INTRODUCTION

Calcaneal fractures are serious, debilitating injuries that are difficult to treat and rehabilitate. The severity of the injury is dependent on the type of fracture. The most difficult to manage are the intra-articular fractures which occur in seventy-five percent of all calcaneal fracture cases (Colburn et al., 1989). The mechanism of the intra-articular calcaneal fracture has been attributed to two major factors - the magnitude of the angle of Gissane (Essex-Lopresti, 1952) and the eccentric loading of the Sustentaculum Tali (Burdeaux, 1983). The current study focuses on these two mechanisms with regards to principal compressive calcaneal strains. By examining the influence of geometry and age on the calcaneal strain, an understanding of the interplay between lower limb configuration and intra-articular fracture may be determined.

METHODS

Experiments were performed on eighteen human cadaveric limbs dissected at the distal third of the tibia. The foot was instrumented with rosette strain gages on the medial calcaneus bisecting the angle of Gissane (AG) and the lateral side perpendicular to the Sustentaculum Tali (ST). The Achilles tendon was dissected and attached to a load cell via a freeze clamp. Each limb was mounted in a custom made testing apparatus with two impacting surfaces and load cells on the heel and forefoot (Figure 1).

Figure 1: Experimental Testing Apparatus

The forefoot was constrained to maintain the foot in a neutral position. Two five-pound weights were placed on the impactor and it was raised 15 cm above the plantar surface of the calcaneus. The Achilles tendon was preloaded for 1 second and the tension was maintained for an additional second before the impactor was released. Data were collected on a PC at 2000 Hz using a custom LabVIEW® program. Signals were recorded for the impact portion of the trial only and included: Achilles tendon, heel and forefoot forces as well as the three strain signals from each of the rosette gages. Principal strain and the direction of the strain were calculated using the principles of Mohr’s circle.

RESULTS

Forces acting on the foot are shown in Table 1. The calcaneal force is defined as the sum of the Achilles tendon force and the external impact at the heel.

Table 1: Measured Forces Acting on the Calcaneus

<table>
<thead>
<tr>
<th>Force (N)</th>
<th>Mean</th>
<th>St. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achilles Tendon</td>
<td>926</td>
<td>897</td>
</tr>
<tr>
<td>Heel Impact</td>
<td>540</td>
<td>218</td>
</tr>
<tr>
<td>Calcaneal</td>
<td>1466</td>
<td>879</td>
</tr>
</tbody>
</table>

The limbs were categorized by age into two groups. Older feet ranged from 74 to 93 years of age while the younger group varied in age from 41 to 57 years. Significantly higher principal compressive strains were found in older feet, 1302 ± 392 με, was significantly different from AG strain, 416 ± 433 με (p=0.027, Figure 2). No difference between medial and lateral strains was found for older feet (p=0.413).

Figure 2: Mean Principal Strains

The orientation of the principal strains was defined from the angle from the first grid in the rosette strain gage affixed to each side of the calcaneus. On the lateral side of the calcaneus, grid one was oriented to bisect the angle of Gissane. For the medial side, the baseline was perpendicular to the ridge of the ST. The typical magnitude and orientation of the maximum compressive principal strain during a single impact of 0.1 seconds is found in Figure 3. The length of the arrow represents the magnitude of strain. The high level of variability of the angle parameter precluded any definitive conclusions to be drawn with respect to age and the magnitude of strain or force.

DISCUSSION

Impact forces produced relatively high strains at Gissane's angle and beneath the Sustentaculum Tali, which were dependant on age. In the older group the strain was five times higher at the apex of Gissane, whereas, at the ST site, the strains for the older group were twice those found in the younger group. There were no age-related differences in the strain directions, most likely due to the fact that age does not affect gross bone geometry as it does bone stiffness. The consistent effect of bone geometry also resulted in relatively consistent strain directions within each trial (Figure 3). In terms of the practical significance of these findings, it seems as though younger calcanei are at more risk on the medial side, whereas older specimens are at risk on both sides of the os calcis.

REFERENCES


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