Strength of Fixation with Transosseous Sutures in Rotator Cuff Repair

GEORGE L. CALDWELL, JR., JON J. P. WARNER, MARK D. MILLER, DOUGLAS BOARDMAN, JEFFREY TOWERS and RICHARD DEBSKI
J Bone Joint Surg Am. 1997;79:1064-8.

Strength of Fixation with Transosseous Sutures in Rotator Cuff Repair*

BY GEORGE L. CALDWELL, JR., M.D.†, JON J. P. WARNER, M.D.‡, MARK D. MILLER, M.D.§, DOUGLAS BOARDMAN, M.D.‡, JEFFREY TOWERS, M.D.¶, AND RICHARD DEBSKI, M.S.‡, PITTSBURGH, PENNSYLVANIA

Investigation performed at the Department of Orthopaedic Surgery, the Musculoskeletal Research Center, University of Pittsburgh, Pittsburgh

ABSTRACT: **The effect of various configurations of placement of transosseous sutures on the immediate strength of fixation was studied in forty-five fresh-frozen humeri from cadavera of older individuals (mean age at the time of death, sixty-three years). The ultimate strength (the strength to failure) was significantly greater ($p < 0.05$) when the sutures were placed at sites more distal to the tip of the greater tuberosity or when the sutures were tied over a wider bone bridge. Cortical augmentation with use of a plastic button through which the transosseous sutures were tied increased the ultimate strength approximately 1.9-fold. The increase in the ultimate strength of the transosseous repair corresponded significantly with the increasing mean thickness of the cortical bone as the sutures were placed more distally along the lateral aspect of the humerus. We concluded that the strength of the fixation of a rotator cuff repair can be increased by placing the transosseous sutures at least ten millimeters distal to the tip of the greater tuberosity and by tying them over a bone bridge that is at least ten millimeters wide. When bone is very osteoporotic, cortical augmentation with a readily available plastic button strengthens the repair.**

The repair of a rotator cuff tendon generally consists of reapproximation of the torn edge to a prepared bone surface. Fixation of the tendon into a bone trough in the greater tuberosity with use of transosseous sutures — the McLaughlin technique — is considered to be the standard method for such a repair[1,2,4,10,11].

Recurrence of a tear of a tendon after operative repair is a well recognized complication, and recurrence of large or massive tears may occur relatively frequently[8]. Failure of the fixation may be caused by rupture of the suture material, loss of the suture's so-called grasp of the tendon, or loss of the suture anchor in the bone. In most previous *in vitro* studies of rotator cuff repair, these three modes of failure could not be examined independently as testing involved loading of all three elements of the repair. The mode of failure during testing has often varied, yielding little information about the specific changes in technique that would maximize the strength of each individual component[6,9,12,13]. Gerber et al. provided valuable information on each of the three modes of failure individually. They identified stronger suture materials and improved tendon-grasping techniques but suggested that suture fixation to bone may be the weak link of a standard transosseous repair, especially in elderly individuals who have a chronic tear[7]. They concluded that, in such patients, the osteoporotic bone of the proximal part of the humerus provides poor fixation and the fixation should be augmented to improve the over-all strength of the repair.

Furthermore, the immediate strength of repair with transosseous sutures has been used as a benchmark for the adequacy of newer suture anchors[5,7,9,12] and that of different techniques to augment suture-bone fixation[6,7,13]. However, the exact anatomical placement of the transosseous sutures has not been detailed in any of these studies; thus, the so-called control values are susceptible to variability. To date, we are not aware of any investigation of the effect of different sites for placement of transosseous sutures on the immediate strength of suture fixation to bone.

Therefore, the purpose of our study was to assess how varying the site of transosseous sutures through the greater tuberosity influenced the immediate strength of the repair and to relate these observations to the thickness of the cortical bone in the proximal part of the humerus. Furthermore, we wanted to determine how augmentation of transosseous fixation with a readily available plastic button would affect the ultimate strength (the strength to failure) of the repair.

Materials and Methods

Forty-five fresh-frozen humeri were obtained from the cadavera of individuals who had been a mean of sixty-three years old (range,

*No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article. No funds were received in support of this study.

†6000 North Federal Highway, Fort Lauderdale, Florida 33308.

‡The Shoulder Service, Center for Sports Medicine, University of Pittsburgh, 4601 Baum Boulevard, Pittsburgh, Pennsylvania 15213.

§Department of Orthopaedic Surgery, United States Air Force Academy Hospital, 4102 Pinion Drive, Suite 100, United States Air Force Academy, Colorado Springs, Colorado 80840-4000.

¶Department of Radiology, University of Pittsburgh Medical Center/Montifiore University Hospital, 5th Floor, 200 Lothrop Street, Pittsburgh, Pennsylvania 15213.

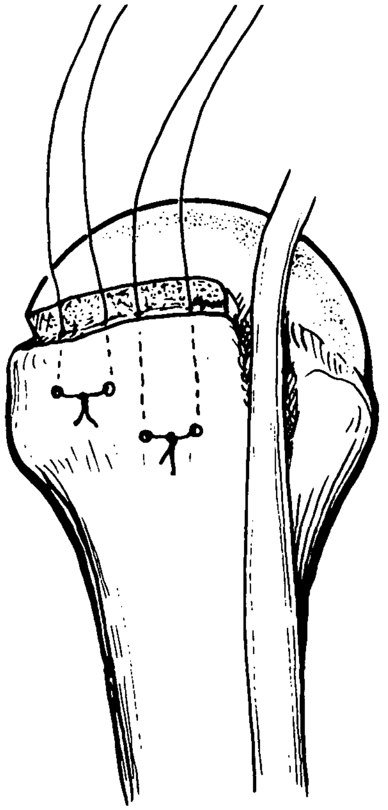

FIG. 1-A

Diagram showing two of the distances between the tip of the greater tuberosity and the placement of the sutures.

fifty-eight to seventy-one years old) at the time of death. The specimens were dissected free of all soft tissue.

Radiographic Analysis

High-quality micro-fine radiographs of thirty-five of the specimens were made, in the anteroposterior plane, before strength-testing was performed. The thickness of the cortical bone along the lateral aspect of the humerus was measured, with use of a calibrated magnifying loupe, at ten, twenty, and thirty millimeters distal to the tip of the greater tuberosity.

Fixation with Transosseous Sutures

A bone trough, four to five millimeters wide and twenty-five millimeters long, was prepared, with use of an osteotome, in the juxta-articular portion of the greater tuberosity in each specimen. Four sutures then were placed through the bone trough and were passed through four drill-holes, placed ten, twenty, or thirty millimeters distal to the tip of the greater tuberosity, in the lateral cortex of the humerus (Fig. 1-A). The four sutures were divided into pairs, and the two sutures of each pair were tied to one another over the bone bridge between the two drill-holes. The precise placement of the drill-holes permitted the pairs to be positioned in the test configurations to be described.

The bone bridge was either five or ten millimeters wide (Fig. 1-B). Because of the distal narrowing of the proximal part of the humerus, there was no ten-millimeter-wide bone bridge at a site thirty millimeters from the greater tuberosity.

A high-density polyethylene suture button (Smith and Nephew Richards, Memphis, Tennessee), with a diameter of nineteen millimeters and a thickness of 1.4 millimeters, was trimmed with a bone-cutter (Fig. 2-A). Pairs of sutures were placed ten millimeters from the tip of the tuberosity and tied over a ten-millimeter-wide bone bridge that had been reinforced with the button (Fig. 2-B). The ultimate strength of augmented fixation was compared with that of non-augmented fixation at the same site. Seven tests were performed on both the augmented and the non-augmented repairs.

Testing Protocol

Number-five braided non-absorbable polyester sutures were used in the present study. This large suture was chosen in an attempt to eliminate the effect of suture breakage on the ultimate strength of the repair. All free ends of the suture were brought out through the bone trough and tied into a loop, ten centimeters long, over a bar in the crosshead of an Instron machine (model 4502; Canton, Massachusetts), and testing to failure was performed at an extension rate of fifty millimeters per minute. A specially designed clamp allowed the angle of pull to be adjusted to 50 degrees relative to the long axis of the humerus. Statistical comparisons of subgroups were performed with use of two-tailed Student t tests.

Results

Radiographic Analysis

The mean cortical thickness (and standard deviation) ten millimeters from the tip of the greater tuberosity (0.22 ± 0.11 millimeter; range, 0.05 to 0.55 millimeter) was significantly less ($p < 0.001$) than the thickness at the twenty-millimeter site (0.36 ± 0.13 millimeter; range, 0.15 to 0.65 millimeter), which in turn was significantly less ($p < 0.001$) than the thickness at the thirty-millimeter site (0.86 ± 0.35 millimeter; range, 0.16 to 1.50 millimeters) (Fig. 3).

Strength of the Repair

We evaluated the effect of the distance between the site of fixation and the tip of the greater tuberosity as

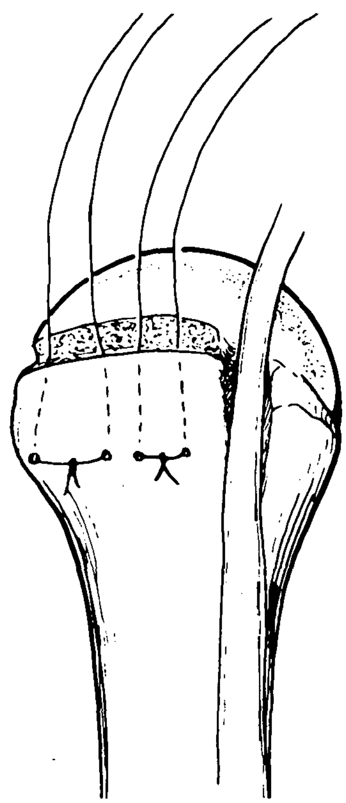

FIG. 1-B

Diagram showing the two widths of the bone bridge.

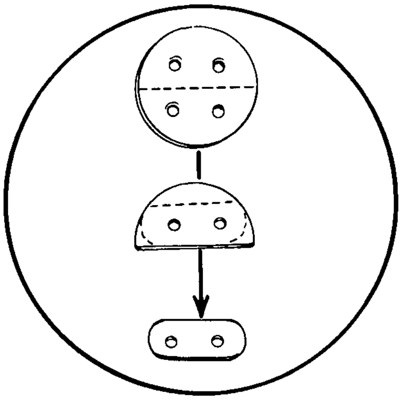

FIG. 2-A

Diagram showing the plastic button, which is divided in half and trimmed to a rectangular shape.

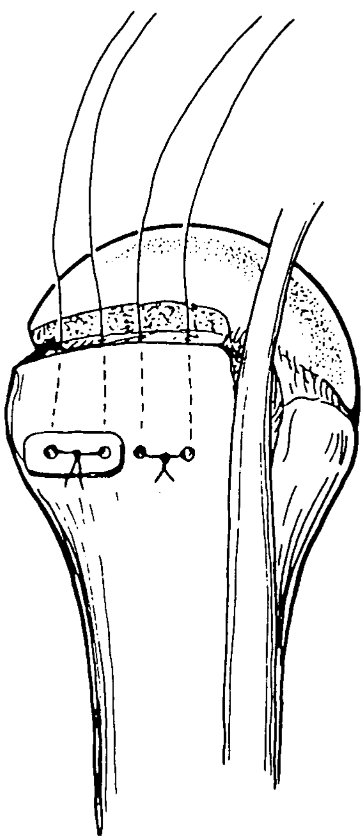

FIG. 2-B

Diagram showing the transosseous sutures tied over the the augmentation device as well as the non-augmented fixation.

well as the effect of the width of the bone bridge on the ultimate strength of the repair.

Effect of the Placement of the Sutures

Five-millimeter-wide bone bridge (constant variable): When the distance between the site of fixation and the tip of the greater tuberosity increased from ten to twenty millimeters, the ultimate strength increased significantly ($p < 0.05$), from 69 ± 22 newtons to 94 ± 31 newtons. Similarly, the ultimate strength at the thirty-millimeter site (247 ± 26 newtons) was significantly greater ($p < 0.001$) than that at the twenty-millimeter site (Table I). The ultimate strength of the osseous fixation at the thirty-millimeter site exceeded that of the suture material in all specimens. This site was the only one at which the sutures broke; at the other two sites, all of the suture pulled through the bone at a force that was less than the ultimate strength of the suture material.

Ten-millimeter-wide bone bridge (constant variable): The ultimate strength was significantly greater ($p < 0.005$) at the site twenty millimeters from the tip of the greater tuberosity (165 ± 49 newtons) than at the ten-millimeter site (100 ± 26 newtons) (Table I).

Effect of the Width of the Bone Bridge

Ten millimeters distal to the tip of the greater tuberosity (constant variable): Increasing the width of the bone bridge from five to ten millimeters significantly increased ($p < 0.05$) the ultimate strength of the fixation from 69 ± 22 newtons to 100 ± 26 newtons (Table I).

Twenty millimeters distal to the tip of the greater tuberosity (constant variable): When the width of the bone bridge was increased from five to ten millimeters, the ultimate strength of the fixation significantly increased ($p < 0.05$) from 94 ± 31 newtons to 165 ± 49 newtons (Table I).

Effect of Augmentation

The mean ultimate strength of augmented fixation (183 ± 57 newtons; range, 101 to 252 newtons) was significantly greater ($p < 0.005$) than that of non-augmented fixation (96 ± 54 newtons; range, forty-two to 176 newtons).

Discussion

The fixation of a rotator cuff tendon to the proximal part of the humerus may fail in the early postopera-

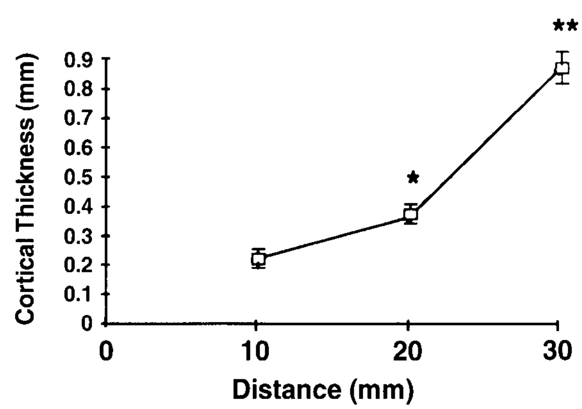

FIG. 3

Graph of the thicknesses of the cortical bone at the three sites on the lateral aspect of the greater tuberosity. The I-bars denote the standard deviation. One asterisk denotes a significant difference compared with the ten-millimeter site and two asterisks denote a significant difference compared with the twenty-millimeter site ($p < 0.001$ for both).

TABLE I
MEAN ULTIMATE STRENGTH (NEWTONS) OF FIXATION ACCORDING TO LOCATION OF SUTURES AND WIDTH OF BONE BRIDGE

Distance between Sutures and Tip of Greater Tuberosity	5-mm Bone Bridge	10-mm Bone Bridge
10 mm	69 (37-100) (n = 8)	100 (73-147) (n = 10)
20 mm	94 (67-158) (n = 7)	165 (74-250) (n = 10)
30 mm	247 (212-285) (n = 6)	—

tive period before the tendon has healed adequately. Retearing of a repaired rotator cuff has been associated with diminished functional results[8]. Furthermore, the results of operative revision of a rotator cuff repair have been less encouraging than those of primary repair[3]. Ideally, the technique for repair of a rotator cuff tendon should maximize the strength of the fixation in the immediate postoperative period. Stronger fixation may allow early rehabilitation without complete failure and may also prevent the formation of a gap at the tendon-bone interface, which may inhibit healing. In practical terms, the repair of a tendon to bone includes three separate components: the material properties of the suture, the grasping power provided by the suture technique, and the strength of the fixation to bone. The current study was designed to examine only the component of fixation to bone by negating the variables of suture material and tendon-grasping power.

Radiographic analysis demonstrated that the cortical thickness of the greater tuberosity progressively increases distally; this means that the ability of the cortex to hold transosseous sutures increases as well. Hecker et al. reported that the holding strength of suture anchors in the proximal part of the tibia was increased by more distal placement, where cortical bone was thicker. Although this concept initially may appear to be self-evident, it is surprising that previous reports[6,7,13] on rotator cuff repair have not included the details of the exact placement of the sutures relative to the greater tuberosity or of the width of the bone bridge over which the sutures were tied. Moreover, some investigators[5-7,13] have compared fixation with transosseous sutures, as a control group, with augmented fixation or fixation with use of suture anchors, as experimental groups, without stating the exact placement of the sutures. The comparisons of the techniques in those studies may be inaccurate because the investigators did not control for these variables.

We studied specimens from the cadavera of older individuals in order to obtain data relevant to a patient who has a chronic large or massive tear of the rotator cuff. We used specimens from individuals who were in the sixth, seventh, or eighth decade of life, as this is the age-group in which tears usually develop. Furthermore, in this age-group, osteopenia of the proximal part of the humerus may make it difficult to secure transosseous fixation for rotator cuff repair.

In our study, the mean strength at a single site of fixation with transosseous sutures ranged from sixty-nine to 247 newtons, depending on its exact placement. Thus, the conclusion in most previous studies[7,13], that the transosseous fixation is the so-called weak link in a rotator cuff repair, is inaccurate. Those studies did not account for the distance of the fixation from the tip of the greater tuberosity or the width of the bone bridge, both of which may affect the strength of the repair.

The purpose of the augmentation device was to increase the functional surface area of the bone bridge and to distribute the stresses of the repair effectively over a greater surface area. Several investigators have demonstrated that the strength of transosseous fixation may be improved by reinforcement of the bone along the lateral cortex of the greater tuberosity[6,7,13]. Gerber et al. noted that the ultimate strength was 2.3 times greater when fixation was augmented with an absorbable poly(L-/D-lactide) membrane, and Sward et al. demonstrated that the ultimate strength was 1.7 times greater when fixation was augmented with a polyethylene patch. Again, those studies did not include the details of the operative methods; that is, there was no information regarding the exact location of the sutures or the width of the bone bridge. Therefore, it is difficult to make direct comparisons among the different augmentation techniques. In the present study, fixation was significantly stronger when it was augmented with a modified, readily available plastic suture button; the augmented repair was approximately 1.9 times stronger than the non-augmented repair when the sutures were placed ten millimeters distal to the tip of the greater tuberosity and the bone bridge between the sutures was ten millimeters wide.

When such distal placement of sutures is not feasible or when the bone is very osteoporotic, the repair can be strengthened by tying the sutures over a bone bridge that is reinforced with a plastic button.

References

1. **Bassett, R. W.,** and **Cofield, R. H.:** Acute tears of the rotator cuff. The timing of surgical repair. *Clin. Orthop.,* 175: 18-24, 1983.
2. **Bateman, J. E.:** The diagnosis and treatment of ruptures of the rotator cuff. *Surg. Clin. North America,* 43: 1523-1530, 1963.
3. **Bigliani, L. U.; Cordasco, F. A.; McIlveen, S. J.;** and **Musso, E. S.:** Operative treatment of failed repairs of the rotator cuff. *J. Bone and Joint Surg.,* 74-A: 1505-1515, Dec. 1992.
4. **Cofield, R. H.:** Current concepts review. Rotator cuff disease of the shoulder. *J. Bone and Joint Surg.,* 67-A: 974-979, July 1985.
5. **Craft, D. V.,** and **Moseley, J. B.:** The fixation strength of rotator cuff repairs with third generation suture anchors vs the transosseous suture technique. *Orthop. Trans.,* 19: 368, 1995.

6. **France, E. P.; Paulos, L. E.; Harner, C. D.;** and **Straight, C. B.:** Biomechanical evaluation of rotator cuff fixation methods. *Am. J. Sports Med.,* 17: 176-181, 1989.
7. **Gerber, C.; Schneeberger, A. G.; Beck, M.;** and **Schlegel, U.:** Mechanical strength of repairs of the rotator cuff. *J. Bone and Joint Surg.,* 76-B(3): 371-380, 1994.
8. **Harryman, D. T., II; Mack, L. A.; Wang, K. Y.; Jackins, S. E.; Richardson, M. L.;** and **Matsen, F. A., III:** Repairs of the rotator cuff. Correlation of functional results with integrity of the cuff. *J. Bone and Joint Surg.,* 73-A: 982-989, Aug. 1991.
9. **Hecker, A. T.; Shea, M.; Hayhurst, J. O.; Myers, E. R.; Meeks, L. W.;** and **Hayes, W. C.:** Pull-out strength of suture anchors for rotator cuff and Bankart lesion repairs. *Am. J. Sports Med.,* 21: 874-879, 1993.
10. **McLaughlin, H. L.:** Lesions of the musculotendinous cuff of the shoulder. I. The exposure and treatment of tears with retraction. *J. Bone and Joint Surg.,* 26: 31-51, Jan. 1944.
11. **McLaughlin, H. L.:** Rupture of the rotator cuff. *J. Bone and Joint Surg.,* 44-A: 979-983, July 1962.
12. **Reardon, J. P.; Moseley, J. B.; Noble, P. C.; Alexander, J. W.;** and **Tullos, H. S.:** The fixation strength of suture anchors in the shoulder. *Orthop. Trans.,* 16: 665, 1992-1993.
13. **Sward, L.; Hughes, J. S.; Amis, A.;** and **Wallace, W. A.:** The strength of surgical repairs of the rotator cuff. A biomechanical study on cadavers. *J. Bone and Joint Surg.,* 74-B(4): 585-588, 1992.