An Anatomical Study on the Safe Placement of Orthopedic Hardware for Syndesmosis Fixation

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Abstract

Articular cartilage and bony contact at the distal tibiofibular cartilage contact zone (TFCCZ) is variable. The appropriate placement of syndesmotic hardware would benefit from a more accurate characterization of the proximal extent of the TFCCZ allowing surgeons to place hardware that simultaneously improves biomechanical stability and decreases the risk of iatrogenic cartilage damage. In addition, Ilizarov wire fixation through the distal fibula and tibia can pass through the syndesmosis recess. Anatomically defining the proximal extent of this recess can help decrease the risk of inadvertent capsular penetration. This study anatomically defines the TFCCZ and syndesmosis recess establishing a safe and biomechanically advantageous distance from the plafond for orthopedic fixation. This study measured the height of the TFCCZ and the syndesmotic recess in 3158 anatomical and cadaveric specimens. A TFCCZ was present in 59% of the Robert J. Terry Anatomical Collection specimens. Maximal height of the TFCCZ averaged 5.7±1.7 mm (99% confidence interval [CI], 5.6-5.8 mm) for anatomical specimens and 5.6±1.6 mm (99% CI, 4.6-6.5 mm) for cadaveric dissections. The maximum TFCCZ height was 11.71 mm. Maximal height of the syndesmotic recess averaged 12.8±2.1 mm for anatomical specimens and 13.7±2.7 mm for cadaveric specimens. The “3 cm rule” appears to be appropriate for fine wire fixation accounting for capsular distension that can be associated with injuries but not applicable for syndesmotic fixation. There is a less than 0.1% chance of encountering the TFCCZ cartilage at 10.9 mm above the plafond and a less than 0.01% chance at 12 mm above the plafond. [Orthopedics. 2017; 40(2):e329-e333.]
Cadaveric studies have elucidated important syndesmotic anatomical structures and boundaries including a distinct hyaline tibiofibular cartilage contact zone (TFCCZ) and a syndesmotic recess, described as a synovial fold of the distal tibiofibular articulation that extends proximally.4,6 Placement of surgical hardware within this area requires an understanding of the anatomical structures at risk for iatrogenic injury. For example, fine wire external fixation in the distal fibula should be located above the synovial-lined syndesmotic recess that extends up to 25 mm cranially to minimize the risk of septic arthritis. In addition, hardware placed at the level of the ankle joint risks injury to the TFCCZ (Figure 2).

Unlike the syndesmotic recess that is almost always present, the TFCCZ is highly variable; initial reports from 1891 described its presence in only 20% of tibial specimens.8 Although cadaveric studies have described the TFCCZ as 3 to 9 mm in length and approximately 2 to 5 mm in height, limited sample sizes have prevented the generation of formal recommendations to direct hardware placement that simultaneously increases biomechanical stability while decreasing the risk of iatrogenic cartilage damage.4,6 A large volume of specimens is therefore needed. This study used cadaveric and anatomical specimens to generate 3158 measurements for both the proximal extent of the TFCCZ and the syndesmotic recess to establish definitive anatomical borders promoting the standardization of protocols for the placement of orthopedic hardware traversing the syndesmosis (Figure 3).

**MATERIALS AND METHODS**

Review of the senior author’s private collection of anatomical tibia specimens revealed a smooth area within the incisura of the distal tibia (incisura fibularis tibiae) (Figure 3A). This smooth area corresponded to the previously described location of the TFCCZ and matched the area populated by articular cartilage in cadaveric specimens (Figure 3B).4,6 Because of nearly identical measurements of the height of the TFCCZ in these initial specimens, anatomical models were believed to be appropriate surrogates for cadaveric dissections, leading to the use of the Robert J. Terry Anatomical Collection at the Smithsonian Institution in Washington, DC.

The Terry Anatomical Collection is one of the most widely studied skeletal collections in the world and comprises 1728 complete skeletons with demographics previously published; the age at death ranged from 14 to 102 years.9 Tibiae specimens (n=3456) were evaluated for the presence or absence of a TFCCZ. A TFCCZ was considered present if a bony ridge at least 2 mm in height was identified, and the maximum height (mm) was measured from the tibial plafond using calipers (Neiko 01407A accurate to 0.02 mm; calibrated and zeroed following each measurement) (Figure 4). The maximum height of the syndesmotic recess was measured in a similar manner.

Both left and right tibiae were used; measurements were recorded as right or left including the specimen number (sex and race) and age in a statistical spreadsheet. Due to ankylosed joints (presumed infection and neuropathic changes), malunited fractures, above and below knee amputations, and damaged specimens with exposed cancellous bone, 323 tibiae specimens could not be used for measurements, leaving a total of 3133 final data points obtained for both the TFCCZ and syndesmotic recess.

All measurements were repeated in quadruplicate by the 2 lead authors (F.D.S., D.W.) in a blinded fashion for the first 250 specimens. An initial check of these measurements confirmed accuracy and identical technique. Following this initial data check, duplicate measurements of the remaining 1478 specimens were obtained in an identical manner.

To validate the use of the anatomical specimens as a surrogate for cadaveric dissections in TFCCZ and the syndesmotic recess measurements, limited cadaveric dissection was used. Following initial consultation with a biostatistician, 13 cadavers were used from the Human Gift registry at Marshall University. The
incisura of the distal tibia was exposed with measurements obtained as described by the 2 lead authors for 25 specimens (damage occurred to the TFCCZ in the first specimen, and this specimen was excluded from data analysis). Data were recorded as right or left including the sex and age of the specimen.

**Statistical Analysis**

A biostatistician determined statistical significance. Equivalences of left and right TFCCZ and left and right syndesmotic recess measurements were established by computing 99% confidence intervals (CI) for the left-right in each data set. All data are reported as mean±SD. All calculations were performed using R version 2.14 (www.r-project.org).

**RESULTS**

A TFCCZ was present in 59% of the Terry Anatomical Collection specimens and absent in 41%. The maximal height of the TFCCZ averaged 5.7±1.7 mm (99% CI, 5.6-5.8 mm) for anatomical specimens and 5.6±1.6 mm (99% CI, 4.6-6.5 mm) for cadaveric dissections. The maximal height of the syndesmotic recess averaged 12.8±2.1 mm for anatomical specimens and 13.7±2.7 mm for cadaveric specimens (Table). Six anatomical specimens had TFCCZ measurements greater than 10 mm in height, with the maximum measurement being 11.71 mm. Seven anatomical specimens had syndesmosis recess measurements greater than 19 mm in height, with the maximum measurement being 19.51 mm. There were no statistically significant differences between the right and left TFCCZ and syndesmotic recess measurements in either anatomical or cadaveric specimens.

To test for equivalence of the data between the anatomical and cadaveric specimens, a level of equivalence of 2.5 mm was established, and the 99% CI for the difference between mean TFCCZ height and mean syndesmotic recess height was computed. The 99% CI was -1.05 mm.

**Table**

<table>
<thead>
<tr>
<th>Specimen</th>
<th>TFCCZ</th>
<th>Syndesmotic Recess</th>
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</thead>
<tbody>
<tr>
<td>Anatomical (n=3133)</td>
<td>5.7±1.7</td>
<td>12.8±2.1</td>
</tr>
<tr>
<td>Cadaveric (n=25)</td>
<td>5.6±1.6</td>
<td>13.7±2.7</td>
</tr>
</tbody>
</table>

Abbreviation: TFCCZ, tibiofibular cartilage contact zone.

**Figure 3:** Photographs showing the incisura fibularis tibiae in an anatomical specimen (A) and a cadaveric dissection (B). The smooth area in the anatomical specimen corresponds to the area populated by articular cartilage in the cadaveric dissection. Statistical analysis following the measurement protocol in this study demonstrated that the use of anatomical specimens to measure tibiofibular cartilage contact zone is a validated proxy for cadaveric dissections.

**Figure 4:** Photograph showing an anatomical specimen (A). The location of the tibiofibular cartilage contact zone (TFCCZ) (yellow shaded area) and the syndesmosis recess (white shaded area) are identified on the same anatomical specimen (B). The maximal height in mm was recorded for each structure.
to mean TFCCZ height (cadaveric specimens – anatomical specimens), and the 99% CI was -0.55 mm to 2.43 mm for the difference between syndesmotic recess height. In both cases, the difference between means fell within the region of equivalence of 2.5 mm, indicating no statistical difference between the cadaveric and anatomical data sets. This supports the assertion that the anatomical specimens served as an acceptable proxy for cadaveric specimens.

**DISCUSSION**

Bartoníček⁴ noted direct syndesmotic contact in 23 of 30 specimens, with a hyaline cartilage contact ranging from 2 to 5 mm in height and 3 to 9 mm in width. The syndesmotic recess also has been noted as a highly variable synovial fold extending 4 to 25 mm proximally from the tibial plafond.⁶ Although many anatomical studies have confirmed the presence of these 2 structures, no previous studies have provided detailed measurements of these entities for a large sample to account for the variability reported in limited data sets. Because the TFCCZ is composed of hyaline articular cartilage, iatrogenic cartilage damage can occur with syndesmotic fixation. The syndesmotic recess is concurrent with the synovial lining of the ankle articulation and must be avoided to decrease the risk of septic arthritis of the ankle when placing fine wires in fixation techniques, thus necessitating an accurate estimate of its extent.⁷

This anatomical study clearly mapped the distal TFCCZ and syndesmotic recess as a function of distance from the tibial plafond. This study confirmed the report that the TFCCZ is not always present (absent or <2 mm in 41% of anatomical specimens). In addition, the findings of this study also established that the TFCCZ extends an average of 5.7 mm above the plafond, with a less than 0.1% chance of finding a TFCCZ above 10.9 mm. There is a less than 0.01% chance the TFCCZ extends more than 12 mm in height and should be used as the optimal location for placement of syndesmotic fixation (Figure 5). With these data and the observation that no TFCCZ was more than 12 mm in height, the “3 cm rule” therefore does not appear to provide an appropriate level for syndesmotic fixation that simultaneously increases biomechanical stability while decreasing the risk of TFCCZ cartilage penetration (Figure 5).

In addition, on average the highly variable syndesmotic recess height was established with the maximal height measured at 19.51 mm. It is important to note that it was expected the anatomical measurement of the syndesmotic recess would underestimate the maximal height generated during injuries or magnetic resonance arthrogram protocols due to capsular distension. Therefore, since the previously reported maximal syndesmotic recess height was 25 mm, this measurement should be used for fine wire fixation with the previous “3 cm rule” applicable.

Strengths of this study include the large sample size and statistical validation that anatomical specimens can be used as a proxy for cadaveric dissections. In addition, the large number of specimens used to generate the 3158 measurements for each structure provided sufficient power to accurately describe these anatomical structures. Weaknesses of this study include a potential for sampling error due to the demographics of the Robert J. Terry Anatomical Collection, which included a wide variety of ethnicities and socioeconomic variability and may not be truly representative of the current population. However, the statistically consistent data with cadaver dissections argues against this as a weakness.

With these anatomical landmarks identified, future research can be aimed at determining whether it is clinically advantageous to place hardware closer to the plafond in this defined safe zone, with optimal placement appearing to be 12 mm above the plafond for syndesmotic fixation. McBryde et al⁸ noted a distinct biomechanical advantage in cadavers by moving syndesmotic screws from 3.5 cm from the plafond to 2 cm from the plafond; it is anticipated that moving screws to 1 cm above the plafond would provide an additional advantage. However, this will require formal testing protocols. In addition, due to the variability of the TFCCZ combined with some surgeons placing hardware close to the plafond using the “3 cm rule,” this study provides a foundation for additional clinical outcome protocols to elucidate whether more distal hardware placement is associated with increased incidence of early osteoarthritis.

**CONCLUSION**

This study clearly defined the proximal TFCCZ and syndesmotic recess. In addi-
tion, anatomical specimens were validated statistically as a proxy for cadaveric dissection for these measurements. The “3 cm rule” appears to be appropriate for fine wire fixation, accounting for capsular distension that can be associated with injuries but not applicable for syndesmotic fixation that can be placed closer to the joint.

REFERENCES


