Introduction
The first-metatarsal-cuneiform arthrodesis traditionally required a prolonged period of non-weight-bearing postoperatively, though this has been challenged in recent years and weight bearing advancement has been more aggressive recently [1-4]. In order for patients to begin weightbearing earlier in the postoperative phase, the construct used for fusion must be strong enough to withstand this stress. In the quest for the ultimate construct for the Lapidus arthrodesis, the concept of applying fixation to the plantar aspect of the first metatarsal cuneiform joint has also been investigated, as it theoretically provides a stronger construct due to the fixation resisting bending on the tarsal side of the joint (7-11).

We sought to investigate in a laboratory setting the strength of a plantarly-applied Lapidus locking plate with intraplate lag screw technology. In doing so, we compared the strength of this construct to a previously described construct using a plantar lag screw and a medially-applied low profile locking plate (5, 11). Our hypothesis was that the plantarly-applied plate would have superior strength to the medially-applied plate.

Materials and Methods
Eight matched pairs of fresh cadaveric lower limbs were used in this study. In all specimens, a medial approach was made along the first metatarsal cuneiform joint. The construct was prepared using a cuneiform technique, keeping the subchondral plate intact. One specimen in each matched pair was then fixed with a medially-applied low profile system (LPS) locking Lapidus plate (Arthrex, Naples, FL) with an additional 4.5 mm cannulated screw directed from plantar-dorsal to proximal-dorsal (Fig. 1). The second specimen in the matched pair was fixed using a plantarly-applied locking plate, which incorporates a 4.0 mm compression screw into a distal slot, placing the screw from plantar-dorsal to proximal-dorsal (Figs. 2, 3).

After surgical repair, the medial cuneiform and first metatarsal were dissected on bloc in all 16 specimens. A pilot hole was then created in the navicular using a 0.094” drill pin. Each specimen was then placed into a 1.5” schedule 40 PVC pipe. A 0.094” drill pin was then placed through the PVC pipe and the navicular bone. Specimens were then potted using polymethylmethacrylate (PMMA) bone cement, taking care to cover as much bone as possible without covering the surgical repair site. The potted specimens were then fixed to the base of the Instron 8871 Servo Hydraulic Materials Testing System (Instron, Canton, MA) by securing the PVC pipe in a V-block at approximately 15 degrees from horizontal in order to simulate an anatomic weight bearing position. A plunger with a rounded tip was positioned 4cm from the repair site. Specimens were then loaded to failure at a compressive rate of 5mm/min (Fig. 4, 5).

The ultimate load to failure, moment, and stiffness of the constructs was recorded for analysis. Statistical analysis was then performed by way of a paired t test, with the confidence level set at α=0.05.

Results
There were 8 matched pairs used in this study. One foot from each of the matched pairs underwent a first metatarsal cuneiform arthrodesis with a medial approach as described above in the methods section. In the first group, the arthrodesis site was fixed with a medially-applied LPS plate and a plantar-distal to dorsal-proximal 4.5 mm cannulated intraplate screw. The ultimate load to failure in this group after being tested was 253.38 ± 153.38 N. The moment at time of failure was 10.22 ± 6.22 Nm, and the stiffness was 25.73 ± 15.74 N/m.

The second group was fixed using a plantarly-applied Lapidus plate (Arthrex, Naples, FL). The ultimate load to failure in this group was 197.48 ± 108.61 N. The moment at time of failure was 7.89 ± 4.34 Nm, and the stiffness was 17.33 ± 11.49 N/m.

Statistical analysis was performed using a paired t test, with the confidence level set at α=0.05. There was no significant difference found between the two groups with respect to ultimate load to failure (p=0.402), moment at time of failure (p=0.402), or stiffness (p=0.243). The results of the experiment are summarized in Table 1.

Discussion
While we hypothesized that the plantarly-applied plate would be stronger than the medially-applied plate, the results show that the opposite was true, though this difference did not reach statistical significance.

Plantar plating for Lapidus arthrodesis has been an attractive option for foot and ankle surgeons, with more anatomic plates becoming available commercially (9). Adding to the popularity of the plantarly-applied plates are several studies comparing the strength of fixation to 3.5mm screws alone (6) or to dorsally-applied plates (8). Sawma et al. also looked at plantarly-applied fixation in a clinical study and commented on the importance of fixing the plantar, or tension side, of the joint (7).

While we expected the plantar plate to be at least as strong as the medial plate, this was not actually the case. One possible reason for this deviation from the expected result is the observation that the tension side of the first metatarsal cuneiform joint in a foot with hallux valgus is not truly on the plantar side, but actually lies on the medial-proximal side. The concept of the plantar aspect of the joint being the tension side comes from the AO/ASIF principles of fracture management (12). This theory is that the plantar aspect of the first metatarsal cuneiform joint being the tension side of the joint may represent a simplified application of this concept, using two-dimensional, diagrammatic thinking and applying it to a three-dimensional concept. Further research directed at determining the three-dimensional aspect of the first metatarsal cuneiform joint and its tension and compression side may be warranted, though it is beyond the scope of the current investigation.

Table 1
<table>
<thead>
<tr>
<th>Ultimate Load (N)</th>
<th>Moment (Nm)</th>
<th>Stiffness (N/m²)</th>
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<tbody>
<tr>
<td>197 ± 109</td>
<td>8 ± 4</td>
<td>17 ± 11</td>
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<td>255 ± 155</td>
<td>10 ± 6</td>
<td>26 ± 16</td>
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References