3: 15 mm × 5 mm). Group 4 used a left-sided, 45° bent ARTHRO-PIERCÉ™ instrument with 5 mm × 15 mm suture configuration (Fig. 1). Each stitch was created using a no.2 FiberWire® (Arthrex, Inc., Naples, FL, USA) suture.

Biomechanical testing

The tendon repair construct was mounted securely in the jaws of a materials testing system (AG-I 10 kN; Shimadzu Corp., Kyoto,
failure. The ultimate tensile load was considered to be the peak load versus displacement (in millimeters) was recorded until failure. The average of the peak-to-peak displacement from the tear edge and that the use of 45° suture placement at a rate of 1 mm/s. Elongation and peak-to-peak displacement were determined during cyclic testing. Elongation is the difference in y displacement between the first cycle’s peak and the twentieth cycle’s peak. The average of the peak-to-peak displacement values of the eighteenth, nineteenth and twentieth cycles were defined as peak-to-peak displacement. Load (in Newtons) versus displacement (in millimeters) was recorded until failure. The ultimate tensile load was considered to be the peak load. Stiffness was calculated by determining the slope of the load—displacement curve using a best-fit line on the load versus displacement curve. Cyclic elongation (mm), peak-to-peak displacement (mm), ultimate load (N), stiffness (N/mm) and failure mode were recorded for each specimen.

Statistical analysis

The null hypothesis was that increasing the bite size of the mattress configuration would not compensate for the shorter bite distance from the tear edge and that the use of 45° bent ARTHRO-PIERCÉ™ instrument would not cause the strength of the configuration to weaken. Kruskal–Wallis’ one-way analysis of variance was used to analyze the groups and evaluate overall differences. When an overall group difference was observed, a Mann–Whitney U test was used to identify the specific location of the statistically significant difference with the significance level set at p < 0.05.

Results

The specimen data are summarized in Table 1. The mean tendon thickness was higher in Group 3 in comparison to Group 1. The mean ultimate load in Group 1 was higher in comparison to Group 3 and the peak-to-peak displacement was significantly higher in Group 4 than Group 1 (p < 0.05). Further comparisons between groups including cyclic elongation, peak-to-peak displacement, ultimate load, and tendon thickness were not different.

The predominant failure mode in Group 1, 2 and 4 was suture rupture (Group 1 had six suture ruptures and one suture cut through the tendon; Group 2 had four suture ruptures and three suture cut-throughs; Group 4 had seven suture ruptures). In Group 3, most of the specimens failed due to suture cuts through the tendon; two specimens failed due to suture rupture.

Table 1

| Specimen data. | Group 1 (5 × 15 mm) (Mean ± SD) | Group 2 (7.5 × 10 mm) (Mean ± SD) | Group 3 (15 × 5 mm) (Mean ± SD) | Group 4 (5 × 15 mm) (Mean ± SD) |
|----------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| Tendon thickness (mm) | 3 ± 0.5 | 3 ± 0.6 | 3.6 ± 0.4 | 3.4 ± 0.5 |
| Cyclic elongation (mm) | 0.9 ± 0.3 | 0.9 ± 0.3 | 0.8 ± 0.2 | 1.1 ± 0.2 |
| Peak-to-peak displacement (mm) | 3.4 ± 1.2 | 3.5 ± 1.2 | 3.4 ± 0.6 | 5 ± 0.9 |
| Ultimate load (N) | 301 ± 16 | 225 ± 91 | 209 ± 62 | 305 ± 100 |
| Stiffness (N/mm) | 11 ± 5 | 12 ± 2 | 11 ± 3 | 9 ± 5 |

N: Newton, SD: standard deviation.

Discussion

The main finding of the present study was that an increase in the bite size of the mattress configuration did not compensate for a more lateral localization of the suture. In addition, a left-bent suture passing device resulted in higher peak-to-peak displacement than a straight device.

Recent biomechanical studies have reported that medial placement of sutures at the tendon can increase the suture retention properties of the construct. Wang et al reported that sutures placed at the myotendinous junction were stronger than sutures placed laterally close to the free tendon edge in torn specimens. The authors claimed that this was due to the smaller fibril diameter and fibril fraction area at the lateral edge of the tendon. In another study, Wieser et al reported that suture positioning lateral to the tendon resulted in significantly lower suture retention properties compared to positioning the suture medial to the tendon. Similarly, Ponce et al reported that a 10 mm bite from the tear edge resulted in a higher failure load compared to a 5 mm bite. It is possible that the longer distance the suture has to slide through the tendon, compared to lateral positioning, contributed to the mechanical advantage of the medial positioning of the stitch. Although the results presented in this study reveal that the mediolateral bite has a higher tendency to re-tear, recent literature suggests paying more attention to Type 2 failures and musculotendinous junction failures with the suture bridge and double-row repair techniques, driving the debate on the strength or failure risk.

In one clinical scenario, it is not always possible to pass the sutures medially due to different tear configurations and/or tear degeneration. Recently, Tamboli et al demonstrated that increasing the bite size of the mattress suture increased the ultimate strength of the configuration and prevented the suture-tendon interface failure. Based on these, the hypothesis of the study was that lateral placement of the sutures can be compensated by an increase in the suture bite of the mattress configuration. In other words, if the area of the tendon covered by the suture is kept constant (bite size of mattress × distance from the edge of the tendon), the strength of the configuration will not change significantly.

This hypothesis was not totally confirmed in the present study. The ultimate load of Group 3 was lower than Group 1 with most failure at the suture-tendon interface instead of suture rupture. There was no difference between Group 1 and 2. In contrast to recent studies, reporting less gap formation and strain with a 4-mm wide mattress compared to a 10-mm wide mattress, we found no difference between the groups in terms of cyclic loading parameters. However, the distance from the tendon edge was kept constant and anchor fixation with knot-tying over the tendon was incorporated in this study, precluding the opportunity to purely test the holding capacity of the tendon.

Ponce et al recently outlined the variables within the control of the surgeon, in order of increasing importance: 1) type of instrument used 2) size of the tissue bite taken, and 3) type of stitch placed with a higher failure load associated with a 10-mm bite.
compared to a 5-mm bite. As the size of the suture passing device increased, the failure load decreased with no effect on cyclic elongation or displacement. In another study,18 it was reported that a SutureLasso™ (Arthrex Inc., Naples, FL, USA) and a tapered needle failed at higher loads after cyclic loading, compared to a straight BirdBeak® (Arthrex Inc., Naples, FL, USA) or Viper™ (Arthrex Inc., Naples, FL, USA) instrument.3 Contrary to both studies, the present study sought to determine whether the curvature of the same device (straight or 45° bent) had any effect on the strength, which could only be demonstrated at peak-to-peak displacement.10,16

One limitation of this study was the use of the bovine model. Animal models allow a more predictable and uniform tendon quality, unlike human cadaver specimens which have a great deal of variability. Bovine infraspinatus have also been validated in previous biomechanical studies.19,20 Moreover, this study did not evaluate the behavior of a long-term rotator cuff repair and only addressed the initial security of the suture-tendon interface, thus removing potentially confounding variables related to the tendon-bone and bone-anchor interfaces.

In conclusion, the bite size from the edge of the tendon seems to be more important than the width of the mattress in rotator cuff repair. The curve of the suture passing device may also have an effect on the strength of the suture-tendon interface.

Conflict of interest

None.

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