Biomechanical Comparison Of A Novel Suture Configuration As An Alternative Single-Row Repair Technique For Rotator Cuff Repair

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Citation

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Abstract

Background Arthroscopic techniques of rotator cuff repair are constantly evolving. Although biomechanically stronger, double-row repair techniques have not been proven to be clinically superior. There are also situations where double-row techniques are not suitable and/or indicated. In these circumstances typical single-row sutures used are the simple suture or the modified Mason-Allen suture. We describe an alternative single-row suture technique – the 'Down Under Suture Technique' (DUST). We hypothesise that this suture has an improved tendon-to-bone contact area and pull-out strength than the established alternatives. Methods In a controlled laboratory study, 1cm tears of the infraspinatus tendon were created in 42 fresh frozen porcine shoulders. The tears were repaired using either a simple suture, a modified Mason-Allen suture or a DUST suture. The tendon-to-bone contact area was measured and compared in 15 shoulders, and suture pull-out strength was measured in the remaining 27 specimens. Results
The DUST suture achieved a tendon-to-bone contact area of 122 mm^2, significantly higher than that achieved by the Mason-Allen (48 mm^2, p=0.008) and simple suture (51 mm^2, p=0.01). Suture pull-out strength was 191N, significantly higher than the simple suture (97N, p=0.028), but not significantly higher than the Mason-Allen suture (127N, p=0.22). Conclusions We conclude that the DUST has favourable biomechanical properties when compared to other single-row suture techniques. It is a useful arthroscopic alternative where a single row cuff repair is needed.

INTRODUCTION

Techniques of rotator cuff repair have undergone several evolutions over the past 20 years. The goals of achieving good patient satisfaction with a strong, healed tendon repair are clear, however the single best method of achieving this is still a matter of much debate.

Traditional open repair was performed using transosseous suture techniques. This has since been superseded by arthroscopic repair, initially with single-row and then double-row techniques. Most recently, suture-bridge or transosseous equivalent techniques have been described.

Repairs should achieve high initial fixation strength, minimize gap formation, maintain mechanical stability under cyclic loading, and optimize the biology of the tendon-bone footprint until the cuff heals biologically to the bone [1].

Biomechanical studies to date have shown that double-row repairs reconstruct the anatomic footprint of the rotator cuff better than single-row constructs. Double-row repairs also have less gap formation, improved tensile strength, and a lower failure load [2]. Retear rates have also been shown to be significantly lower for double-row repairs, however only for tears of greater than 1cm [3].

This however has not translated into improved clinical outcomes. In 2 recent literature reviews, Sadaris et al reported that there was little evidence to support any functional differences between the 2 techniques, except possibly for patients with large cuff tears of >3cm [4], whilst Nho et al found that there were no clinical differences between repair techniques [5]. Furthermore, double-row repairs generally will take longer as more anchors are needed, and are thus more expensive. Double-row repairs also strangulate a greater area of tendon as well as violate more bone with the increased number of anchors.

There are also situations where a double-row repair is contraindicated. To achieve restoration of the footprint the retracted torn tendon must be advanced back to the edge of the greater tuberosity. If high tensions are created the repair will be overloaded and will fail [6]. In these circumstances it may be more appropriate to use a single-row repair at the articular margin.

The question arises, which is the optimal suture configuration for tears of 1cm or less? These will not always be suitable for a double-row repair. In these circumstances one single suture anchor may be all that can be placed into the repair site. Given the main theoretical disadvantage of single-row fixation is a poorer tendon-to-bone footprint, any suture configuration which can increase tendon-to-bone contact area using single-row fixation, without compromising fixation strength, may be beneficial for healing of rotator cuff tears.

We describe a Single-Row suture configuration which can be employed arthroscopically for rotator cuff repairs of less than 1cm. The tendon-to-bone contact area and maximal pull-out strength of this configuration are compared to those of the Modified Mason-Allen suture and a simple single-row technique.

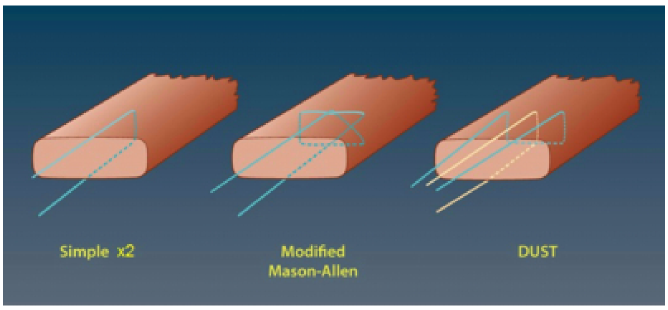
MATERIALS AND METHODS

SPECIMEN PREPARATION

A single-row mattress suture – coined the ‘Down Under Suture Technique’, or DUST, was compared to a simple suture and a modified Mason Allen suture (Fig. 1). Testing was performed on a porcine model. 42 specimens in total were used.

Figure 1

Figure 1

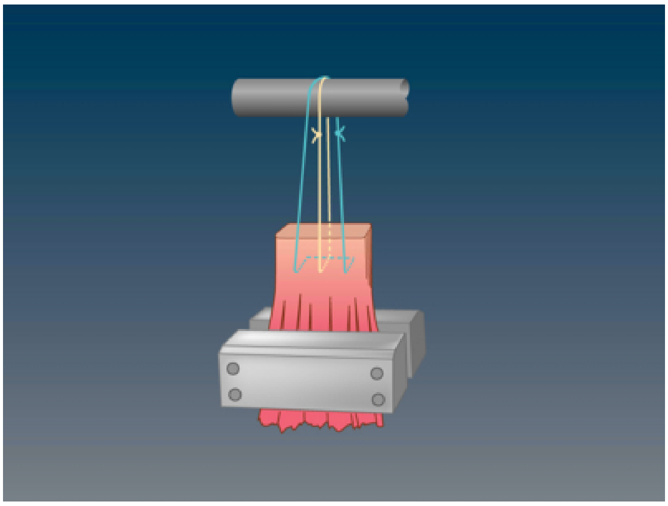


For tendon-to-bone contact area testing, 15 fresh frozen porcine forequarters were thawed out at room temperature. The overlying soft tissues were carefully dissected from each specimen, leaving the scapula, humerus and the interconnecting rotator cuff complex. No pre-existing rotator cuff abnormalities were noted in any of the specimens based on direct inspection. The infraspinatus tendon was elevated off the greater tuberosity using sharp subperiosteal dissection to a width of 1cm to simulate a tear. A single, double-loaded 5.5mm copolymer suture anchor was inserted into the greater tuberosity (Allthread; Biomet, Warsaw, IN) at a ‘dead man’s angle’ [7], and according to manufacturer’s guidelines. Specimens were divided evenly into three groups and the tendons repaired with one of the three techniques described below.

For suture pull-out strength testing the infraspinatus musculotendinous unit was dissected free from the porcine forequarter in 27 specimens. The muscle belly was frozen with carbon dioxide and held with cryogenic grips. Specimens were divided evenly into three groups and suture configurations were re-created in each tendon according to one of the three techniques described below, using a No. 2 Maxbraid suture (Biomet, Warsaw, IN). The sutures were then tied over a bar with care taken to ensure even tension and length of each suture (Fig 2).

Figure 2

Figure 2



REPAIR TECHNIQUE

Three different suture configurations were used to repair the infraspinatus tendon to the bone – a simple single-row repair, a modified Mason-Allen repair, and the ‘Down Under Suture Technique’.

SIMPLE SINGLE ROW REPAIR

Both sutures of the double-loaded suture anchor were used to create 2 simple sutures in the repaired tendon. Each suture loop was passed 10mm medial from the tendon edge, and the two suture limbs were positioned 10mm apart from each other at their widest point.

MODIFIED MASON-ALLEN REPAIR

One suture was discarded and the remaining loaded suture was used to recreate the modified Mason-Allen suture loop 10mm medial to the tendon edge. The transverse limb was 10mm wide.

DOWN UNDER SUTURE TECHNIQUE

We have coined this technique the ‘Down Under Suture Technique’ as it involves an inverted mattress suture in its composition. One suture of the double-loaded anchor was used to create an inverted mattress suture 10mm medial to the tendon edge. The transverse limb was 10mm wide. A simple suture was then passed medial to the transverse limb of the inverted mattress suture to lock the construct.

BIOMECHANICAL TESTING

TENDON-TO-BONE CONTACT AREA

Tendon-to-bone contact area measurements were made with an I-Scan 6900 electronic pressure sensor (Tekscan, Boston, MA). Following suture insertion, the sensor was placed between the infraspinatus tendon and bone and the shoulder internally rotated to 30 degrees to tension the repair. A real-time recording of the area of contact was made and the peak contact area in mm^2 recorded.

SUTURE PULL-OUT STRENGTH

The maximal pull-out strength of each suture was determined using a Mechanical Testing Machine (MTS MiniBionix 858, MN) in displacement control. A pre-load of 5 N was applied to each specimen prior to loading. A distraction force was then applied, and increased at 5 mm/minute until failure, with failure being defined as a decreasing load with increasing displacement.

All data were analysed using analysis of variance followed by a post-hoc Games Howell analysis. A p-value of 0.05 was taken as significant.

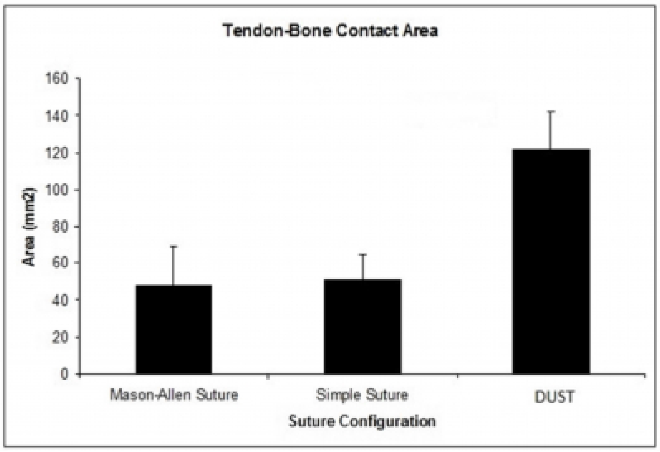
RESULTS

TENDON-TO-BONE CONTACT AREA

The DUST achieved the highest tendon-to-bone contact area, with a mean area of 122 mm^2, which was significantly higher than that achieved by both the Mason-Allen configuration (48 mm^2, p=0.008), and the simple suture configuration (51 mm^2, p=0.01). There was no statistically significant difference between the Mason-Allen and simple configurations (p=0.95). These results are demonstrated in Figure 3.

Figure 3

Figure 3



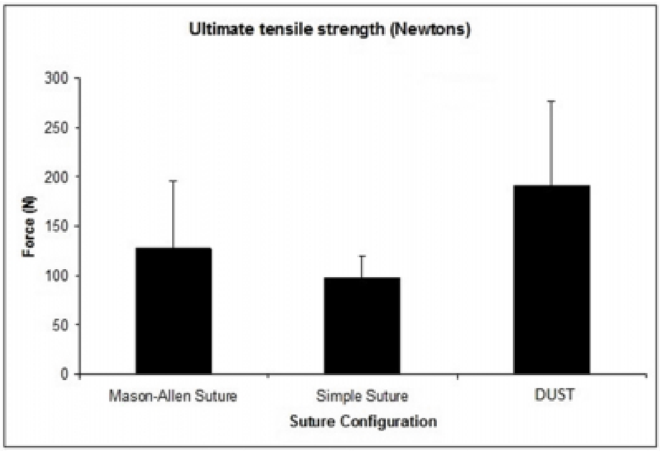
SUTURE PULL-OUT STRENGTH

All sutures failed through the suture-tendon interface. There were no failures at the suture knot or through the cryogenic grips. The DUST achieved the highest tensile pull-out strength, with a mean of 191 N, followed by the Mason-Allen suture, with a mean of 127 N. The difference between these results was not significant (p=0.22).

The simple suture configuration achieved the worst pull-out strength with an average tensile force at failure of only 97 N. This was significantly lower than that for the DUST (p=0.028), but not significant compared to the Mason-Allen (p=0.22). This is illustrated in Figure 4.

Figure 4

Figure 4



DISCUSSION

The objective of this study was to test a novel and easily replicated arthroscopic suture technique for a single-row rotator cuff repair. Our results show that the DUST has favorable biomechanical properties to traditional techniques.

Although in this study the sutures were all recreated using open techniques, the DUST lends itself well to an all-arthroscopic approach. This is in contrast to the modified Mason-Allen suture which is very difficult to deploy arthroscopically. The senior author uses a suture passer with an automated retrieval action to pass the suture (BiPass Suture Punch; Biomet, Warsaw, IN), first with an inverted action and then in standard fashion. The final locking loop is also passed with the suture passer.

The supraspinatus footprint on the greater tuberosity measures approximately $350mm^2$ [8]. It is about 25mm in length in the anterior-posterior plane, and 14mm medial-lateral. Recent studies have shown that a double-row repair can provide up to 74% more footprint restoration than a single-row repair [9] [10]. We have demonstrated that the single-row mattress suture configuration recreates a $122mm^2$ contact area; significantly larger than both a simple as well as a modified Mason-Allen suture (139% and 154% more, respectively).

The ultimate tensile strength of the single-row mattress suture was also higher than both two simple sutures, and the modified Mason-Allen suture, although not significant for the Mason-Allen suture. The theoretical benefit of a larger tendon-to-bone contact area and tensile strength is to optimize the healing potential and strength of a repair. This may be of importance as several studies have documented better subjective and objective results after rotator cuff repairs when they have been documented to heal [3] [11].

This study does have some limitations. In this study a porcine model was used. Although these results were not replicated on a human cadaver model, the mechanical properties of tendon tissue of other animals such as cattle, pigs and dogs have been previously shown to be similar to those of human tendons [12]. We feel that the primary aim to compare the suture configurations was adequately served with this model.

The sutures were also statically tensioned and not cyclically loaded. This decision was made as our main aim was to test the overall static strength of the suture configurations only.

We have described a novel type of single-row repair configuration which is a biomechanically favourable construct than traditional single-row techniques. It is easily reproducible using arthroscopic means and can be a useful tool for tears for which a double-row repair is not possible. The senior author currently uses this suture in his daily surgical practice. We feel that it adds to the surgical arsenal in treating rotator cuff tears.

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