Headless Compression Screw Fixation of Vertical Medial Malleolus Fractures is Superior to Unicortical Screw Fixation

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Take-Home Points

- Optimal fixation of vertical shear ankle fractures is unknown.
- Headless compression screws are stiffer than cancellous screws in offset axial load.
- Headless compression screws have a higher load to failure than cancellous screws.
- Headless compression screws may offer a soft tissue friendly fixation of method for vertical shear ankle fractures.
- These findings may not apply when subject to cyclic loads or in osteoporotic bone.
Headless compression screws are cannulated tapered titanium screws with variable thread pitch angle, allowing a fully threaded screw to apply compression along its entire length. These screws have been most commonly used for scaphoid fractures but have also been studied in fractures of small bones, such as capitellum, midfoot, and talar neck, and arthrodesis in the foot, ankle, and hand. Headless compression screws have been found to produce equivalent fragment compression to partially threaded cancellous screws while allowing less fragment displacement. The lack of a head may decrease soft tissue irritation compared with the partially threaded cancellous screws. Finally, headless compression screws are independent of cortical integrity, as the entire length of the screw features a wide thread diameter to capture cancellous bone in the proximal fragment, unlike partially threaded cancellous screws, which only possess a thread purchase in the distal fragment and depend on an intact cortex.

Vertical shear fractures of the medial malleolus occur through the supination-adduction of the talus exerted onto the articular surface of the medial malleolus. Optimal fixation of these fractures must be sufficient to maintain stable anatomic reduction of the ankle joint articular surface, allowing early range of motion, maintaining congruency of the ankle joint, and decreasing the risk of future post-traumatic arthritis to maximize functional outcome.

A wide variety of techniques are available for fixation of these fractures, including various configurations of cortical screws, cancellous screws, tension bands, and antiglide plates. Clinically, 2 parallel 4.0-mm partially threaded cancellous screws are most often used. Limited evidence indicates that headless compression screws may be a viable option for fixation of medial malleolar fractures. One case reports the use of a headless compression screw for a horizontal medial malleolar fracture, and a small retrospective case series that used headless compression screws for all medial malleolar fractures showed satisfactory outcomes, a high union rate, and low patient-reported pain.

We evaluate the stiffness, force to 2-mm displacement of the joint surface, and elastic properties of these 2 different constructs in vertical medial malleolar fractures in synthetic distal tibiae. We hypothesize that the parallel headless compression screw fixation will be stiffer and require more force to 2-mm displacement than parallel unicortical cancellous screw fixation.

**Material and Methods**

Identical vertical osteotomies (17.5 mm) were made from the medial border of the medial malleolus using a custom jig in 20 left 4th-generation composite synthetic distal tibiae (Sawbones, Pacific Research Labs; Model No. 3401) to simulate an Orthopaedic Trauma Association type 44-A2.3 fracture. The tibiae were then cut 18 cm from the tibial plafond and randomized to 2 fixation groups (n = 10 specimens for each group): parallel unicortical screw fixation or parallel unicortical headless compression screw fixation (Figures 1A-1D). Custom polymethylmethacrylate jigs were used to reproducibly drill identical holes with a 3.2-mm drill for the parallel unicortical screw construct and the drill bits provided by the Acutrak 2 Headless Compression Screw System (Acumed). The parallel unicortical screw construct consisted of 2 parallel 4.0-mm-diameter, 40-mm partially threaded cancellous screws (Depuy Synthes), and the headless compression fixation construct consisted of 2 parallel 4.7-mm-diameter, 45-mm titanium Acutrak 2 screws parallel to each other in the transverse plane. The Acutrak screws were placed per manufacturer instructions by first drilling with the Acutrak 2-4.7 Long Drill bit (Acumed), followed by the Acutrak 2-4.7 Profile Drill bit for the near cortex.

Specimens were fixed to the base of a servohydraulic testing machine (Model 809, MTS Systems Corporation) with an axial-torsional load transducer (Model No. 662.20-01; Axial capacity of 250 kg, torsional capacity 2.88 kg-
m; MTS Systems Corporation). The specimens were set in a vice tilted at 17° in the coronal plane to allow the MTS crosshead to apply an offset axial load simulating supination-adduction loading, which has been described previously (Figure 2).\textsuperscript{14,15} Load was applied to the inferolateral articular surface of the medial malleolus at 1 mm/s to a crosshead displacement of 6 mm and then cycled back to 0 mm. Load and axial displacement were measured at 60 Hz. The markers on the distal tibia and medial malleolus fracture fragment were tracked using high-resolution video (Fastcam PCI, Photron USA Inc). The motion of the video markers was determined using digitization and motion analysis software (Motus 9, Vicon).

Stiffness was calculated as the slope of the linear portion of the load-displacement curve over a range of 0.5 to 2.0 mm (Figure 3) and reported as mean (standard deviation). The force at 2 mm of fragment displacement was defined as a clinical failure.\textsuperscript{16,17} Student’s $t$ test was used to determine the difference in construct stiffness and force for 2 mm displacement of the 2 groups. Significance was defined as \( P < .05 \). Institutional Review Board approval was not required for this study.

**Results**

With offset axial testing to simulate supination-adduction force along with video motion analysis, the mean stiffness (± standard deviation) measured 180 ± 48 N/mm for the parallel unicortical screw fixation construct and 360 ± 131 N/mm for the headless compression screw fixation construct (Figure 4A). The headless compression screw fixation construct was over 2 times stiffer than the parallel unicortical construct during initial displacement of the fracture, indicating a statistically significant difference (\( P < .0001 \)).

The mean force for 2 mm of fracture displacement, defined as clinical failure, reached 342 ± 83 N for the parallel unicortical screw fixation construct and 719 ± 91 N for the headless compression screw fixation construct (Figure 4B). The headless compression screw fixation construct resisted displacement significantly more (\( P = .0001 \)) than the parallel unicortical screw construct, presenting a 100% increase.

Upon cycling of the servohydraulic testing machine back to 0-mm displacement, the parallel unicortical construct demonstrated no elastic recoil, remaining displaced at 4 mm, whereas the headless compression screw construct rebounded to almost 0-mm displacement, which is well below the clinical definition of fixation failure of 2 mm (Figure 5).

**Discussion**

When subjected to offset axial load, we observed that the headless compression screw construct exhibited significantly increased stiffness and load to 2 mm of displacement compared with a parallel unicortical screw construct. The headless compression screw also demonstrated elastic recoil to almost 0 mm of displacement, which is well below the 2-mm displacement.

We made reproducible fractures and fixation methods in synthetic distal tibiae, which feature less variability in size and quality than the cadaveric bone. Offset axial loading, rather than direct axial loading previously described by Amanatullah and colleagues,\textsuperscript{18} is the most physiologically relevant mode of force application to simulate the loading of the tauts onto the medial malleolus in the supination-adduction mechanism of injury.

The limitations of this study include the use of synthetic rather than cadaveric bone. Fourth-generation sawbones have been validated as possessing similar biomechanical properties as real bone.\textsuperscript{7,19} These results may also be inapplicable to osteoporotic bone, which would be significantly less dense than sawbones. This study is also an
artificial situation designed to only test construct stiffness and load to clinical failure in a single mode of stress, offset axial loading and neglects other possible modes of force. This testing setup also disregards the structures surrounding the medial malleolus and tibia, including the talus, fibula, or soft tissue attachments, including the deltoid ligament and flexor retinaculum. These results are only relevant immediately after fixation and before bone healing occurs. We also tested the load to clinical failure rather than cyclic loading. Our testing more closely modeled a single traumatic force rather than the considerably smaller stresses that would be repeatedly exerted on the construct over several weeks after fixation in a clinical situation. This research is also not a clinical outcome study, rather, it suggests that headless compression screws are a viable, stronger, and possibly superior method for the initial fixation of vertical medial malleolar fractures.

As the load is offset axial, the larger thread purchase of the headless compression screws may lead to increased pullout strength, possibly increasing headless compression screw construct stiffness. Also, the variable diameter of headless compression screw, which reaches up to 4.7 mm, would increase the stiffness of the construct compared with the diameter of the cancellous screws. The elasticity of the headless compression construct may be because screws are made of titanium rather than stainless steel. Such property and given that the screws are cannulated rather than solid may also play a role, although several studies have shown variable results for cannulated vs solid screws of the same diameter.\textsuperscript{20,21} The elastic section modulus of both screws would have to be calculated to determine their exact effect on fixation.

**Conclusion**

The headless compression screw construct was found to be stiffer and features a higher load to clinical failure than a parallel unicortical cancellous screw construct for fixation of vertical medial malleolus fractures. Although significantly increased cost occurs with this construct, the headless design may decrease soft tissue irritation, and the elastic recoil of the construct after displacement may decrease clinical failure rates of this fixation method. This condition would eliminate the need for revision surgeries and thus be a cost effective alternative overall.

*This paper will be judged for the Resident Writer’s Award.*

**Key Info**

**Figures.Tables**

Figures / Tables:

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Figure 1. Anterior-to-posterior radiographs of the (A) parallel unicortical cancellous screw construct and (B) headless compression screw construct. Axial radiographs of the (C) parallel unicortical cancellous screw construct and (D) headless compression screw construct. Dashed lines indicate osteotomy cuts.

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Figure 2. Offset axial servohydraulic compression of the medial malleolus simulating a supination-adduction force of the talus against the medial malleolus. The tibiae were set at 17° from vertical by the vice; the MTS crosshead (MTS Systems Corporation) provided direct downward force onto the medial malleolus. Video motion tracking markers on the distal tibia and medial malleolar fragment.
Figure 3. Overlaid representative plots of force vs displacement curves for the 2 fixation constructs: parallel unicortical cancellous screws (parallel) and headless compression screws.
Figure 4. Bar graph showing (A) stiffness and (B) load at 2 mm of displacement with offset axial loading of each construct. Data are reported as mean with error bars indicating standard deviation. Statistical significance between indicated groups (asterisks) is defined as P < .05.
References


**Multimedia**

**Product Guide**

- **STRATAFIX™ Symmetric PDS™ Plus Knotless Tissue Control Device**
- **STRATAFIX™ Spiral Knotless Tissue Control Device**
- **BioComposite SwiveLock Anchor**
- **BioComposite SwiveLock C, with White/Black TigerTape™ Loop**

**Citation**

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