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Research Article

The Use of Barbed Sutures in Repair of the Shoulder Rotator Cuff Tendons—A Pilot Study In Vitro

S. M. Thompson, R. J. Emery, P. R. Reilly, and A. A. Amis

Department of Mechanical Engineering, South Kensington Campus, Imperial College London, London SW7 2AZ, UK
Address correspondence to S. M. Thompson, s.m.thompson@imperial.ac.uk

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Abstract *Background.* Tears of the rotator cuff are common, some are repaired surgically. There are problems associated with repair and arthroscopic knot tying, and retear rates can be as high as 94%. It is known that surgical knots can slip or break and may cause ischemia and infection, affecting the healing process. *Method.* A barbed suture was developed. A materials testing machine measured the pull out strength of the sutures from the ovine infraspinatus tendon. Four groups of eight tendons were tested, using one, two, three or four knot-free suture loops for each repair. The maximum tensile strength was recorded. A control group with one knotted suture was used. *Results.* One suture had a mean strength of 38.9 N, two sutures 82.3 N, three sutures 138.8 N, and four sutures 176.6 N; each difference was significant. The single knotted suture of the same material had a mean strength of 59 N. *Discussion.* Barbed sutures inserted without knots had significant tensile strength. They may offer an alternative to current rotator cuff repair methods, being technically easier and quicker. *Conclusion.* The use of barbed sutures may be feasible in the repair of the rotator cuff, but further testing is required.

Keywords barbed sutures; rotator cuff; shoulder; repair

1. Introduction

Surgical repair of the rotator cuff can be performed either open or arthroscopically. A recent study has shown that there is no benefit of one over the other [11]. Although both procedures have a high retear rate, their clinical outcomes are better than preoperative function [6, 8].

Arthroscopic rotator cuff repair using sutures is technically demanding and requires arthroscopic knot tying. These repairs rely on the surgeon's ability to tie secured knots, which is a challenging and time consuming process. Improper tying and handling can result in knot breakage or slippage, suture extrusion, infection, inflammation, ischemia, and potentially wound dehiscence. Further, knots may impede wound healing, constrict blood flow, distort tissue or increase scar formation [1, 2, 3, 4, 5, 9]. To alleviate these problems, attempts have been made to design self-anchoring sutures [14].

A barbed suture has been developed specifically for the repair of the rotator cuff without the need to place a surgical knot (Quill SRS, Angiotech Pharmaceuticals, Vancouver, BC, Canada). The barbs are introduced into the surface of a monofilament suture by micro-machining. It was hoped that this new suturing technique would allow a quicker and easier arthroscopic repair. This may, in turn, lead to a decrease in the retear rates being experienced with current procedures. There is, however, no data available on the strength of attachment of the barbed sutures into rotator cuff tendons. The aim of this study, therefore, was to investigate the pull-out strength of these barbed sutures from tendons in vitro.

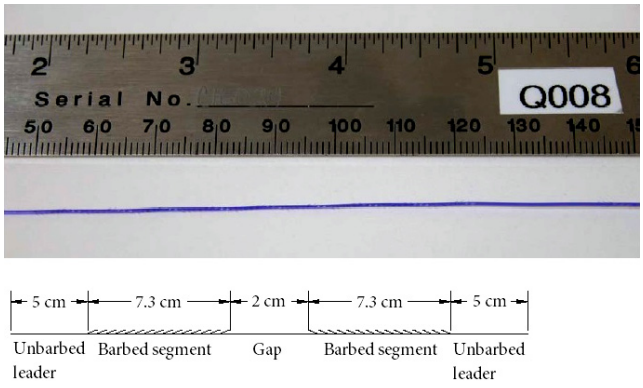

Figure 1: Configuration of the suture with two opposing barbed segments and plain ends for needle attachment.

2. Methods

The barbed sutures used were absorbable Polydioxanone monofilament, size 2.0. There was a 50 mm unbarbed leader on both ends of the suture, two 73 mm opposing barbed segments, and a central unbarbed length of 20 mm (Figures 1 and 2). The test suture configuration was to the design of the authors and was intended to represent a central smooth zone where the suture would engage a post/anchor

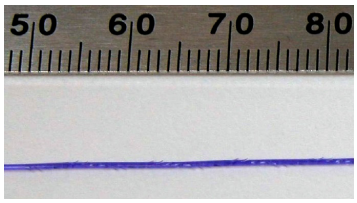

Figure 2: A unidirectional barbed segment of the suture (scale: mm)

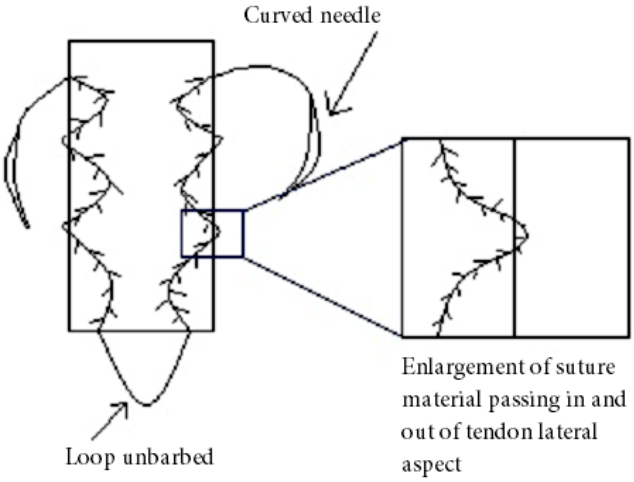

Figure 3: The "helical" system of placing a suture with a curved needle, creating a 3D repair within the tendon substance.

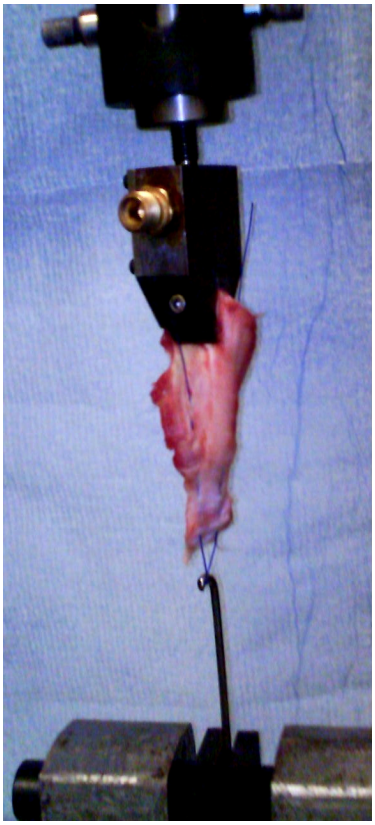

Figure 4: The tensile testing setup: the frozen clamp at the top of the tendon, the J-shaped rod attached to the suture loop at the bottom.

fixation to the humerus, barbed lengths to grip within the tendon, plus leaders for needles. Half-circle diamond-point 26.2 mm needles were attached to both ends.

Ovine infraspinatus tendons were used; these are morphologically similar to the human rotator cuff [7]. The specimens used in this study were obtained from the same farm, freshly slaughtered adult sheep with bilateral normal shoulders. Four test groups, each with eight infraspinatus tendons 40 mm long, were used.

The tendons of each group had 1, 2, 3 or 4 sutures inserted. The two ends of each barbed suture were passed along the tendon in a helical path, using the curved needle, leaving the midpoint of the suture protruding from the cut end of the tendon as a U-shaped loop (Figure 3). Each end of the suture was passed into the tendon three times. The suture loops were secured on to a metal hook which was clamped onto the base of an Instron 5565 materials testing machine (Instron, High Wycombe, UK). The hook was used to represent a bone anchor.

The top end of the infraspinatus tendon was attached to the moving cross-head and load cell of the Instron machine using a metal cryo-clamp. This clamp represented the muscular end of the tendon and was frozen in-situ by passing liquid CO_2 through small holes in it, freezing the muscular end of the tendon into the clamp [12]. The frozen zone did not approach the suture material (Figure 4). The specimens were then extended until they failed, at a speed of 100 mm/min. The failure strengths of each group were compared using the Mann-Whitney test, assuming $P < .05$ for significance. The control group repair was tested with a single nonbarbed PDS suture of the same size with a standard knotted repair formation.

3. Results

The failure strengths of the tendon-plus-sutures constructs increased significantly as the number of sutures increased: $P < .01$ between one and two sutures pull out, and between two and three sutures pull out; $P = .037$ between three and four sutures (Figure 5). For control an individual knotted suture had a failure strength of 59 ± 1.1 N (mean $\pm$SD).

4. Discussion

This study has shown that polymeric sutures with a barbed surface were able to sustain considerable tensile loading before they were pulled out of a tendon when inserted in a helical pathway without any securing knots. It also showed

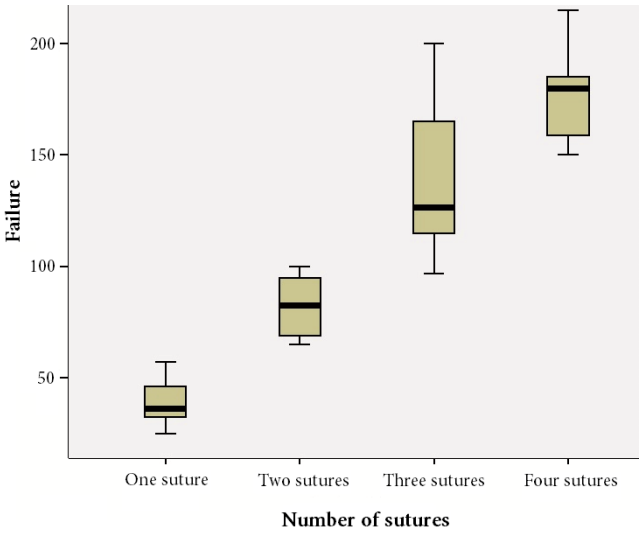

Figure 5: A box-plot graph showing the results for the individual suture groups. The y-axis is failure strength in Newtons.

that the strength of the construct increased significantly as the number of barbed sutures was increased. These preliminary results suggest that barbed sutures may be useful for tendon repairs, although considerably more development and testing will be needed prior to clinical use [13, 15].

The barbed sutures used in this study were developed for use in dermal wound closure and cosmetic surgery [10]. An absorbable Polydioxanone monofilament suture was used, as it was deemed to be a popular suture used for such a repair. We did not test other types of suture (i.e., nonabsorbable or different materials or sizes). This may have an influence on results, and further testing exploring these parameters may be of use. The testing protocol using a calibrated Instron machine and freezing the clamp at one end of a tendon specimen in order to find the tensile strength has been used previously [12].

Due to the nature of the tendon barbs, a ratchet effect was seen from initial slippage of the suture to failure. This means that as the suture started to fail, the barbs tended to give way sequentially, therefore slipping small distances. This meant that the sutures pulled part-way out of the tendon, but that the repair did not fail completely until sometime after the maximum pull out strength had been achieved. This ratchet and slippage effect should be studied under cyclic loading at nonfailure forces. It may well be that the barbed sutures offer a good repair by resisting gap formation at low cyclic forces representative of rehabilitation during tendon healing. The control group fails differently as a midsuture failure.

Gerber et al. suggested that a minimum tensile strength of 187 N is needed for rotator cuff repairs [7]. This study had mean strengths of 139 N with three sutures, and 177 N with four. It is possible that higher strength could be obtained with different suture materials, barb geometry, or insertion technique, all of which suggest the value of further development work.

5. Conclusion

This pilot study found that barbed sutures inserted without knots had a tensile strength of attachment to ovine infraspinatus tendons which approached that required for human rotator cuff repairs.

There needs to be further assessment of the sutures prior to use in vivo. Further testing may include the study of cyclical loading in human cadaveric specimens.

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