Increased Biomechanical Stability Offered by Headless Screw Technique for Fixation of Standard Joint Depressed Intraarticular Calcaneus Fractures
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Introduction
Anatomic reduction with internal fixation of intraarticular calcaneus fractures has gained popularity over the past 15 years (1, 2). Internal fixation of the os calcis is often complicated by prolonged soft tissue management and posterior facet disruption (3). Biomechanical analysis of calcaneal fixation has also been difficult and a variety of techniques have been described (2, 4, 5). An ideal calcaneal construct would include minimal hardware prominence, sturdy posterior facet fixation and minimal soft tissue disruption. The purpose of this study was to develop such a construct and provide a quality biomechanical analysis comparing our novel technique with standard calcaneus internal fixation. This study expands on a previous study by using improved testing methodology and having greater statistical power.

Methods and Materials
Twenty fresh-frozen cadaver calcanei (10 matched pairs) were selected for testing. A reproducible calcaneal osteotomy was created which simulated a Sanders type-IIB (joint-depressed) fracture pattern. Computed tomography (CT) was used to validate the model with fracture patterns seen clinically. One calcaneus of each pair was randomized to be fixed using our headless screw technique. Our technique included placement of two headless compressive screws (Acumed, Hillsboro, OR), both entering inferior to the dense subchondral bone posterior to the calcaneo-cuboid joint, and the other anchoring into the dense bone inferior to the anterior and medial facets at the sustentaculum. The joint depressed piece was fixed with two 4.0 cancellous screws placed in a lateral to medial direction (Figure 1). The contralateral matched calcaneus was fixed with a nonlocking calcaneal plate (Synthes, Paoli, PA), placing two cancellous screws in the anterior, subcutaneous, and joint depressed fragments respectively.

Axially loading of the specimen was done using an Instron materials testing machine. The calcaneus was rigidly held by the posterior fragment and the load was applied through the talus. The calcaneus was cyclically loaded at a frequency of 1 Hz for 4000 cycles. This force increased by 250 N every thousand cycles starting at 250 N and ending at 1000 N.

An Optotrak motion capturing system was used to detect motion of the three fracture fragments. Five recordings lasting 30 seconds were taken during testing. Each of the three fragments was marked as a rigid body with 4 markers dedicated to its movement. A total of eight comparison points (16 markers) were utilized and digitized motion and proper orientation of the fragments relative to one another. With this ability, we were able to track gapping (horizontal separation) and step-off (vertical displacement) at the fracture lines as well as assess relative rotation at the primary fracture line in the coronal plane.

Results
There was more horizontal displacement of the fracture line with the plate and screw construct compared to the headless screw technique at seven of the eight comparison points (Table 1). Significant displacement occurred at two points along the inferior margin of the primary fracture, while a trend toward significance was observed in the third inferior point (inf 3) (Figure 2). When assessing vertical displacement at the primary fracture line through the posterior facet, the headless screw construct also performed better at every load (p = 0.052) (Figure 3a). Assessment of rotation showed that on average those fractures fixed with the headless screw technique had less rotation than those fixed with the side plate technique at every load (p = 0.041 at 750 N) (Figure 3b). Observer assessment revealed superior torsional rigidity at the posterior facet fracture line with the headless screw technique compared to the side plate construct and fewer failures.

Discussion
We have developed both a new technique for calcaneus fracture fixation and a reliable method for biomechanical analysis. This fixation technique provides a minimally invasive approach with the potential for percutaneous internal fixation. Although further testing is needed, the biomechanics of the proposed technique may be more similar to intramedullary fixation, producing increased torsional rigidity and stiffness over a plate and screw construct (6). Our technique has biomechanical validation, and generates less horizontal displacement, vertical displacement, and rotation at the fracture site based on our model and the numbers tested.

Table 1. Outcome measures for fracture stability at 750 N of axial load.

<table>
<thead>
<tr>
<th>N</th>
<th>Screw (mm)</th>
<th>Plate (mm)</th>
<th>p (0.05)</th>
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<tbody>
<tr>
<td>Gapping</td>
<td>art 1</td>
<td>art 2</td>
<td>art 3</td>
</tr>
<tr>
<td>750</td>
<td>4.58 (1.41)</td>
<td>11.34 (1.93)</td>
<td>14.13 (2.14)</td>
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Figure 1. CT reconstruction of specimen showing novel construct using 2 headless compression screws (and two compression screws) for fixation of standard joint depressed intraarticular calcaneus fractures.

Figure 2. Location of measurement points on articular surface (art 1, art 2, art 3); points on secondary fracture line (sec 1 and sec 2); and one of the three inferiorly located points (inf 1).

Figure 3. Comparison of horizontal separation (step off) at the primary fracture line through the posterior facet between the headless screw construct and the contralateral matched calcaneus. The headless screw construct also performed better at every load (p = 0.052) (Figure 3a). Assessment of rotation showed that on average those fractures fixed with the headless screw technique had less rotation than those fixed with the side plate technique at every load (p = 0.041 at 750 N) (Figure 3b). Observer assessment revealed superior torsional rigidity at the posterior facet fracture line with the headless screw technique compared to the side plate construct and fewer failures.

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References