Lag Screw Trajectory in Supination-External Rotation Fractures: Does the Direction of the Fibula Lag Screw Have an Effect?

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Background: The fracture obliquity of supination-external rotation injury of the fibula is often amenable to lag screw insertion. The purpose of the study was to determine whether biomechanical differences exist between lag screws inserted from an anterior to posterior direction and from a posterior to anterior direction and the thickness of the anterior and posterior fibular cortices were correlated with biomechanical testing.

Methods: Ten cadaver fibulae were harvested and submitted to material testing following 3.5-mm cortical screw insertion from either an anterior to posterior direction or a posterior to anterior direction. Screw torsional insertion strength and axial pullout strength were measured. Computed tomography images of 40 consecutive patients undergoing preoperative planning for fractures excluding the fibula were examined to define fibular cortical thickness and correlate anatomic findings with the biomechanical testing.

Results: The axial pullout strength of lag screws inserted from posterior to anterior was significantly greater than that of lag screws inserted from anterior to posterior ($p < 0.05$). Screw insertion torque measurements demonstrated a similar trend although the data did not reach statistical significance ($p = 0.056$). The anterior cortex of the distal fibula exhibited a radiographically greater thickness than that of the posterior cortex at the same level ($p < 0.001$).

Conclusions: For oblique fractures of the distal fibula, posterior to anterior lag screw insertion exhibited improved biomechanical properties when compared with a similar screw inserted from anterior to posterior. These results correlated with the thicker cortical bone present along the anterior fibula.

Keywords: *Fibula, Ankle injuries, Bone screw, Biomechanics*

Fractures of the lateral malleolus are common, accounting for up to 55% of all ankle fractures.[1] Lauge-Hansen supination-external rotation type 4 fractures are conventionally treated with operative intervention.[2,3] The lateral malleolar fracture configuration is typically oriented from distal anterior to proximal posterior at the syndesmotic level[4] (Fig. 1).

This fracture obliquity is readily amenable to compression with an obliquely placed lag screw. This implant may be inserted either from proximal anterior to distal posterior or from distal posterior to proximal anterior.[5] Due to ease of insertion, anterior to posterior screw fixation is commonly performed;[6,7] however, the posterior to anterior approach has been suggested to achieve effective, if not improved, compression.[7]

This study's goals were to determine whether insertion torque and pullout strength differ between lag screws inserted anterior to posterior and those inserted posterior to anterior and if there were anatomical differences in cortical thickness between the anterior and posterior cortices, which would explain the differences in biomechanical testing.

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METHODS

Five matched intact cadaver fibulae pairs were harvested via a lateral approach, an osteotomy of the proximal head, and dissection of the syndesmosis. The distal fibulae were intact, without prior history of fracture, infection, or instrumentation. The mean age of cadavers was 87.2 years (range, 81–91 years). A supination-external rotation fracture line was defined along the lateral aspect of each fibula originating from the distal anterior surface at the cranial cartilaginous portion of talofibular articular surface and extending proximally at a 45° obliquity to the longitudinal fibular axis. A small fragment lag screw was inserted according to the AO standard technique.[8] The near cortex was overdrilled with a 3.5-mm drill. A 2.5-mm drill sleeve was inserted into the near cortex drill hole, perpendicular to the fracture obliquity, to drill the far cortex colinear with the drill sleeve. This was performed in an anterior to posterior direction for one fibular specimen (Fig. 2A)
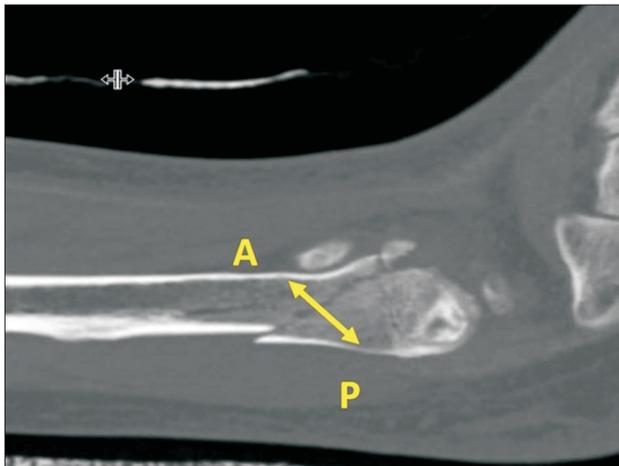
Fig. 1. Sagittal computed tomography scan showing typical fracture planes for supination external rotation weber B fracture. The yellow arrow shows screw orientation for anterior to posterior or posterior to anterior screw. A: anterior, P: posterior.

and from posterior to anterior in the matched pair (Fig. 2B). A pair of spacers were placed between the screw head and the near cortex in order to facilitate mounting to the material testing machine. The paired spacers allowed for compressive forces without compromising testing, as pullout strength and insertional torque were dependent upon engagement with the opposite cortex. Each screw was then subjected to insertion torque and axial pullout testing.
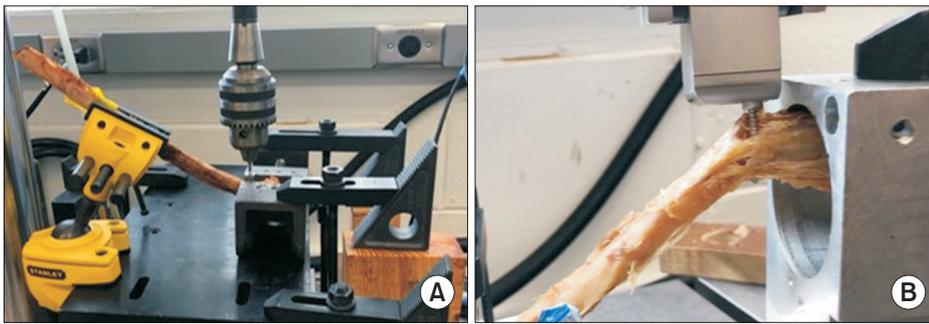
Insertion Torque

Each screw was inserted in two steps. First, the screws were manually driven until fixation was subjectively accurate based on the surgeon's experience and the tip of the screw penetrated at least 2 mm beyond the far cortex, ensuring maximal engagement of screw threads with cortex. Then each bone was mounted onto a biaxial material testing machine (Instron 8874; Instron, Norwood, MA, USA). An adjustable clamp setup secured the fibula proximal and distal to the screw and maintained a 45° angle between the fibula and the actuator, allowing for vertical alignment of the screw and the driver attachment of the material testing machine. The actuator applied a clockwise rotation of 240° at a rate of 180°/sec (i.e., 30 rpm: American Society for Testing and Materials [ASTM] F543 standard) to the tip of screw while maintaining the axial load of 10 N. During screw insertion, torque was measured. The insertion torque was defined as the maximum torque measured during screw driving (Fig. 3A).

Pullout Tests

Each fibula was mounted onto a biaxial testing machine (Instron 8874; Instron) using a similar adjustable clamp setup. The screw and fibula were suspended by the washers using a custom wedge grip fixed to the load cell. The fibula was then clamped at an angle so that the long axis of the screw was parallel to the direction of loading. A tensile load was applied to the screw at a crosshead speed of 5 mm/min (ASTM F543 standard) until the screw was released from the bone. The pullout strength was defined as
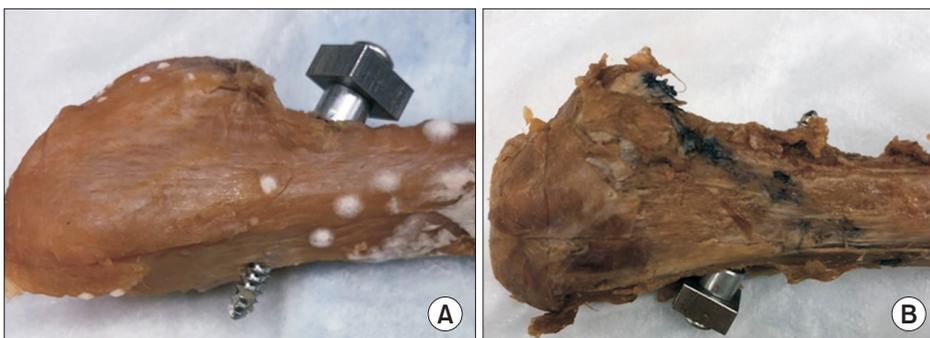
Fig. 2. (A) Cadaver distal fibula showing orientation of the anterior to posterior lag screw. (B) Cadaver distal fibula showing orientation of the posterior to anterior lag screw.

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Fig. 3. (A) Insertion torque measurement setup on Instron. (B) Pullout strength testing setup on Instron.
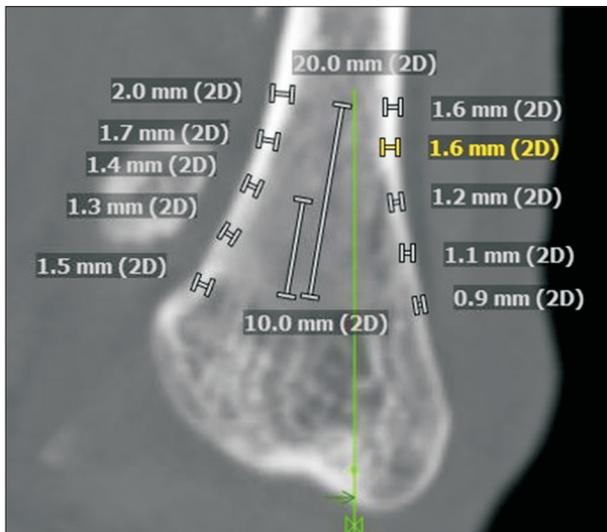
Fig. 4. Anterior and posterior cortical thickness measurement on sagittal plane computed tomography. 2D: two-dimensional view.

the maximum force recorded during screw removal from the bone (Fig. 3B).

Anterior versus Posterior Cortical Thickness

Approval was obtained from the Institutional Review Board of Yale New Haven Hospital (IRB No. 2000023332). Informed consent was not needed as this was a cadaver study involving retrospective review of imaging. Two of the authors (AS and AS) independently analyzed computed tomography (CT) data on 40 consecutive patients with CT scans performed via Siemens Somatom Sensation 64 for the purpose of preoperative planning for ankle trauma without fracture involvement of the lateral malleolus. All CT scans were performed with 1-mm sections. The measurement of anterior and posterior cortical thickness was taken in sagittal plane CT scans. The sagittal plane with the maximum width of the fibular canal was used for measurements. The sagittal cuts on the CT scan were scrolled from anterior to posterior. The cut with maximum fibular canal diameter

was used to measure the cortical thickness. This was done to ensure that we measure the cortical thickness at the same place in all cases. The readings were started at the distal most part of syndesmosis and measurements were performed at five different sites 5 mm apart proximal to it in order to cover the most frequent locations for supination eversion fractures of the lateral malleolus.[9] The measurement was done on the Visage PACS imaging software (Visage 7.1; Visage Imaging, Berlin, Germany) (Fig. 4).
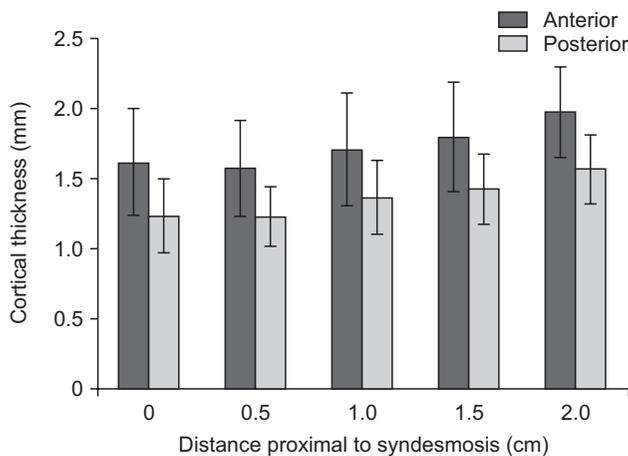
Statistical Analysis

The difference in anterior and posterior cortical thicknesses was measured using paired t-test and the percentage agreement between the observers was analyzed using Bland-Altman plots. Mann-Whitney U-test was used to analyze the difference between the pullout strength and insertion torque in both groups. Correlation and regression analyses were used to identify a correlation between insertion torque and pullout strength.

RESULTS

The anterior cortical thickness was significantly greater than the posterior thickness ($p < 0.001$) in the paired t-test at all points measured (Fig. 5). Bland-Altman plots showed greater than 95% agreement between observers for CT assessment of fibular cortical thickness at all points measured. The pullout strength was significantly greater in the posterior to anterior group as compared to the anterior to posterior group ($p < 0.05$). Fig. 6 shows the maximum pullout loads for each pair of fibulas.

The insertion torque was greater in the posterior to anterior group (Mean, 4.90 N/mm) as compared to the anterior to posterior group (mean, 4.26 N/mm) but did not exhibit statistical significance ($p = 0.056$). There was no correlation between the insertion torque and pullout strength ($R^2 = 0.22$; p-value for correlation = 0.169).

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Fig. 5. Bar diagram showing anterior and posterior cortical thicknesses as measured on computed tomography scan.

Fig. 6. Maximum load during pullout testing of paired cadaver fibulas for the posterior to anterior and anterior to posterior lag-screw approaches.

DISCUSSION

The typical fibular fracture orientation in supination-external rotation patterns is from distal anterior to proximal posterior.[1,9] Following anatomic fibular reduction, a common technique is to insert a lag screw in an oblique manner, from proximal anterior to distal posterior.[5] In this manner, the lag screw is placed perpendicular to the fracture obliquity and thus it creates maximal compression at the fracture site.

Strikingly, the distal fibular cortical osteology has not been examined previously in this regard. Based on CT data, the anterior fibular cortex was significantly thicker than the posterior cortex at the level of the syndesmosis. In this cadaver biomechanical analysis, we determined there was a significantly greater axial pullout strength for screws inserted from posterior to anterior, compared with those inserted from anterior to posterior. The insertional torque demonstrated a similar trend; however, this investigation did not render statistical significance, likely due to sample size. The biomechanical findings may be explained by the conspicuous fibular osteology and fracture orientation. The far cortex for a posterior to anterior lag screw involves the thicker anterior cortex, whereas the far cortex for an anterior to posterior lag screw involves the thinner posterior cortex (Fig. 1).

Insertion torque and pullout strength were the two parameters used to evaluate the screw strength. Pullout strength traditionally has been used for evaluating the screw bone stability;[10-13] however, Ricci et al.[14] suggested that insertion torque is more important in assessing screw bone stability than pullout strength. It is argued that insertion torque is more closely correlated with the magnitude
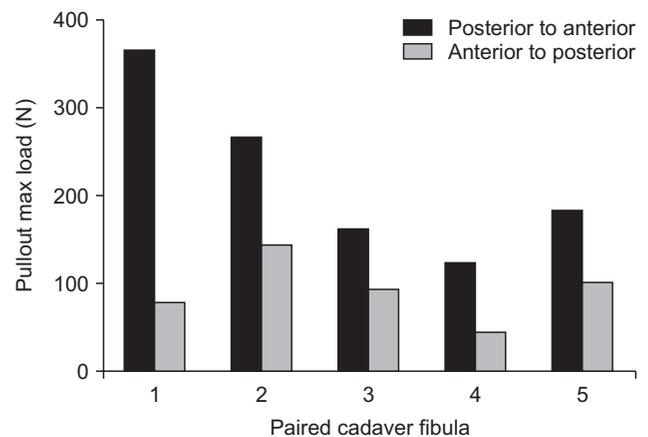
of plate bone compression effected by the screw. Our study, similar to other previous studies,[14-16] also found that insertion torque and pullout strength were not related to each other.

The clinical implication of this study is that posterior to anterior lag screws in distal fibula can be utilized in routine practice while addressing fibular fractures to make the construct more stable. This can be done with the patient in supine position and the leg placed over a bone foam. The leg can be brought to the edge of the bed for posterior to anterior screw insertion. Depending on the fracture and surgeon's preference, a neutralization lateral plate or an anti-glide posterior plate can be added. If the surgeon is planning to use an anti-glide posterior plate, then the posterior to anterior lag screw can be inserted through the plate.

This study has limitations. The sample size for the biomechanical testing was small due to the limited availability of the cadaver bones. The level of osteoporosis was not measured, although the specimens would all likely exhibit components of osteoporosis due to age (mean age, 87.2 years). The fracture simulation and cyclic loading were not done; however, in clinical scenarios, these fractures require a neutralization plate and possibly more lag screws. This study focused only on testing the strength of single lag screws.

In summary, the biomechanical strength of the posterior to anterior lag screw in distal fibula was greater than that of the anterior to posterior lag screw. However, its clinical relevance needs to be studied further with prospective controlled trials.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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