EXPERIMENTAL STUDY

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Biomechanical comparison of headless antegrade screw versus retrograde cortical screw for coronoid fracture fixation

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Objective: Posterior-to-anterior directed screws are stronger than anterior-to-posterior directed screws for coronoid fracture fixation. Anterior approaches that facilitate direct reduction and fixation of coronoid fractures have been described. The present study was based on the hypothesis that anterior-to-posterior headless screw (Acutrak Mini® 3.5 mm × 26 mm, Acumed, Hillsboro, Oregon, USA) fixation of coronoid fractures would be as strong as posterior-to-anterior 2.7 mm Association for Osteosynthesis (AO) cortical screw fixation.

Methods: This study included 14 ulnas obtained from 14 formalin-preserved adult cadavers. Coronoid type 2 fractures were created and fixed randomly using anterior-to-posterior headless screws (antegrade group) and posterior-to-anterior 2.7 mm AO cortical screws (retrograde group). The experimental constructs were loaded until 2 mm of displacement. Failure load (N), fixation stiffness (Nmm^{-1}), and indentation stiffness were calculated.

Results: Failure load was higher in the retrograde screw group ($p=0.03$), whereas loading stiffness values of the fixation devices and bones did not differ between the 2 fixation groups ($p>0.05$).

Conclusion: The present study failed to show that anterior-to-posterior directed headless screw fixation of coronoid fractures could adequately replace posterior-to-anterior placed screw fixation.

Keywords: Coronoid fracture; fixation; headless screw.

Fractures of the coronoid process of the ulna generally occur due to relatively high-energy injury and are commonly associated with injuries to other structures in the vicinity of the elbow.[1] Restoration of the coronoid's anterior buttress is critical for future elbow stability.[2] The optimal fixation technique depends on the fragment size and fracture pattern.[3–5] Coronoid tip subtype 2 fractures, which occur most commonly in severe triad injuries, are sufficiently large to be secured with 1 or 2 screws when minimally comminuted.[6] Screws can be placed antegrade or retrograde, but retrograde placement is stronger.[7]

However, retrograde pin placement is more difficult, as the fracture fragment is often too small to fix with cannulated 3.5 mm screws, especially in type 2 fractures.[8] Recently, anterior approach by splitting the brachialis

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muscle, bringing the surgeon directly onto a tip fragment of the coronoid with excellent visualization of the entire articular surface of the fractured coronoid and allowing anterior-to-posterior screw fixation perpendicular to the fracture line, has been described.[9,10]

Acutrak Mini® screws (Acumed, Hillsboro, Oregon, USA) are designed for interfragmentary compression and elimination of articular or soft tissue impingement on the exposed screw head. Furthermore, the design of Acutrak Mini® screws obviates the need for countersinking and the subsequent removal of subchondral bone that is necessary for adequate purchase in small fragments.

Retrograde 2.7 mm Association for Osteosynthesis (AO) cortical screws are stronger than antegrade 2.7 mm AO cortical screws; however, retrograde application may complicate surgery, as longer screws require purchase of both the posterior and anterior cortexes, which is associated with the potential risk of joint penetration or fragment comminution during screw fixation. The potential for such risk can be reduced via use of short headless Acutrak Mini® screws, which facilitates direct fixation through the fracture fragment under visualization of the fracture fragment reduction. The hypothesis of the present study was that antegrade Acutrak Mini® screw fixation would be as strong as retrograde 2.7 mm cortical screw fixation of type 2 coronoid fractures in a cadaver ulna biomechanical model.

Materials and methods

The study included 14 ulnas obtained from 14 formalin-preserved adult cadavers. Specimens were stripped of all soft tissues and osteotomized from the lower middle third of the diaphysis. Coronoid type 2 fractures were created via transverse osteotomy at the middle of the coronoid, referencing from the tip of the olecranon across the base of the coronoid parallel to the long axis of the diaphysis, creating a fragment of approximately 50% of the bony height of the coronoid.[7,11]

The specimens were then numbered randomly. Specimens 1, 3, 5, 7, 9, 11, and 13 were fixed with a 2.7 mm

Fig. 1. **(a)** Screws tested. **(b)** Test set-up. [Color figures can be viewed in the online issue, which is available at www.aott.org.tr]

Table 1. Results of the groups.

	Antegrade fixation	Retrograde fixation	p
	Mean±SD	Mean±SD	
Failure load (N)	49±16	77±32	0.03
Stiffness (Nmm^{-1})	28±7	29±15	NS
Indentation stiffness (Nmm^{-1})	27±8	33±11	NS

NS: Not significant; N: Newton; Nmm^{-1} : Newton/millimeter.

AO cortical screw (retrograde group). Specimens 2, 4, 6, 8, 10, 12, and 14 were fixed with Acutrak Mini® 3.5 mm × 26 mm screw fixation (antegrade group) (Figure 1a).

To achieve interfragmentary compression in the retrograde group, the near cortex was drilled with a 2.7 mm drill bit, and the far cortex was drilled with a 2 mm drill bit. Screw length was determined using a depth gauge. In the antegrade group, fractures were fixed directly following reduction of the fragment and provisional fixation with K-wire and drilling of the anterior cortex with a 2 mm drill bit. The distal half of the ulna was potted with bone cement, leaving the proximal end free.

Before load testing, olecranon was excised to facilitate free axial load application. The construct was mounted securely in the jaws of a materials testing machine (AG-I 10 kN®, Shimadzu, Kyoto, Japan) (Figure 1b). Load was applied 3 mm anterior of the osteotomy site at a displacement rate of 10 mm/min^{-1} . Fixation failure load (N) was defined as a load that caused 2 mm of displacement at the osteotomy site. Fixation stiffness (Nmm^{-1}) was calculated from the slope of the linear portion of the load-displacement curve. After the fixation constructs were load tested, the implants were removed, and indentation testing was performed using a 5 mm diameter rod at the metaphyseal part of the proximal ulna, so as to verify the strength of the bones tested. Bone stiffness was calculated from the slope of the linear portion of the load-displacement curve.

The Mann-Whitney U test was used to compare the groups. Statistical significance was set at a $p<0.05$.

Results

The findings are shown in Table 1. Failure load was higher in the retrograde group ($p=0.03$), whereas loading stiffness of the fixation devices and bones did not differ between groups ($p>0.05$). Failure mode was separation of the fracture fragment in all specimens. There was no further fracture fragment comminution or screw pull-out.

Discussion

The primary finding of the present biomechanical study is that retrograde 2.7 mm cortical screw fixation yielded a higher failure load than antegrade headless screw fixation. Repair and/or fixation of even small tip fractures of the coronoid is advised, especially in the presence of complex elbow fractures, in order to prevent the development of additional elbow instability.[1,12] Based on fracture fragment size and pattern,[3–5] fixation options include K-wires, plates, and screws.[3,5,13] Although according to the literature, posterior-to-anterior screw fixation is preferred due to such advantages as avoidance of neurovascular structures and high fixation strength,[7,14,15] anterior—including endoscopy-assisted—approaches that avoid neurovascular structures have also been described using direct fixation, which appears to be easier than retrograde screw placement, allowing the placement of screws perpendicular to the fracture line, with visualization of the entire articular surface of fractured coronoid fragment.[8,16]

Accordingly, the hypothesis of the present study was that as Acutrak Mini® screw fixation is stronger than that associated with currently available headless screws or that it would be at least as strong as retrograde 2.7 mm cortical screw fixation in a type 2 coronoid fracture model,[17] with the possible advantages of direct fracture fixation and shorter duration of scopy than required during retrograde screw fixation[18] and avoidance of longer screw usage associated with the possible risk of joint penetration and fragment communition. Acutrak Mini® 3.5 mm × 26 mm screws were used instead of 2.7 mm or 3 mm headed screws.

Medial and lateral exposures for elbow fractures require a large soft tissue dissection and are still unable to provide sufficient exposure. An anterior approach by splitting the brachialis muscle, which has the advantage of direct fracture fixation, has been described. However, this approach puts neurvascular structures at risk and requires anterior capsule detachment; this may further jeopardize the vascularity of the fracture fragment, which may be prevented by arthroscopy-assisted anterior approach.[8,10,16] The present study's hypothesis was disproved, as retrograde conventional cortical screw fixation yielded a higher failure load than antegrade headless screw fixation, an outcome that may have resulted from the shorter headless screws without purchase of the far cortex; however, the longest available screw was used in the present study. Although the required strength of coronoid fixation remains unknown, retrograde screw fixation seems to be stronger than antegrade screw fixation. This is to say that that when antegrade headless screw fixation is used, multiple screws and/or larger and/or longer screws with far away cortex purchase should be used.

There are some limitations to the present study. The experimental model employed cannot be directly compared to *in vivo* fixation. In addition, formalin-fixed bones were used instead of fresh frozen cadaver bones. Formalin-fixed bones, although reported to be stiffer than fresh frozen bones, have been validated for use in biomechanical research.[19–22]

The primary aim of the present study was to test the hypothesis that antegrade headless screw fixation would as strong as retrograde screw fixation in homogeneously distributed cadaver bones, which was measured by similar indentation test stiffness of the groups. In conclusion, the present study failed to show that anterior-to-posterior directed headless screw fixation of coronoid fractures could replace posterior-to-anterior placed screw fixation, with possible advantages of easier insertion and removal due to subcutaneous localization on the posterior proximal ulna.[7]

Conflics of Interest: No conflicts declared.

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