Biomechanics of the Proximal Radius Following Drilling of the Bicipital Tuberosity to Mimic Cortical Button Distal Biceps Repair Technique

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Abstract

Background: A fracture through the proximal radius is a theoretical concern after cortical button distal biceps fixation in an active patient. The permanent, nonossified cortical defect and medullary tunnel is at risk during a fall eliciting rotational and compressive forces. We hypothesized that during simulated torsion and compression, in comparison with unaltered specimens, the cortical button distal biceps repair model would have decreased torsional and compressive strength and would fracture in the vicinity of the bicipital tuberosity bone tunnel. **Methods:** Sixteen fourth-generation composite radius Sawbones models were used in this controlled laboratory study. A bone tunnel was created through the bicipital tuberosity to mimic the exact bone tunnel, 8 mm near cortex and 3.2 mm far cortex, made for the BicepsButton distal biceps tendon repair. The radius was then prepared and mounted on either a torsional or compression testing device and compared with undrilled control specimens. **Results:** Compression tests resulted in average failure loads of 9015.2 N in controls versus 8253.25 N in drilled specimens ($P = .074$). Torsional testing resulted in an average failure torque of 27.3 Nm in controls and 19.3 Nm in drilled specimens ($P = .024$). Average fracture angle was 35.1° in controls versus 21.1° in drilled. Gross fracture patterns were similar in compression testing; however, in torsional testing all fractures occurred through the bone tunnel in the drilled group. **Conclusion:** There are weaknesses in the vicinity of the bone tunnel in the proximal radius during biomechanical stress testing which may not be clinically relevant in nature. **Clinical Relevance:** In cortical button fixation, distal biceps repairs creates a permanent, nonossified cortical defect with tendon interposed in the bone tunnel, which can alter the biomechanical properties of the proximal radius during compressive and torsional loading.

Keywords: elbow, radial neck fracture, distal biceps, tendon rupture, trauma, sawbones, biomechanics, cyclic loading

Introduction

Distal biceps tendon ruptures are relatively uncommon injuries, with an incidence of 1.2 per 100 000 individuals.²¹ Risk factors include male sex, age in the fourth decade of life, and tobacco use. Mechanism of injury typically involves eccentric contraction of the biceps, and the majority of ruptures involve tendon avulsion from the bicipital tuberosity.^{15,20} Operative intervention has been shown to improve forearm supination and elbow flexion strength.¹⁶ There are various methods of anatomic repair, including transosseous bone tunnel fixation, suture anchor repair, interference screw fixation, and cortical button fixation.^{14,23} Cadaveric biomechanical studies demonstrate superiority of cortical button fixation with the highest load to failure.^{8,11,13}

In distal biceps fixation, repairs create a permanent cortical defect in the proximal radius. Although there is certainly progressive incorporation of the repaired biceps tendon, there remains a permanent area disrupting the cortical continuity due to the presence of the tendon. Osteolysis of the bone tunnel is a concern when using bioabsorbable screw fixation, which could further impact the biomechanical characteristics of the bone.¹⁸ Our main concern stems from

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the cortical window and medullary tunnel which permanently contains tendinous, nonossified matrix in cortical button fixation techniques. A fracture through the proximal radius is a theoretical concern in an active patient population and has been reported in the literature to have occurred during a revision distal biceps repair.¹

A fall on an outstretched arm elicits a combination of rotational and compressive forces. We hypothesized that during simulated torsion and compression, a cortical button fixation model, in comparison with unaltered controls, would have decreased torsional and compressive strength and would fracture in the vicinity of the bicipital tuberosity bone tunnel.

Methods

Sixteen fourth-generation composite radius Sawbones (Pacific Research Laboratories, Vashon, Washington) models, validated in previous studies^{4,5,7,17,19} for biomechanical testing, were used in this study. For the experimental model, a bone tunnel was created through the bicipital tuberosity to mimic the exact bone tunnel (8 mm near cortex and 3.2 mm far cortex) made for a BicepsButton (Arthrex, Naples, Florida) distal biceps tendon repair (Figure 1). The radius was then prepared and mounted on either a torsional or compression testing device and compared with undrilled control specimens.

Compression testing utilized the MTS Instron (Material Test Systems, Eden Prairie, Minnesota) 8511.20 test frame unit with a 5000-lb load cell. The radii were tested with a compressive load through the radial head via molded hardened putty simulating the capitellum with the distal end potted using polymethylmethacrylate (PMMA) cement and attached to the MTS Instron machine. Following a 10-N preload, the bones were compressed at 100 mm/s to simulate a fall. Data were collected at 100 Hz using a custom LabVIEW (Laboratory Virtual Instrument Engineering Workbench, National Instruments, Austin, Texas) program to capture compressive load and displacement (Figure 2).

The radii were tested in torsion about the proximal radius after both the distal and proximal ends of the bone were potted using PMMA. The proximal 1.5 cm of the radius and the distal 2 cm of radius were potted, after which the experimental models were drilled. A Schaevitz R3B2SS machine (Measurement Specialties, Hampton, Virginia) was used with a positive and negative 45° rotary variable differential transformer transducer in a Honeywell (Honeywell, Morristown, New Jersey) 2110-2k inch-pounds-force reaction torque sensor. Data were collected using MTS 458.20 MicroConsole and MTS Teststar II software (Material Test Systems, Eden Prairie, Minnesota) at 100-Hz sample rate. Both experimental and undrilled specimens were tested to failure at 75°/s, without a preload, to mimic the torsional component of a fall (Figure 3).

Figure 1. Fourth-generation composite radius models. Note. Bone tunnels were made in the experimental group through the bicipital tuberosity to mimic the exact bone tunnel made for a BicepsButton (Arthrex, Naples, Florida) suture button distal biceps repair.

Figure 2. An intact radius specimen shown with the distal end potted and attached to the MTS Instron machine (Material Test Systems, Eden Prairie, Minnesota).

Note. Testing was performed with a compressive load through the radial head against the molded hardened putty to mimic the capitellum.

Stiffness, load to failure (compression), failure torque, fracture angle (torsional), and gross fracture characteristics were then collected in both the control and experimental models.

Results

The proximal radius specimens that were tested in compression had an average failure load of 9015.2 N in the control group and 8253.25 N in the drilled specimens ($P = .074$;

Figure 3. A drilled radius specimen shown with both proximal and distal ends potted and attached to the Schaevitz R3B2SS machine (Measurement Specialties, Hampton, Virginia) for torsional testing.

Table 1). The stiffness calculated in compression testing was 1825.48 N/mm in controls versus 2161.33 N/mm in the drilled group ($P = .10$).

For the radius specimens tested in torsion, the average failure torque was 27.3 Nm in control specimens and 19.3 Nm in drilled specimens, which was significantly different ($P = .024$; Table 2). The fracture angles also differed significantly ($P = .025$), with the control specimens fracturing at an average angle of 35.1° , whereas the drilled specimens fractured at an average angle of 21.1° . Stiffness during torque testing was also calculated and found to be 0.8 Nm per degree in controls versus 0.9 Nm per degree in drilled specimens ($P = .038$).

The gross fracture pattern was fairly similar between groups when tested in compression (Figure 4). When testing in torsion, however, it was observed that fracture occurred through the bone tunnel in the bicipital tuberosity in the drilled radius compared with the radial shaft in control specimens (Figure 5).

Discussion

The cortical button fixation model for distal biceps repairs, popularized by Bain et al,² utilizes a single anterior incision

resulting in a construct strong enough to allow immediate elbow motion. This type of fixation has been shown to have the best performance in comparative biomechanical studies.³ Although these studies¹⁰⁻¹³ have measured the strength of the repaired tendon, they have not studied the effect of the bone tunnels upon the proximal radius itself.

There is evidence in the shoulder literature that bone tunnel size during coracoclavicular reconstruction correlates with strength reduction of the clavicle.²⁴ The cortical button repair model uses a bone tunnel that is occupied by the distal biceps tendon that creates a permanent corticocancellous stress riser in patients. Despite maturation at the repair site, this has not been demonstrated to reossify and thus remains a cortical defect.

We sought to evaluate this potential concern for fracture through the vicinity of the bone tunnel in the proximal radius. Although statistically similar in compression, a difference was noted during torsional stressing of the proximal radius. Although this difference was significant between drilled and control groups, clinically this difference may be supraphysiologic. In testing specimens in compression, which mimics an axial load or fall on an outstretched hand, there does not appear to be significant difference in failure loads or stiffness between drilled and control radius specimens. As a simplistic illustrative example, the impact force needed to produce a fracture in both controls and drilled specimens would be approximately equivalent to a 70-kg man falling 2.5 m directly onto an outstretched arm, when calculating the average impact force using the work-energy principle ($F = mgh/s$).

We used composite bone models and not cadaveric bone for our biomechanical testing. Current fourth-generation composite bone models do provide an accurate reproduction of human bone when used for bending, axial, and torsional loads.^{4-7,9,22} It should also be noted that we tested proximal radius specimens with ideally placed bone tunnels and that we did not fill these tunnels with any graft, interference screw, or suture button fixation, which may also change the biomechanical strength of the proximal radius

Table 1. Compression Test Results.

Compression testing	Drilled	Control	P value
Load to failure	8253.25 N	9015.2 N	.074
Stiffness	2161.33 N/mm	1825.48 N/mm	.10

Table 2. Torsional Test Results.

Torsional testing	Drilled	Control	P value
Failure torque	19.3 Nm	27.3 Nm	.024
Fracture angle	21.2°	35.1°	.025
Stiffness	0.9 Nm/degree	0.8 Nm/degree	.038

Figure 4. Gross fracture patterns after compression.
Note. Most fractures occurred proximally in both drilled and control groups.

Figure 5. Torsional results.
Note. In control specimens, fractures occurred through the middiaphysis. In drilled specimens, fractures occurred through the bone tunnels in all samples.

itself. We sought to mimic the permanent cortical defect anticipated with this procedure. If the placement of a bone tunnel by the surgeon was not directly in the footprint and centered in the proximal radius, this may change the biomechanical properties around the tunnel and have potential ramifications in terms of failure and concern for fracture.

In our study, with standardized placement of the bone tunnel, we found that there are some differences during biomechanical testing; however, they may not have any consequences from a clinical standpoint, unless there is secondary trauma.

Conclusions

Distal biceps tendon repairs using cortical button fixation have the potential of creating important biomechanical consequences in the proximal radius but may not be clinically relevant during routine physiologic conditions.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

This article does not contain any studies with human or animal subjects.

Statement of Informed Consent

Not applicable.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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