Effects of Suture Tension on the Footprint of Rotator Cuff Repairs
Technical Note

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Abstract
The footprint is thought to be an important fact in rotator cuff repairs and has been used to compare various cuff fixation techniques. The following experiment used two different measurement sensors to evaluate the footprint as it is affected by suture tensions in a transosseous equivalent suture bridge repair. It was found that suture tension has a direct effect on footprint contact area and pressure and thus could affect healing and fixation stability and should be characterized in any study of comparative fixation techniques.

The area of contact between the rotator cuff and humerus (footprint) and contact pressure are thought to effect healing and also fixation stability. Investigators have used various methods for these measurements, such as a retrograde inserted pressure sensor, pressure sensitive film, and thin film electronic sensors, and have focused on comparison of fixation techniques. We recently showed that suture tensions in the repair can affect fixation stability and wondered how they affect the footprint. The following pilot study was designed to determine the effects of suture tension on the contact areas and pressures of the footprint.

Materials and Methods
Three fresh frozen human cadaver shoulders were obtained and stored at -20°C. The specimens were thawed for 24 hours before dissection, and all specimens went through only one freeze cycle for this experiment. The mean age of the cadaver shoulder specimens was 57 years (range, 55 to 59), and all were male specimens with no pre-existing shoulder pathology, including rotator cuff tears. The supraspinatus tendon and muscle with the humerus were removed, and the humeral shafts were mounted into square aluminum tubes with acrylic cement that were then placed into a vise.

The entire supraspinatus attachment was sharply dissected from its insertion on the greater tuberosity and the medial, muscular portion folded over the straight portion of a large metal D-ring and sutured to itself to provide a means of uniformly loading the tendon. A cord was tied to the curved portion of the D-ring, passed through a pulley on a ring stand, and the free end attached to a 10 N weight. The height of the pulley determined the cuff loading angle of 45° to the humeral shaft.

An area of 13 mm wide (medial to lateral) and 25 mm in length (anterior to posterior) of the greater tuberosity was then prepared with a rasp. All specimen tissues were kept moist with saline soaked gauze throughout the dissection, preparation, and testing.

A transosseous equivalent suture bridge repair was performed on the specimens with the weight applied to the tendon in order to create some tension during the repair to simulate an in vivo scenario. The repairs used two medial 4.5 mm PEEK FT corkscrew anchors (Arthrex, Naples, FL) in all specimens; the anchors were inserted just lateral to the articular margin of the humeral head into punched holes. All medial holes were placed at a 45° angle relative to the footprint surface. The antero-medial suture anchor was placed 5 mm posterior to the bicipital groove, and the posterior-medial anchor was placed 12.5 mm posterior to the anterior anchor. The suture anchors were pre-loaded with a No. 2 Fiberwire® suture (Arthrex, Naples, FL). Both suture ends were passed through the supraspinatus tendon in a horizontal mattress configuration using an ExpresSew™ suture passer (DePuy Mitek, Raynham, MA) just lateral to
the musculotendinous junction. The suture passes were 7 mm apart in the anterior-posterior plane and centered over each corresponding medial suture anchor.

A sliding Roeder knot was tied and backed up with three alternating half-hitches on alternating posts using an arthroscopic knot pusher. The suture ends were not cut after tying. A punch was used to create two lateral row holes 1 cm distal to the lateral edge of the supraspinatus tendon in line with the medial row anchors, 12.5 mm apart in the anterior-posterior plane. These holes were an average of 17 mm (range, 15 mm to 20 mm) from the medial holes. A 2.5 mm drill was used to extend these holes to the medial aspect of the humerus.

The four, free suture legs were passed through these lateral holes and their ends attached to a spring force gauge on the medial side of the humerus (Fig. 1). This configuration enabled a pressure sensor to be inserted between the tendon and bone, loaded with a fixed suture tension, and removed allowing multiple measurements with the same specimen. Loads used were 40, 60 and 80 N. These were chosen on the basis of a pilot study in which three separate surgeons pulled on a suture loop with one end fixed to an electronic force gauge in a manner similar to that they would use for a cuff repair. This testing showed an average of 30 N (as this was applied to two legs, the total load on all four would be 60 N).

Two types of sensors were used in separate tests that were repeated three times in each humerus for each suture load: 1. a FlexiForce® thin film resistance sensor (5 N) and 2. 1 cm x 3 cm strips of Prescale™ Film (Super Low pressure)
made into a sandwich with the ends fixed with tape (both from Tekscan, Boston, MA). The FlexiForce® sensor was inserted inferiorly beneath the tendon (Fig. 2) and used two registration pins to fix its position; its resistance was measured with an ohmmeter during the applied suture tensions. The Prescale™ film was inserted anteriorly across the repair footprint beneath the tendon between the medial anchors and lateral holes and removed after suture tensioning was held for five seconds. The Prescale™ film impression was copied on a flatbed scanner at 1200 pixels per inch, and areas of similar color density (pressure on the basis of calibrated standards) determined by NIH ImageJ.

Results

Graphs of suture tension versus resistance for the Flexiforce® sensors are shown in Figure 3 and were linear (r = 0.991 to 0.994) with similar slopes but different intercepts. The Prescale™ film also showed a linear behavior of suture tension versus area (pressure > 1.5 Mpa). The area increased approximately 50% with doubled pressure (Fig. 4).

Discussion

These results indicate that suture tension has a direct effect on footprint contact area and pressure. Most of the load on the footprint occurs beneath the sutures, and it appears that the contact area here does not increase linearly meaning that local pressures increase. This has potential implications for tissue patency.5

Only one suture pattern was studied; others could show different behaviors. Only three specimens were tested, and although they were used for multiple tests, there is a possibility that the soft tissue properties could have been affected. The readings from the FlexiForce® sensor are only representative of pressure on the footprint as the whole sensor surface is not uniformly loaded as would be during calibration and also vary due to sensor positioning (however constant for each specimen). Others have used custom sensors with multiple small areas to partially address this problem.4,5 Prescale™ film only measures the maximum pressure and cannot account for any subsequent loosening. It also should be apparent that any studies comparing footprints due to various cuff fixation techniques also need to quantify and control suture tensions.

Conclusion

It was found that suture tension has a direct effect on footprint contact area and pressure and thus could affect healing and fixation stability. Suture tension should be characterized in any study of comparative fixation techniques.

Disclosure Statement

The author has no financial or proprietary interest in the subject matter or materials discussed, including, but not limited to, employment, consultancies, stock ownership, honoraria, and paid expert testimony.

References