Kinematic and contact pressure changes in the ankle joint with syndesmosis injury: a cadveric study

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My disclosure is in the Final AOFAS Mobile App.

I have no potential conflicts with this presentation.
Introduction

- Ankle Injuries are among the most common injuries incurred by all levels of athletic competition.

- Syndesmosis injuries have been reported to range from 1% to 24% of ankle ligamentous injuries\(^1\)\(^-\)\(^3\)

- Ligamentous injuries to the distal tibiofibular syndesmosis are predictive of long-term ankle dysfunction\(^4\)

- Mild and moderate syndesmotic injuries can be difficult to stratify

- The impact of syndesmosis injury on the magnitude and distribution of forces within the ankle joint during athletic activities is unknown
Introduction

The distal tibiofibular syndesmosis is stabilized by five structures:
- The anterior-inferior tibiofibular ligament (AITFL)
- The interosseous ligament (IOL)
- The transverse ligament (TL)
- The interosseous membrane (IOM)
- The posterior-inferior tibiofibular ligament (PITFL).

The deltoid ligament helps to stabilize the talus in the mortise and indirectly supports the syndesmosis by preventing lateral translation of the talus.

Depending on the magnitude of the external rotational force encountered, the syndesmosis and deltoid ligament sequentially fail in a predictive pattern:
- AITFL
- Anterior Deltoid Ligament
- IOL and TL
- IOM
- PITFL
- Then the full deltoid ligament, which can then lead to dislocation of the tibiotalar joint.
Purpose and Hypothesis

• The purpose of this study is to examine ankle joint kinematics and contact area distribution during axial loading and during axial loading with external rotation, in a cadaveric model.

• Our secondary objective is to measure fibular and talar displacement with increasing severity of syndesmotic injury with simulated weight-bearing.

• Our tertiary objective is to stratify mild (AITFL and/or anterior deltoid), moderate (IOL, TL, and/or PITFL), and severe (complete deltoid) syndesmotic injuries in terms of intra-articular force and contact biomechanics change with increasing injury severity.

• We hypothesize that progressive ligamentous syndesmotic injury will significantly:
  – Increase fibular and talar rotation
  – Increase syndesmotic widening
  – Increased tibiotalar contact pressure
  – Reduce contact area when undergoing axial loading with external rotation
Methods

• Eight below knee cadaveric specimens were obtained for testing (Mean Age: 54 ± 4 yrs, Range: 51 to 60 yrs, all male)

• Figure 1 illustrates the test set-up employed in the study

• Biomechanical testing was conducted on an Instron ElectroPuls E10000 (Instron Corporation, Norwood, MA) with a 10 KN, 100 Nm Dynacell biaxial load cell

• A motion capture system was used to identify landmark points on the tibia, fibula, and talus in order to define local bone coordinate systems

• Intra-articular tibiotalar pressure data was acquired using an I-SCAN pressure measurement system (software version 5.23) with model 5033 sensors (Tekscan Inc, South Boston, MA)

Figure 1: Photograph of experimental set-up used for mechanical testing. Motion trackers were rigidly attached to the tibia, fibula, and talus. Axial and torsional Loads were applied to the IM rod inserted into the proximal tibia.
Methods

- The eight below knee cadaveric specimens were tested in the intact state.
- The specimens were then tested after sequential sectioning of the anterior-inferior tibiofibular (AITFL), anterior deltoid (1 cm), interosseous and transverse (IOL/TL), posterior-inferior tibiofibular (PITFL), and full deltoid ligaments.
- In each condition, the specimen was loaded in axial compression (AL) to 700 N and then externally rotated (ER) to 20 Nm torque.

Table 1: Definitions of the 6 ankle conditions examined in the study.

<table>
<thead>
<tr>
<th>Test Condition</th>
<th>Ligaments Sectioned</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None (Intact State)</td>
</tr>
<tr>
<td>2</td>
<td>AITFL</td>
</tr>
<tr>
<td>3</td>
<td>AITFL, Ant. Deltoid</td>
</tr>
<tr>
<td>4</td>
<td>AITFL, Ant. Deltoid, IOL/TL</td>
</tr>
<tr>
<td>5</td>
<td>AITFL, Ant. Deltoid, IOL/TL, PITFL</td>
</tr>
<tr>
<td>6</td>
<td>AITFL, Full Deltoid, IOL/TL, PITFL</td>
</tr>
</tbody>
</table>

*Note that Condition 6 was not included in the analysis. See text for details.

- Paired t-tests were performed to compare mean contact pressure, peak pressure, and contact area.
- A mixed-effects regression was used to evaluate the effects of each test condition.
Results

- For each specimen, after complete deltoid release (i.e., condition 6), the ankle joint dislocated completely with even a small amount of external rotation and thus only conditions 1 through 5 are presented.
- During AL + ER testing, both the fibula and talus rotated significantly after each ligament sectioning compared to the intact condition (Figure 2A).
- After IOL/TL release, a significant increase in posterior translation of the fibula was observed (Figure 2B).
- There was no lateral translation of the fibula relative to the tibia during AL+ER relative to AL alone for any condition tested (Figure 2C).

Figure 2: (A) Rotation about the long axis and (B,C) axial plane translations of fibula and talus with respect to tibia during external rotation to 20 Nm with a constant axial load of 700 N for five ankle conditions. (Mean ± SD)
Results

- Mean tibiotalar contact pressure increased significantly after IOL/TL release, and the center of pressure shifted posterolaterally, relative to more stable conditions, after IOL/TL release (Figure 3).

- During AL+ER, the center of pressure (COP) shifted anteriorly and medially on the talus (Figure 5).

- The relative location of the center and pressure was posterior and slightly lateral in conditions 4 and 5, after the IOL/IOM and PITFL were sectioned, respectively.

**Figure 3:** Representative intra-articular tibiotalar pressure distribution during axial loading only and combined axial loading with external rotation. Images recorded during testing of condition 3.

**Figure 5:** (A) M-L and (B) A-P COP translations recorded by pressure sensors during external rotation to 20 Nm with a constant axial load of 700 N for five ankle conditions. (Mean ± SD)
Results

- There were significant increases in mean contact pressure and peak pressure along with a reduction in contact area with AL + ER compared to AL alone for all 6 conditions (Figure 4)

**Figure 4:** (A) Mean contact pressure, (B) peak pressure, and (C) contact area recorded by pressure sensors during axial loading only and combined axial loading with 20 Nm external Rotation for five ankle conditions. (Mean ± SD)
Conclusion

• Our study characterizes the magnitude and distribution of forces within the ankle joint during axial loading and external rotation in a cadaveric model of successive syndesmosis injuries

• We show:
  – A significant reduction in contact area and a significant increase in mean and peak pressure during axial loading and external rotation relative to axial loading alone in all testing conditions
  – Significant increases in tibiotalar contact pressures occur when external rotation stresses are added to axial loading
  – Moderate and severe injuries are associated with a significant increase in mean contact pressure combined with a shift in the center of pressure, and rotation of the fibula and talus

• Considerable changes in ankle joint kinematics and contact mechanics may explain why athletes with even moderate syndesmosis injuries take longer to heal and are more likely to develop long term dysfunction and potentially arthritic changes after these injuries

• This study suggests the importance of limiting rotational forces in the rehabilitation of moderate and severe syndesmosis injuries