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A new intramedullary fixation method for distal biceps tendon ruptures: a biomechanical study

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Background: Various techniques have been described for distal biceps tendon reinsertion. Although high success rates have been reported, all current techniques have specific shortcomings, with complications such as heterotopic ossification, nerve damage, and gap formation. The purpose of the present study was to biomechanically evaluate a new intramedullary fixation device that might reduce the risk of posterior interosseous nerve lesions. We therefore compared the fixation strength of this new intramedullary button with an extramedullary placed classic extracortical button.
Methods: A standard bicortical button was compared to the new intramedullary fixation device using fresh-frozen cadaveric specimens. The fixation strengths were tested both cyclically and statically. Load to failure and method of failure were also recorded.
Results: There were no failures during the cyclic load testing. The mean tendon-bone displacement was 0.87 ± 0.13 mm for the bicortical group and 0.83 ± 0.13 mm for the new button. During static loading, the mean load to failure for the bicortical group was 296 ± 97 N, whereas the new button group showed a higher mean load to failure of 356 ± 37 N. Breakout through the anterior cortex was recorded in 2 of 6 bicortically placed buttons and 1 of 6 in the new device.
Conclusions: The new intramedullary fixation device yields comparable loads to failure compared with currently used techniques in a biomechanical setup. These findings together with the theoretical advantages suggest that this technique may be a valuable solution for the repair of distal biceps tendon rupture.
Level of evidence: Basic Science Study; Biomechanics

Keywords: Distal; biceps; fixation; intramedullary; repair; tendon

Distal biceps tendon ruptures are relatively uncommon. Their incidence is estimated to be 1.2 in 100,000.[16,17] The most common mechanism is a forced eccentric contraction of the biceps brachii muscle with the elbow positioned in flexion and supination.[19] Operative treatment is usually indicated to ensure maximum recovery of elbow strength and endurance.[2,6] Various fixation methods have been described, including suture anchors, interference screws, and fixation buttons.[1,12,14,24] The construct with the highest load to failure is the extramedullary bicortical fixation button

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method as first described by Bain and colleagues.[1,13] This allows for early active range of motion, and loading, almost immediately after surgery. A second advantage of this fixation technique is the intraosseous placement of the distal biceps tendon, minimizing the chance of gap formation between the tendon stump and the bone during active biceps contraction.[13,21] The main disadvantage of the extramedullary cortical button is that the distal biceps tendon cannot be anatomically reattached at the insertion site at the radial tuberosity as this would place the posterior interosseous nerve at significant risk for entrapment behind the cortical button.[11] To protect the nerve, the biceps tendon has to be attached more anterior on the radius, but this potentially decreases the final supination strength.[20]

The purpose of the present study was to evaluate a new intramedullary fixation device. Because this button is placed inside the intramedullary canal of the radius, it allows safe reattachment of the distal biceps tendon at its anatomic footprint. We compared the fixation strength of this new intramedullary button with the classic bicortical button. We hypothesize that both buttons provide comparable fixation strength.

Materials and methods

Specimens

Twelve elbows were harvested from 6 fresh-frozen cadavers and thawed at room temperature. The contralateral specimens were used to compare the standard extramedullary bicortical EndoButton technique (EndoButton; Smith & Nephew, Watford, UK) to the new intramedullary fixation button.

New button design

The button was designed using 3D software (Autodesk Fusion 360) and printed in titanium (Materialize, Leuven, Belgium) (Fig. 1). The initial designs were printed in a polyamide plastic and tested on 12 radius specimens to determine size. The design features a bell shape of 3 mm depth to allow the tendon to be pulled into the bone with a maximum depth of 3 mm plus the thickness of the proximal cortex. The button has a width of 4 mm and a length of 24 mm to span the radial tuberosity. This length also allows purchase on the thick cortical bone alongside the thinner bone of the tuberosity (Fig. 2).

Surgical technique and biomechanical testing

In each specimen, surgery was performed through a 2-cm anterior incision,[5] and the distal biceps tendon was transected at its insertion on the radial tuberosity. A partially absorbable suture (FiberLoop 2; Arthrex, Naples, FL, USA) was passed in a whipstitch fashion in the distal 20 mm of the distal biceps tendon so that its ends emerged at the distal tendon stump. Both ends of the suture were passed though the holes in the button.

Figure 1 The fixation device.

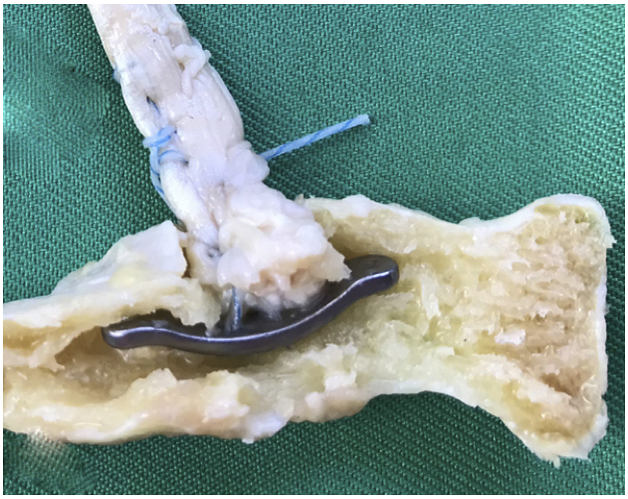

Figure 2 The pedals of the new button span over the radial tuberosity and get support from the thick anterior cortex.

The commercially available extramedullary fixation button is made of titanium. A 4.5-mm guide pin is drilled through the radius at the level of the radial tuberosity. Next, an 8-mm cannulated drill is used to open the near cortex. A 4.5-mm cannulated drill is used to drill through the far cortex. The button is passed through the drill holes in the radius and flipped extramedullary on the posterior cortex. Fluoroscopy was used to confirm the correct position of the button.

For the intramedullary button, the guide pin was drilled only through the near cortex at the footprint of the biceps tendon, and overdrilled with a cannulated 8-mm drill. The button is inserted intramedullary by sliding it into the medullary canal and positioned under the drill hole by pulling on both the sutures simultaneously. The tendon is pulled into the radius by pulling the sutures separately, using the tension slide technique described by Sethi.[22] The tendon is fixed by tying the suture. Fluoroscopy was again used to confirm the correct position of the button (Fig. 3).

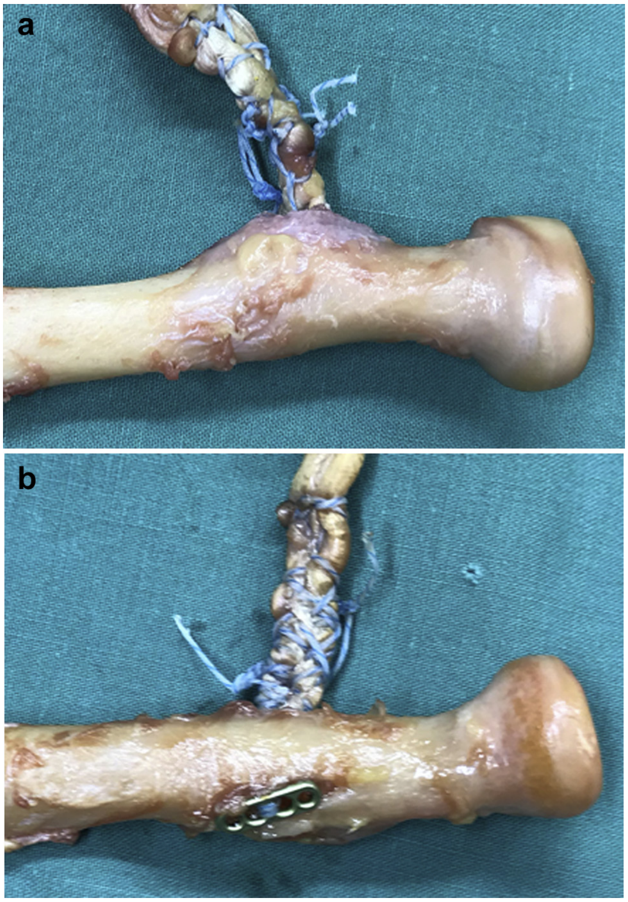

Figure 3 The 2 different setups: (**a**) intramedullary fixation; (**b**) bicortical fixation.

The radii and distal biceps tendon were removed from the forearm, as were all soft tissues. The proximal 10 cm of radial bone was preserved.

Biomechanical testing was performed as previously published by Siebenlist.[3] The radii were clamped to a custom mount (Fig. 4). The tendon was firmly attached to a metal clamp. The line of pull on the biceps was chosen to be at a 30° flexion angle as this was deemed to be a physiological loading condition. For displacement measurements, 3 hand-drawn regions of interest were appointed at the proximal, central, and distal areas of the restored footprint of the distal biceps tendon (Fig. 4). A digital caliper was used to mark the tendon at 1-cm intervals. A video camera was mounted at the side of the construct to achieve a strict lateral view. Specimens were cyclically loaded for 1000 cycles at 2.5 Hz from 5-100 N. Following every 1000 cycles, the load was returned to 5 N (preload) and a still frame of the mounted constructs was taken from the video and the displacement was digitally measured on the screen. Afterward, all specimens in which failure did not occur during cyclic loading were loaded to failure with an extension rate of 4 mm/s. Maximum load to failure was defined at a sudden drop in force of >50% from the applied maximum force. Stiffness of the construct was calculated using the linear portion of the load-displacement graph from the load to failure testing. The mode of failure for each repair was recorded. Measurements were compared using Student *t* test.

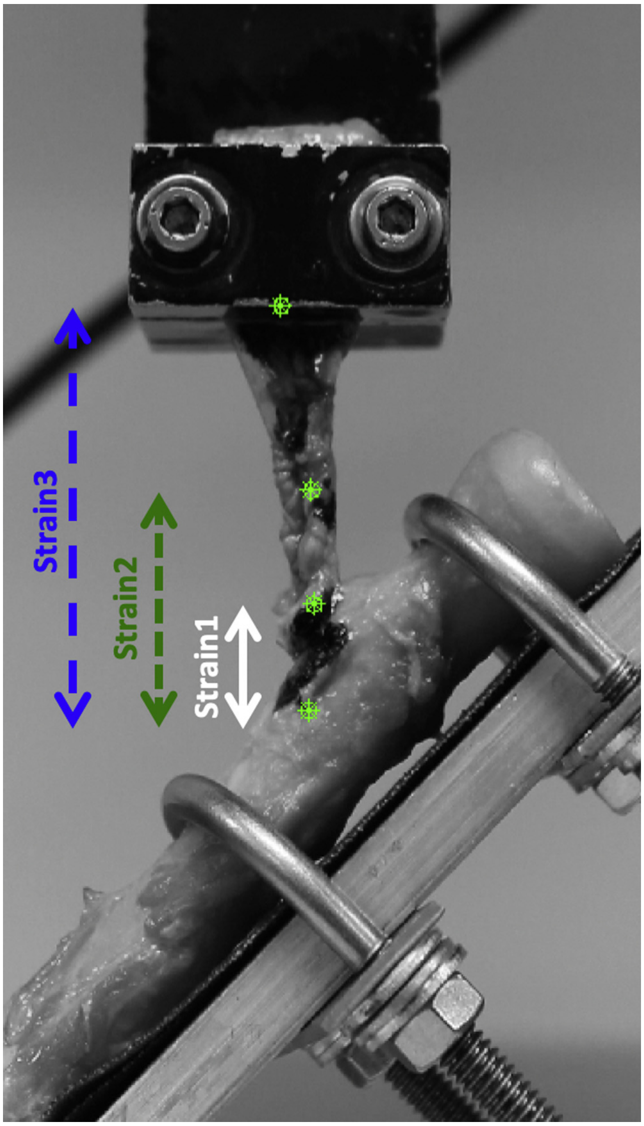

Figure 4 The test setup with a custom mount at 30° to simulate the native line of pull. Hand-drawn lines were used for measuring displacement.

Results

Cyclic loading

All constructs completed the cyclic testing without failure. After 1000 cycles with 100 N, the mean tendon-bone displacement was 0.87 ± 0.13 mm for the bicortical group and 0.83 ± 0.13 mm for the new button group.

Static loading

The mean load to failure for the bicortical group was 296 ± 97 N, and for the new intramedullary button group, it was 332 ± 44 N ($P = .19$). The mean difference in load to failure between both repair groups was not statistically significant. The mean stiffness of the bicortical group was 58.2 ± 9.2 N/mm, and it was 61.1 ± 9.7 N/mm in the new button group ($P = .6$).

There was 1 failure in the bicortical group due to knot failure in an early stage of testing (16%). Three constructs (50%) failed by suture tearing through the tendon and 2 constructs (33%) failed by button pullout with fracture avulsion of the anterior cortex. In the new intramedullary button group, 1 construct failed because of button pullout with fracture avulsion of the anterior cortex (16%). The remaining 5 (83%) failed by suture tearing through the tendon (Table I).

Table I Results of the biomechanical testing

	New fixation device	Bicortical EndoButton	*P* value
Load to failure, mean ± SD	332 ± 44	296 ± 97	.19
Stiffness, N/mm, mean ± SD	61.1 ± 9.7	58.2 ± 9.2	.6
Mode of failure (n = 6)			
Knot	—	1	
Anterior cortex	1	2	
Suture or tendon	5	3	

SD, standard deviation.

Discussion

In distal biceps tendon repair, the anterior single incision approach has gained popularity over the 2-incision technique.[8] The latter has a higher risk of forearm bone synostosis and loss of forearm rotation or rotational strength[10] and a higher risk of posterior interosseous nerve injury.[7]

Several implant types have been described to reattach the distal biceps tendon to the radius through the single-incision approach.[1,12,14] Extramedullary bicortical button fixation is favorable because it provides the strongest initial fixation.[13] However, the local anatomy with the posterior interosseous nerve curving around the radius on the opposite side of the tuberosity creates an increased risk of damaging the nerve when using this device. As a result, it is advised to insert the tendon in a nonanatomic position.[11] However, this leads to decreased supination strength.[18,20]

An intramedullary fixation device that does not violate the posterior cortex of the radius has been advocated to decrease the risk of nerve injury, while allowing an anatomic repair.[23,25] However, fixation on the thin cortex of the radial tuberosity may lead to suboptimal fixation strength and possible button or anchor breakout. Previous biomechanical studies[23] have shown that the load to failure of unicortical fixation is lower than that of bicortical fixation and that the mechanism of failure is potentially catastrophic with a fracture of the anterior cortex. Siebenlist and colleagues therefore advised a stronger double-button unicortical fixation method.[23] However, in their technique, the buttons are essentially used as an anchor with fixation of the tendon onto the bone and not in a bone tunnel. This could lead to gap formation as a result of tendon pistoning. This is inherent of tendon fixation against the bone instead of in a bone tunnel.[13,15,21]

The goal of this study was to biomechanically evaluate a new fixation device developed in response to these concerns. The unicortical fixation decreases the risk of nerve injury while allowing an anatomic position of the repaired tendon. The increased length of the button allows the button to hold against the thicker anterior cortex of the radius instead of the weaker tuberosity. Because of the bell shape of the button, the tendon can be pulled into the bone tunnel, decreasing the potential for tendon-to-bone gap formation.

The biomechanical results of the new button are comparable to other currently used techniques.[13,23] Both load to failure (356 N) and stiffness (61 N/mm) are similar to the excellent results of the bicortical button technique.[13,23] We did not use an additional interference screw because literature has shown tunnel widening with possible catastrophic results, without adding extra strength to the initial fixation.[4] Noteworthy in our bicortical group is that 1 construct of the bicortical group failed early at 116 N as a result of knot failure. Without this, the mean load to failure would be 332 ± 44 N, which is similar to the previous reported results of bicortical fixation. Fracture avulsion of the anterior cortex was only found in a single specimen at maximum load to failure. The load to failure of these techniques and our described results are higher than the native tendon as described by Idler and colleagues.[9] Tendon rerupture is seldom seen because of the high initial fixation strength of the techniques currently used.[10] The new button yields the same initial fixation strength as most other techniques.[9,13,23] This allows for immediate postoperative mobilization and loading.

One possible concern with the new button is the risk of toggling of the button in larger radius during the insertion. Fluoroscopy is used to ensure proper positioning, and we did not find any toggling during our cyclic testing.

There are some limitations of our study. First, the human cadaveric specimens were of an older age than the typical age for distal biceps ruptures, but comparable with the specimen age in other studies. It is possible that in younger specimens with better bone quality, fewer failures with bony avulsions would occur. This may be especially relevant for classical intramedullary buttons, where this was the predominant failure mode. Even in these older specimens, a clear difference is present between the new button and the classical button when used intramedullary. Second, a relatively small group of specimens was used, although this is comparable to other reported biomechanical studies.

Conclusion

The new intramedullary fixation device yields loads to failure that are comparable to those of currently used techniques, when tested in a biomechanical in vitro setup. These findings together with the theoretical advantages suggest that this technique might be a valuable solution for the repair of distal biceps tendon rupture.

Disclaimer

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