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The Effect of Drill Trajectory on Proximity to the Posterior Interosseous Nerve During Cortical Button Distal Biceps Repair

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Abstract

Purpose—The aim of this study was to evaluate the effect that different drill trajectories across the radius have on the proximity of the drill tip to the posterior interosseous nerve (PIN).

Methods—In 10 cadaveric specimens, we drilled from the bicipital tuberosity across the radius using four different trajectories: 1) aiming across the radius at 90° to the longitudinal axis of the radius, 2) distally at 45°, 3) ulnarly, and 4) radially. We measured the distance between the tip of the drill as it exited the dorsal cortex of the radius and the PIN.

Results—Aiming 90° across the radius and aiming ulnarly across the radius resulted in a distance of 11.2 ± 3.2 (95% CI: 8.9, 13.5) mm and 16.0 ± 3.8 (95% CI: 13.3, 18.7) mm, respectively, between the drill tip and the PIN. Aiming the drill 45° distally or aiming radially resulted in a distance of only 2.0 ± 2.2 (95% CI: 0.5, 3.6) mm and 4.2 ± 2.2 (95% CI: 2.6, 5.8) mm, respectively. The differences were found to be statistically significant.

Conclusion—Based on the results of this anatomic study, when using the cortical button distal biceps repair technique, we recommend drilling across the radius at 90° to its longitudinal axis and aiming from 0-30 degrees ulnarly, with forearm in full supination. This provides an increased margin of safety to prevent injury to the PIN compared to drilling radially or distally.

Introduction

Distal biceps ruptures result in symptomatic weakness in elbow flexion and supination [1-4]. Repair of the ruptured tendon to its insertion on the radial tuberosity is effective in restoring elbow strength [5-7]. The repair has classically been performed using a modification of the 2-incision technique described by Boyd and Anderson [8]; however, the extensive dorsal dissection violates the supinator muscle and carries a higher risk of heterotopic ossification. More recently, single incision techniques have become popular in an effort to reduce

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operative morbidity [6]. The cortical button distal biceps repair is an attractive technique as it can be done through a small anterior incision and provides superior initial repair strength, allowing immediate postoperative mobilization [6, 9-11].

The cortical button repair does, however, carry a risk of injury to the posterior interosseous nerve (PIN). The repair is done by drilling a tunnel across the radius, starting at the bicipital tuberosity and exiting the dorsal cortex of the proximal radius. The cortical button is sutured to the distal biceps and pulled through the drill hole in the radius and flipped on the dorsal cortex of the radius, securing the distal biceps to the radius. When the cortical button is flipped on the dorsal cortex of the proximal radius, the PIN can theoretically be trapped between the implant and the radius. The placement of the cortical button can be affected by altering the drill trajectory across the radius. In order to safely repair the biceps using the cortical button technique and to prevent injury to the PIN, it is important to understand how drill trajectory across the radius affects the cortical button proximity to the PIN.

The drill trajectory across the radius will be affected by the skin incision used to expose the radial tuberosity. A small transverse incision in the antecubital crease is a popular approach to repair the biceps tendon. Because this incision is proximal to the radial tuberosity, it is necessary to aim the drill distally from the skin incision to enter the radial tuberosity at the anatomic biceps insertion. This proximal to distal trajectory results in the drill exiting the dorsal radial cortex 1 - 2 cm distal to the entry point on the bicipital tuberosity. An alternative skin incision is a longitudinal incision centered directly over the radial tuberosity. This incision results in the drill traversing the radius perpendicular to the longitudinal axis of the radius. The drill will exit the radius directly dorsal to the bicipital tuberosity.

The purpose of this cadaveric study was to determine how varying the trajectory of the trans-radial guide pin effects the proximity of the cortical button to the PIN. We hypothesized that drilling across the radius at a right angle would place the drill further from PIN, and thus, lessen the chance of iatrogenic PIN injury as the drill exits the dorsal radial cortex.

Materials and Methods

Ten fresh frozen unmatched adult cadaveric arms were brought to room temperature. The arms had been harvested at mid humerus and were intact distally. No visible deformities or evidence of previous surgery were noted in any of the specimens. The gender and side of each specimen were recorded, as well as the length, from tip of ulnar styloid to olecranon process.

The PIN was exposed in each specimen through a longitudinal incision in the proximal dorsal forearm. The posterior interosseous nerve was identified at the distal edge of the supinator and carefully traced proximally by sharply dividing the fibers of the superficial head of the supinator. Care was taken to avoid disturbing the anatomic position of the PIN.

Next, a longitudinal volar incision was made in each specimen, centered over the distal biceps tendon, extending from the radial tuberosity distally to the antecubital crease proximally. The biceps tendon was traced to the radial tuberosity and sharply released, leaving a small stump of tendon on the tuberosity.

The radial socket was created by placing a unicortical guide pin in the radial tuberosity with the forearm in full supination. The guide pin was placed as closely as possible to the center of the biceps tendon stump in the tuberosity. A cannulated 7mm acorn reamer was then drilled over the guide pin unicortically, creating a socket in the radial tuberosity for biceps repair.

At this point, a guide pin was placed into the 7mm diameter radial socket and drilled through the dorsal cortex of the radius in 4 different trajectories. The first trajectory, “A”, was aimed directly across the radius, with the pin exiting the radius at approximately 90° to the longitudinal axis of the radius (Fig. 1). After removing the guide pin from trajectory “A”, the next trajectory “B” was drilled. This trajectory was started in the same radial socket and aimed as distally as possible out the dorsal cortex, exiting the radius at approximately 45° to the longitudinal axis. This approximated the drill trajectory that would be used when drilling from a transverse skin incision at the antecubital crease (Fig. 2). The trajectories “C” and “D” was similarly drilled with the drill tip toggling inside the radial socket and drilling ulnarly and radially, respectively, at approximately 30 degrees (Fig 3). The distance from the tip of the guide pin as it exited the dorsal cortex of the radius to the PIN was measured using digital calipers for each trajectory (Fig 4).

Statistical Methods

There were 4 distance measurements, trajectory A-D, in each of 10 unmatched specimens. These measurements were not normally distributed, as detected by the Shapiro-Wilk test, so the nonparametric test, Friedman test, was used for statistical analysis. If the overall comparison was statistically significant, pair-wise comparisons were performed to see which two drill trajectory groups were statistically different by using two-sided Wilcoxon signed-rank test. There were 6 pair-wise comparisons, and we used the Bonferroni correction to maintain the family-wise error rate. Therefore, a pair-wise comparison was considered statistically significant if its p-value is $< 0.05/6 = 0.0083$. Based on the results, a post-hoc power analysis was performed, with power of 0.8 and significance level of 0.0083.

Results

Five of the specimens were right arms and five were left arms. The mean ulnar length was 27.4 cm, with a range of 24.0 cm - 31.5 cm. Three specimens were female. The average specimen age was 71.8 with a range of 43 - 96.

When drilling across the radius using trajectory A, the guide pin exited the dorsal cortex of the radius an average of 11.2 ± 3.2 (95% CI: 8.9, 13.5) mm from the PIN. Drill trajectory B resulted in an average distance of 2.0 ± 2.2 (95% CI: 0.5, 3.6) mm between the guide pin exiting the radius and the PIN. In three of the specimens, when trajectory B, the distally aimed trajectory, was used, the guide pin was actually in direct contact with the PIN as it exited the radius.

Aiming the guide pin ulnarly through the dorsal cortex of the radius, trajectory C, resulted in the greatest distance from the PIN, averaging 16.0 ± 3.8 (95% CI: 13.3, 18.7) mm. Using the ulnarly directed trajectory, however, resulted in drilling from the radius into the ulna in three specimens. The radially aimed trajectory D resulted in an average 4.2 ± 2.2 (95% CI: 2.6, 5.8) mm from the PIN (Table 1).

The p-value of < 0.0001 of the Friedman test indicates that the distances for the 4 different drill trajectories were statistically significant. For pair-wise comparisons, the distances for any two of the four drill trajectory groups were statistically significantly different at the adjusted significance level $p=0.0083$, except the distances for the two trajectories B and D, which were not statistically significantly different. See Table 2 for details. Based on data given in Table 1, these specimens could provide a power of 0.8 to detect the distance differences of at least 4.4 mm (trajectories A-B), 3.23 mm (A-C), 5.24 mm (A-D), 3.98 mm (B-C), 3.49 mm (B-D), and 4.84 mm (C-D), at a significance level of 0.0083.

Discussion

Repair of distal biceps ruptures has been shown to improve subjective and objective outcome measures compared with non-operative treatment [3, 7, 12]. Using a cortical button to repair the biceps to the proximal radius has recently gained popularity. This novel technique, described by Bain et al, has been shown to have several advantages over previously described repair techniques [13]. First, the cortical button repair has consistently shown stronger initial fixation strength compared with transosseus bridge, suture anchor and interference screw fixation techniques [6, 9-11]. In fact, the initial strength of the cortical button biceps repair has been shown to be sufficient to allow immediate active elbow flexion postoperatively without jeopardizing the integrity of the repair [6, 9]. Presumably, this allows an earlier return of function and an earlier return to work. Furthermore, avoiding postoperative immobilization may reduce the incidence of elbow stiffness after biceps repair.

Another advantage of cortical button biceps repair is a lower reported rate of heterotopic ossification compared with the traditional two-incision approach. There is only one reported case of symptomatic heterotopic ossification after cortical button biceps repair in the literature [14]. In contrast, there have been many reports of radioulnar synostosis and symptomatic loss of forearm rotation after two-incision distal biceps repair. The incidence of clinically significant heterotopic ossification after two-incision distal biceps repair ranges from 4.8- 37.5% [5, 9, 12, 15-17].

One drawback to the cortical button distal biceps repair is the risk of injuring the PIN [1, 2, 7, 18-21]. The PIN is at risk of laceration when drilling through the dorsal cortex of the proximal radius and is at risk of compression or entrapment when the cortical button is deployed on the cortex of the radius. Our study found that by drilling directly anterior to posterior or drilling ulnarly across the radius resulted in a significantly increased distance from the PIN compared with drilling distally or radially across the radius. Our results corroborate the results of Bain et al [13] who found that drilling anterior to posterior is safer than drilling radially. We observed an average distance of 11.2 mm from the PIN in the anterior to posterior trajectory, compared with 4.2 mm in the radial trajectory. Additionally, we confirmed the findings of Saldua et al [22] that drilling ulnarly results in the greatest distance from the PIN, compared with drilling anterior to posterior. An ulnar trajectory resulted in an average 16.0 mm from the PIN, compared with the 11.2 mm in the anterior to posterior trajectory. In 3 of our specimens, however, we encountered a problem by aiming too far ulnarly. The guide pin drilled into the proximal ulna after exiting the radius. By placing a cortical button in such an ulnar position, there is a risk that the implant will impinge on the ulna in supination. Based on our findings, we would not recommend drilling any more ulnarly than the 30° proposed by Saldua et al [22]. Aiming somewhere between direct anterior to posterior and 30° ulnar will result in a distance of between 11 mm and 16 mm from the PIN and provides the safest area to deploy a cortical button.

The effect that aiming the drill distally has on proximity to the PIN has not been evaluated prior to our study. Our observations suggest that a distal drill trajectory across the radius puts the PIN at the greatest risk of iatrogenic injury. We found an average distance of only 2.0 mm between the drill bit and the PIN using this trajectory. In fact, the drill bit came into direct contact with the PIN in 3 out of 10 of our specimens when aiming distally across the radius. This distal trajectory mimics the trajectory that one would drill across the radius from an incision placed transversely in the antecubital crease. This skin incision is approximately 2 cm proximal to the bicipital tuberosity and forces the surgeon to aim distally with the guide pin to enter the center of the biceps footprint. Based on the results of this study, we recommend avoiding a transverse skin incision in the antecubital crease and instead making

a longitudinal incision, starting just distal to the antecubital crease and extending distally approximately 2.5 cm. This allows a direct approach to the bicipital tuberosity and avoids a distal drill trajectory across the radius. In our experience, this more distal incision has not created any difficulty in locating the proximally retracted biceps tendon. In chronic tears, it may be necessary to make a more extensile approach or to make a second proximal incision to identify and mobilize the tendon stump.

A criticism of single anterior incision techniques to repair the distal biceps is the inability to completely access the biceps footprint with an anterior incision [23, 24]. In our study we were able to make similar observations. When the radial tuberosity was exposed dorsally by fully pronating the forearm and incising the remaining supinator fibers over the radius, we were able to directly visualize the position of the radial socket to the anatomic footprint of the biceps. We were unable to completely reproduce the biceps footprint with our radial socket, despite attempting to place the guide pin in the ulnar aspect of the tuberosity with the forearm fully supinated. Deviating the guide pin any further ulnarly would have resulted in blowing out the ulnar cortex of the radius while drilling the radial socket. We found that our radial socket failed to reconstruct the ulnar 1 - 2 mm of the biceps attachment. It is unknown if this slight variance in the biceps attachment would produce any measurable difference in forearm supination strength, but at this point, clinical follow-up studies do not demonstrate any functional difference in outcomes of biceps repairs comparing two-incision vs. anterior approach repairs [5, 6, 16, 20, 25-27]. Both techniques appear to effectively restore elbow supination and flexion strength.

The main weakness of this anatomic study is the number of specimens tested. There may exist anatomic variability in the course of the PIN that was not observed in our 10 specimens. Furthermore, we are unable to comment on the effect that specimen size has on the distance measured between the drill bit and the PIN. In the current study, there exists a large variation in forearm lengths. This may serve as a confounder in the measurements from pin-to-nerve distances. It is also plausible that, in a smaller specimen, there is a smaller margin of safety between implant and nerve when using the cortical button technique to repair distal biceps ruptures.

When drilling the radial socket, the original goal of the radial and ulnar drill trajectories were 30 degrees in each direction. However, the anatomic variation in forearm range of motion, tuberosity location, and diameter of the radius large determined our capability of toggling the drill, to angulate the final trajectory. Although we aimed for an trajectory of approximated 30 degrees, there was likely a 10 degree variability to our drill angle. The optimal angle of drilling was not identified with this study, nevertheless, these preliminary findings suggest that radial directed drilling places the PIN at risk and ulnar angulation up to 30 degrees risks malpositioning the cortical button for impingement against the ulna. We believe that the optimal angle is likely within 0 to 30 degrees, but this will likely require additional investigation.

Conclusion

Based on the results of this anatomic study, when using the cortical button distal biceps repair technique, we recommend drilling across the radius at 90° to its longitudinal axis and aiming from 0-30 degrees ulnarly, with forearm in full supination. This provides an increased margin of safety to prevent injury to the PIN compared to drilling radially or distally.

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Clinical Relevance: by avoiding distal and radial drilling, the risks of PIN injury should be minimized during distal biceps tendon repair.

Figure 1.
Trajectory A- Guide pin placed perpendicularly through the radius

Figure 2.
Trajectory B- Drill directed 45 degree distally toward the bicipital tuberosity

Figure 3.

Trajectory C and D- ulnarly (above) and radially (below) directed pin. The horizontal line represents the plane of the forearm and the vertical line is the neutral axis.

Figure 4.

Pin exit site through dorsal cortex with its relative position to the nerve: distally directed drill with increased risk of injuring posterior interosseous nerve. The asterisk identifies the drill. The distance between the drill and the nerve was also marked.

Table 1

Distance (mm) of pin to posterior interosseous nerve

Trajectories	Specimen #										Mean (mm)	SD	95% CI
	1	2	3*	4	5	6	7	8	9*	10*			
A- A to P	18.2	8	9.8	9.5	8.9	11.9	8.2	10.2	13.8	13.7	11.2	3.2	(8.9,13.5)
B- 45 deg dist	1.9	0	3.1	1	2.1	2.3	0	2.8	0	7.2	2.0	2.2	(0.5, 3.6)
C- ulnar	20.2	14.4	14.5	13.8	11.6	15.2	12.6	15.6	17.7	24.1	16.0	3.8	(13.3,18.7)
D- radial	1.3	6	3.1	1	3.1	6.9	3.6	3.8	5.8	7.4	4.2	2.2	(2.6,5.8)

* denotes specimens in which ulna cortex was penetrated

Table 2

Overall Comparison (Friedman test)
The p-value for comparison of distance among the 4 different angle groups < 0.0001
Pair-wise comparison (two-sided Wilcoxon signed-rank test)
The p-value of A and B = 0.002
The p-value of A and C = 0.002
The p-value of A and D = 0.002
The p-value of B and C = 0.002
The p-value of B and D = 0.0234
The p-value of C and D = 0.002