Tissue Fixation Security in Transosseous Rotator Cuff Repairs: A Mechanical Comparison of Simple Versus Mattress Sutures

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Summary: The primary purpose of this investigation was to compare tissue fixation security by simple sutures versus mattress sutures in transosseous rotator cuff repair. These two repair techniques were each performed in 17 human cadaver shoulders, with two bone tunnels being used for the repair by two simple sutures and two other bone tunnels being used for the repair by one mattress suture. The repairs were loaded to failure in a servohydraulic materials test system. Rotator cuff repair by simple sutures was found to be significantly stronger than repair by mattress sutures (P = .0007). The average ultimate load to failure for the simple suture construct (189.62 N) was 39.72% greater than that for the mattress suture construct (135.71 N). Most of the failures occurred by suture breakage at the knot. Load-sharing by multiple suture tails and multiple knots in the simple suture configuration likely contributed to its superior strength characteristics compared with the mattress suture configuration. Key Words: Rotator cuff—Tendon repair—Suture strength—Ultimate strength—Biomechanical testing.

Security of tissue fixation is the most important element in rotator cuff repair. Various authors have advocated disparate repair techniques with little or no biomechanical data to justify their fixation methods. McLaughlin first described the transosseous technique of rotator cuff repair by means of sutures passed through bone tunnels in the greater tuberosity of the humerus. Using the transosseous approach, other studies have reported generally good results. These studies typically achieved soft tissue fixation by means of a horizontal mattress stitch or modification thereof that exhibited tendon-grasping properties. An interesting twist on the topic of soft tissue fixation is the finding, by independent investigators, of postoperative defects in repaired rotator cuffs that were functioning normally. These defects have been demonstrated by ultrasonography and by arthrography, and confirm a loss of tissue fixation in a significant percentage of repairs.

Recent studies have investigated the mechanical properties of the component interfaces (suture-tendon, suture-bone) of the transosseous construct. However, these studies have failed to quantify the overall tissue fixation security of a given tendon-suture-bone construct. We introduce the concept of tissue fixation security as the strength to failure of an entire tendon-suture-bone construct. This construct can fail in one of four ways: by soft tissue failure, by suture breakage, either at the knot or distant from the knot, by knot slippage, or by bone failure. Regardless of the point of failure, loss of tissue fixation guarantees failure of tendon-to-bone healing.
This study was designed to investigate two related aspects of rotator cuff repair. The primary purpose of the investigation was to determine whether repair by simple sutures or by mattress sutures was mechanically superior, by comparing the ultimate load to failure (tissue fixation security) of the two constructs. The secondary focus of the study was to determine if there was a predominant pattern of failure of the constructs, indicating the “weak link” in the repair components (soft tissue, bone, or suture).

MATERIALS AND METHODS

Seventeen fresh frozen human cadaveric shoulders were used in this investigation. The age and cause of death of each specimen was not known. There were no preexisting rotator cuff tears in these specimens. The specimens were prepared by sharply dissecting the intact rotator cuff attachments from bone, and dissecting the corresponding muscle bellies from the scapula. Each shoulder yielded two segments of rotator cuff used in testing, one segment being the combined supraspinatus-infraspinatus tendon (rotator cable–crescent complex) and the other being the subscapularis. Two bone tunnels were made in the greater tuberosity, 1.5 cm apart, and two similar bone tunnels were made in the lesser tuberosity. The holes at the two ends of each bone tunnel were 2 cm apart. One of the tendon segments was then repaired through the bone tunnels in the greater tuberosity by means of a single mattress suture of number 2 braided polyethylene. The other tendon segment was repaired to the lesser tuberosity with two simple sutures of number 2 braided polyethylene, passing one simple suture through each bone tunnel. A bone trough was not made. A biomechanical and histological study in goats has shown that tendon healing to cortical bone is as strong as tendon healing to a cancellous trough, so our experimental model (without a bone trough) seemed to be a reasonable representation of a clinical repair (Fig 1). The tendon segments (supraspinatus-infraspinatus versus subscapularis) were randomized as to location of repair (greater versus lesser tuberosity). In the mattress suture group, the knot was tied over the top of the rotator cuff tissue to simulate placement of an arthroscopic knot. Each suture was tied manually with a stacked square knot of four throws each. The free end of each repaired rotator cuff segment was affixed to a looped nylon strap by means of multiple mattress sutures as a means to apply load to the repaired tendon. A recent study showing equivalence of the bone density in the lesser and greater tuberosities supports the validity of comparing our repairs at those two sites.

The humerus was fixed by means of a three-axis vise so that the repaired tendon could be longitudinally loaded in the anatomic direction of the repaired muscle-tendon unit. The nylon strap that had been sutured to the tendon was affixed by means of a custom clamp to the vertical actuator of a servohydraulic materials test system (MTS Model 810, MTS Corporation, Minneapolis, MN). An 8.9N preload was applied in each test. Each repair construct was loaded at a constant displacement rate of 31 mm/sec until failure was observed by a sudden decrease in load. This displacement rate was chosen because the rate-dependency characteristics of braided polyethylene were most favorable at 31 mm/sec. In addition, this was a rate that duplicated that of normal human functional activities. The mode of failure was visually observed and recorded (Fig 2).
All data were statistically analyzed by the unpaired \( t \)-test.

**RESULTS**

The primary purpose of this study was to determine which suture repair of the rotator cuff was stronger, the one with transosseous simple sutures or the one with transosseous mattress sutures. The average ultimate load to failure was 189.62 N for the simple suture construct compared with an average ultimate load of 135.71 N for the mattress suture construct (Fig 3). Simply stated, the load required to disrupt the simple suture construct was 39.72% greater than the load required to disrupt the mattress suture construct. Data analysis by the unpaired \( t \)-test indicated that this finding was statistically significant at \( P = .0007 \).

The failure mode was identified as suture failure, bone failure, or tendon failure. Out of 34 tendon-suture-bone constructs, suture failure occurred in 22. This was by far the most common mode of failure in both types of constructs, accounting for 12 failures in the simple suture group and 10 failures in the mattress suture group. Although most of the suture failures occurred by breakage at the knot, two sutures failed by coming untied. This was a surprising finding because all knots were securely tied by hand with four throws of a square knot. Knot slippage may have resulted from knot relaxation over time, because there was a 20-hour delay between tying the knots and testing the fixation in these two specimens. Bone failure occurred almost exclusively in the mattress group (6 mattress, 1 simple). Tendon failure occurred more often in the simple group (four simple, one mattress).

**DISCUSSION**

Tissue fixation security in rotator cuff repair is critically important. Various authors have shown (by means of ultrasonography and arthrography) loss of tissue fixation in a large percentage of attempted rotator cuff repairs, resulting in a residual defect in the rotator cuff. Most reported series of rotator cuff repair have used a mattress suture or a modification of a
mattress suture with tendon-grasping properties. However, the authors are unaware of any study that compares the strength and security of rotator cuff repairs done with mattress sutures versus simple sutures.

The purpose of this study was to compare mechanical tissue fixation security of mattress sutures with simple sutures in transosseous rotator cuff repairs. Two bone tunnels were used for each construct. One might think that the only difference between these two constructs was the suture configuration (simple versus mattress). On closer analysis, however, one realizes that the geometric differences in these two tendon-suture-bone configurations account for significant potential mechanical differences. The geometry of each construct imposes different mechanical conditions on each construct. For example, the simple group has two bone bridges as opposed to one bone bridge in the mattress group. With a larger total amount of bone to resist pullout in the simple group (caused by the two bone bridges in comparison with one bone bridge for the mattress suture), one would expect bone failure to be less common than in the mattress group, and that was the case. Suture failure occurred at a much higher load in the simple group (193.00 N) than in the mattress group (147.74 N). This is to be expected, because there are twice as many "tails" of suture in the simple group as in the mattress group, with a suture "tail" being defined as a limb of a suture that resists load (Fig 4). With more "tails" to resist the applied load, one would expect suture breakage to occur at a higher load. Additionally, the simple group had two knots, compared with one knot in the mattress group. Load-sharing by multiple suture tails and multiple knots in the simple suture configuration may have contributed to its superior strength characteristics.

Virtually all of the suture breakage occurred at the knot. Suture is significantly weakened by tying a knot in it. The knot probably disrupted individual fibers of the braided polyethylene in addition to imposing high local stress concentrations in the knotted suture. A surprising finding in two cases (one mattress and one simple) was that the knot came untied. Many of us have had the uncomfortable feeling in surgery of seeing the final throw of a knotted braided suture come untied before we had the wound closed. One could imagine that with cyclical loading of the repaired rotator cuff, gradual knot relaxation may occur, allowing the knot to come completely untied.

Although the foregoing observations are interesting, the primary goal of this study was to compare the ultimate load to failure of transosseous rotator cuff repair by mattress sutures with that of simple sutures.

The average load required to fail the simple suture construct was 39.72% greater than the load required to fail the mattress suture construct, confirming that transosseous repair by simple sutures was significantly stronger than repair by mattress sutures ($P = .0007$).

To maximize the fixation security of rotator cuff repairs regardless of technique (arthroscopic, open, or mini-open), the surgeon should consider the use of multiple simple transosseous sutures.

**Acknowledgment:** The authors thank Peter Matsuura, M.D., Patrick W. Cawley, O.P.A., R.T., and Dan Pfafter, M.S., for their invaluable contributions to this project. The authors also wish to thank Smith and Nephew DonJoy, Inc., of Carlsbad, California, for the use of their biomechanics laboratory in conducting this investigation.

**REFERENCES**


