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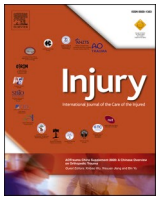

Intraoperative assessment of syndesmotic instability: What technique minimizes surgeon error?

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ABSTRACT

Background: Assessment of intraoperative syndemsotic instability remains a controversial topic. To date, no study has directly compared 5 available methods.

Materials and Methods: The purpose of the present study was to assess the reliability of five stress assessment methods (Cotton Hook, External Rotation, Arthroscopic, Direct Palpation, and Direct Visualization) across various syndesmotic injury conditions (ventral disruption, 2-ligament injury, and 3-ligament injury) in an in-vitro model. It was hypothesized that the Cotton Hook (CHT) and External Rotation (ER) methods would be the least reliable. A cadaveric model of syndesmotic injury was employed in eight through the knee specimens and assessments were performed.

Results: Overall, direct visualization was most reliable for discerning syndesmotic disruption, irrespective of the injury condition ($p = 0.01$). Arthroscopic assessment was reliable in 2 and 3-ligament injury conditions ($p < 0.05$); while Cotton Hook and External Rotation were reliable in 3-ligament injuries ($p = 0.01$, $p = 0.04$). Arthoscopic, Cotton Hook, and External Rotation assessment(s) were unreliable for discerning isolated ventral disruption (anterior inferior tibiofibular ligament).

Conclusions: In the present cadaveric model, direct visualization of the anterolateral articular surface of the ankle was the most reliable method for discerning syndesmotic injury. Discontinuity of the articular surface between the anterolateral tibia and anteromedial fibula was readily identified in all injury conditions. Surgeons should be cognizant of the inherent subjectivity, and limited reliability of historically popularized syndesmotic stress assessment methods.

Level of Evidence: Level V, cadaveric

Introduction

Few topics in the foot and ankle have garnered as much attention, and controversary as the distal tibiofibular "ankle" syndesmosis. Once thought of as an "all or nothing" phenomenon, syndesmotic injury is now better understood to represent a spectrum of ligamentous disruption, with involvement portending a poorer prognosis[1–2]. The incidence of syndesmotic injury has varied widely in the literature, owing in part, to the inherent subjectiveity and known limitations associated with historically popularized intraoperative stress assessment methods, specifically the Cotton Hook (CH) and External Rotation (ER)[3–5]. Nonethless, syndesmotic injury has been reported in 20 to 90 % of ankle fractures requiring fixation, and a focus on the quality of the reduction has been emphasized by multiple authors[6–14].

The inherent subjectivity and limitations of the aforementioned syndesmotic stress assessment methods relying on intraoperative fluoroscopy (CH, ER) has been previously reported, and is well understood. As a result, arthroscopic stress assessment has supplanted both methods in recent years as the accepted "gold standard" for discerning syndesmotic instability in 2 and 3-ligament injury conditions. However, variability in the technique has been published (3 mm vs 4 mm probe, hook pull angled anterior vs. lateral vs posterior), and no consensus has been reached[15–16]. It remains unclear if any available method reliably assesse's the ventral component of the syndesmosis, the anterior inferior tibiofinbular ligament (AITFL), an important stabilizer against external rotation and a potential source of pain generation[17–19]. Nonetheless, many surgeons reliance on two aforementioned, indirect, assessment methods (CH, ER) has continued; despite the research.

Miller et al and Tornetta et al previously proposed an alternative open, direct, assessment technique. The technique was purported to be both more accurate, and reliable[20–21]. However, no previous in-vitro study has sought to validate the findings. The purpose of the present

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study was to assess the reliability of five stress assessment methods (Cotton Hook, External Rotation, Arthroscopic, Direct Palpation, and Direct Visualization) across various syndesmotic injury conditions (ventral disruption, 2-ligament injury, and 3-ligament injury) in an in-vitro model. It was hypothesized that the Cotton Hook (CHT) and External Rotation (ER) methods would be the least reliable. A cadaveric model of syndesmotic injury was employed in eight through the knee specimens and assessments were performed

Materials and methods

Specimen preparation

Eight through the knee lower extremity cadaver limbs (4 specimens) without a history of prior trauma, surgery, or radiographic abnormality were procured (Universty of Texas Southwestern Medical Center, Willed Body Program, Dallas, TX). The proximal tibiofibular joint(s) were intact in all specimens, which were defrosted from -30 ° Celsius at room temperature prior to testing. Three male, and 1 female specimens with an average donor age of 54 years (range, 45 to 68) were used. For each specimen, soft tissue directly overlying the malleoli, and syndesmosis was sharply removed 10 cm proximal to the ankle; periarticular ligaments, and non-ligamentous soft tissues (muscles, tendons) were left intact (Fig 1). The anatomical location of the distal tibiofibular syndesmosis was marked before disruption using a 1.6 mm Kirschner wire (K-wire) placed lateral to medial, adjacent to the anterior edge of the fibula, 1 cm proximal to the ankle joint. The wire was then removed, leaving a mark laterally for the planned assessments.

The present study protocol created a total of 20 primary assessments for each specimen (160 assessments in total); 4 syndesmotic conditions: 1) Intact, 2) ventral injury, 3) 2-ligament injury, and 4) 3-ligament injury assessed using 5 methods (CH, ER stress, Arthroscopic, Direct palpation, and Direct visualization). To simulate injuy, the ankle syndesmosis was destabilized by sequentially sectioning the anterior inferior tibiofibular ligament (AIFTL) for isolated ventral injury, the distal 10 cm of the interosseous ligament (IOL) for the 2-ligament injury conditions, and the posterior inferior tibiofibular ligament (PITFL), and inferior transverse tibiofibular ligament (ITFL) for the 3-ligament injury condition[11]. To simulate complete syndesmotic injury, an osteotome was inserted between the tibia and the fibula to impose a 5-mm syndesmotic gap, resulting in plastic deformation, which was maintained for a period of 2 minutes. The proximal IOL, also referred to as the interosseous membrane was not sectioned, as a prior cadaveric study demonstrated no correlation between the structures proximal sectioning and coronal stability of the syndesmosis. Non-ligamentous soft tissues (muscles, tendons) in proximity, as well as the deltoid ligament (deep, superficial) were also left intact for all conditions, to most closely simulate the in-vivo operative condition(s) following fracture fixation and deltoid ligament repair; prior to syndesmotic stress assessment.

For each condition, a single fellowship trained, podiatric surgeon performed each syndesmotic stress assessment method. The methods included: 1) CH test performed 5 cm proximal to the ankle under fluoroscopy using a digital force gauge (M&A Instruments, Arcadia, CA) to ensure the applied force did not exceed 100 N, 2) Manual ER stress under fluoroscopy, 3)Arthroscopic stress using a 4 mm probe for interposition between the tibia and fibula proximally within the tibial incisura, 4) Direct palpation of the syndesmotic congruence at the incisura 1 cm proximal to the ankle, and 5) Direct visualization of the articular surface congruence between the anterolateral tibial and anteromedial fibula [21]. The distal aspect of the AITFL, and it's inferior fascicle (Bassetts ligament") when present, pass directly over the point of assessment for congruity between the tibia and fibula (Fig 2). Fig. 3 depicts congruity versus incongruity of the antoerlateral aritcular surface. For the direct palpation and visualization methods, only the anterior incisura, or anterolateral plafond was visualized while the other was covered to preclude simultaneous assessment Syndesmotic instability was recorded, (yes or no). The surgeon was not allowed to repeat a competed stress assessment on the same specimen. Stress assessment accuracy was recorded on a password protected database by an independent study assistant.

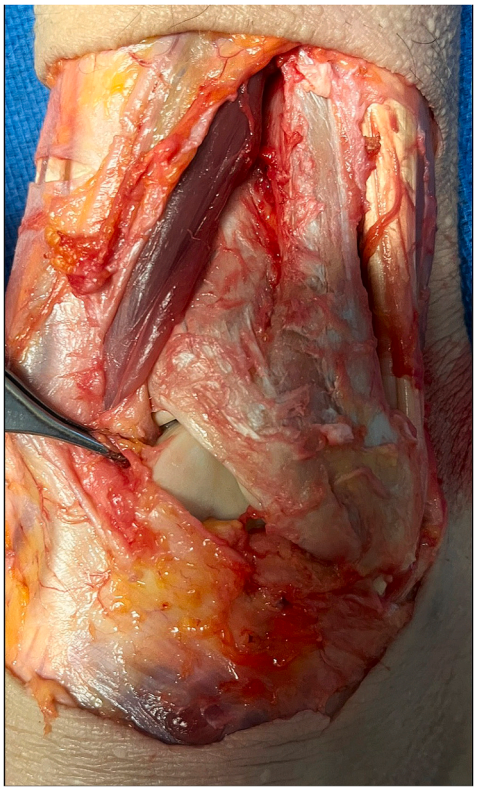

Fig. 1. Image depicting specimen preparation after removal of soft tissue directly overlying the malleoli and syndesmosis 10cm proximal to the ankle; periarticular ligaments, and non-ligamentous soft tissues (muscles, tendons) were left intact.

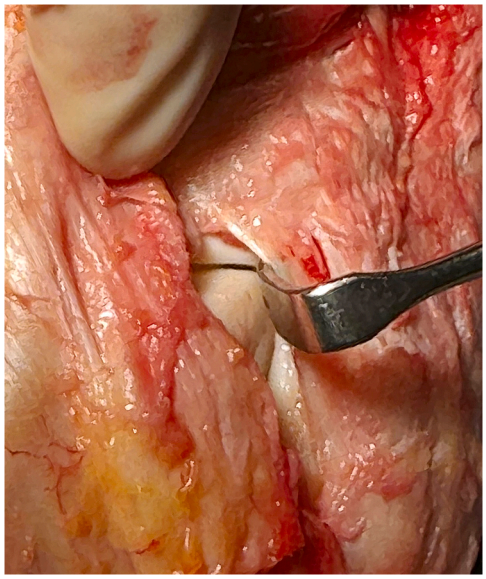

Fig. 2. Direct visualization of the anterolateral articular surface congruity is obscured by the distal aspect of the AITFL and it's inferior fascicle (Bassetts ligament).

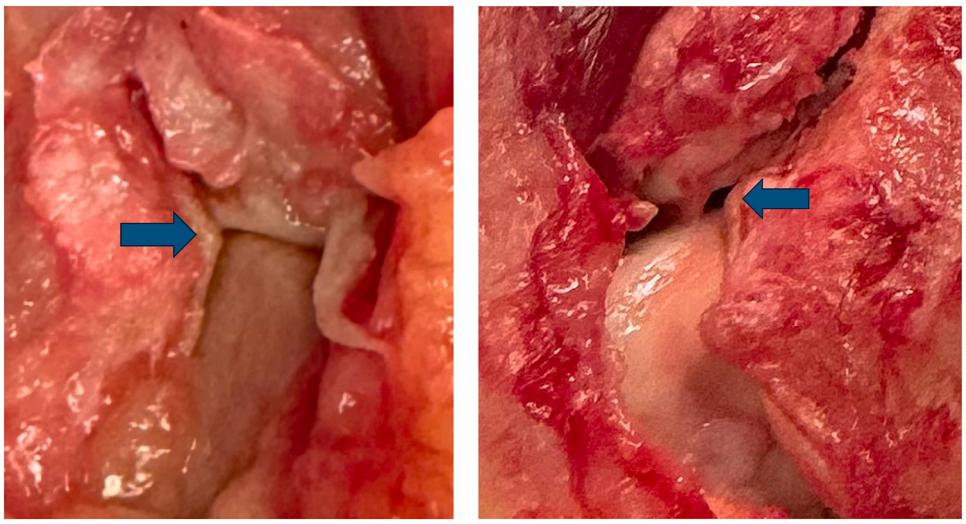

Fig. 3. A-B: images depicting A) congruity and B) incongruity of the anterolateral articular surface using the direct visualization method for syndesmotic assessment.

Statistical analysis

All data sets were reviewed for outliers, missing, and incomplete data. Simple descriptive analyses and paired T-tests were conducted. Differences in the accuracy of each assessment method was assessed using Fisher Exact test where statistical significance set at $p < 0.05$.

Results

Conditions 1 and 2: Intact vs. AITFL sectioned

All assessement methods were negative in the intact state. After sectioning of the AITFL, the DP and DV methods allowed for identification of isolated ventral injury in 6 out 8 (n = 75 %), and 8 out of 8 (n = 100 %) specimens, respectively ($p < 0.05$). The lack of concordance between the methods occurred in a single specimen (2 limbs), where DP was less accurate than DV of the articular surface congruence. The false negative rate for DP for condition 2 was 25 %. In contrast, the CH, ER, and AS assessment methods were unable to detect isolated ventral injury for any specimen(s); false negative rate of 100 %.

Condition 3: AITFL and IOL's sectioned (2- Ligament injury)

The 2-ligament injury condition was simulated by additional sectioning of the IOL and distal 10 cm of the IM. The DP and DV methods allowed for identification of injury in all 8 specimens, with complete conconrdance ($p < 0.05$). The reliability of AS changed in the 2-ligament injury condition, and identification of injury was recorded in 7 out of 8 specimens, and the difference was significant ($p < 0.05$). As with the isolated injury condition, the CH and ER methods failed to identify injury in any specimen (0 out of 8 specimens).

Condition 4: Complete Disruption (3- Ligament injury)

The 3-ligament injury condition was simulated by sectioning of the enitre syndesmosis complex, which included the PITFL/Inferior Transverse Tibiofibular Ligament(s). For the 3 ligament injury condition, injury indentification was recorded in all specimens when assessed using DP, DV, and AS ($p < 0.05$). As with the isolated ventral and 2-ligament inury condtions, DV was the most reliable assessment method for injury indentiifcation ($p = 0.01$). In contrast to the previous conditions, injury identification was recorded when assessed using the CH (4 out of 8 specimens) and ER (3 out of 8 specimens) assessment methods. The difference in the reliability of both methods improved compared to the previous injury conditions (CH, $p = 0.01$ / ER $p = 0.04$). However, injury identification was not identified in approximately half of specimens.

Discussion

To the authors knowledge, the present study is the first to compare the reliability of 5 syndesmotic stress assessment methods across various injury conditions (AITFL, AITFL + IOL, Complete Disruption) in an in-vitro model. Based on the literature, the author hypothesized that historically popularized, "indirect" assessment methods (CHT, ER) would be less reliable for discerning syndesmotic disruption compared to alternative "direct" methods; irrespective of the injury condition. A cadaveric model of syndesmotic injury was employed in eight through the knee specimens, and assessments were performed.

Overall, the present study identified differences in the reliability for both indirect and direct syndesmotic assessment methods, across various injury conditions. Direct assessment (visualization, palpation, arthroscopic) in general, was more reliable for discerning syndesmotic injury compared to historically popularized indirect assessments (CH, ER); confirming the hypothesis. Both indirect methods were unreliable in isolated and 2-ligament injury condtion(s). In 3-ligament injury condition, the reliability of both methods improved (CH $p = 0.01$ / ER $p = 0.04$); however, injury was still only identified in approximately half of the specimens (CH- 4 out of 8 specimens, ER- 3 out of 8 specimens). During the indirect assessment(s), it was clear both methods were hindered by intact medial/lateral ligament complex's. Without laxity/disruption of the superficial deltoid ligament(s) and/or anterior talofibular (ATFL), the medially tethered talus may preclude frank fibular diastasis and/or medial clearspace opening; even in simulated 3-ligament injury coniditons. Although the propagation sequence(s) of sydemsotic injury is without consensus, the findings nonetheless lend credence to the published literature on the limitation(s) of both popularized indirect methods.

Direct visualization of the articular surface congruity between the anterolateral tibia and anteromedial fibula, and direct palpation of the tibiofibular congruence at the level of the syndesmossis were the two most reliable methods for discerning injury; irrespective of the condition. Concordance between the direct assessments was recorded for all but 1 specimen, where intuitively, the subjectivity of palpating for congruence resulted in a "false negative" assessment. Expectantly, arthroscopic assessment was reliable in 2 and 3 ligament injury

conditions, but not isolated ventral injury. Without injury propagation to the IOL, insertion of a 3–4 mm probe within the incisura and subsequent diastasis is hindered. It is important that longitudinal traction (common with non-invasive distractors) be avoided to the foot in order to prevent a "false negative", secondary to tensioning of the lower lateral ankle ligament complex which pulls inward on the distal fibula; resisting any diastasis between it and the tibia. Surgeons utilizing noninvasive distraction should loosen the distraction prior to arthroscopic assessment, or alternatively utilize gravity distraction. It is unclear how alternative techniques would compare to the method employed in the present study. Nonethless, the findings of the present study support the conclusions of Miller et al and Tornetta et al who first proposed an open, direct, assessment technique[20–21].

The findings of the present study should be interpreted with consideration to several limitations. First, an in-vitro model and sequential sequentioning of syndesmotic ligaments was employed for the purposes of the study to simulate an in-vivo inury condition. While the propagation sequence of syndesmotic injury may involve the superficial deltoid ligament, intraoperatively, syndesmotic stress assessment and subsequent repair (when indicated) are typically performed after global stabilization of the ankle. Syndesmotic injury is known to occur more frequently in bi-and tri-malleoalr ankle fractures compared to isolated injury. Therefore, in this in-vitro model, no fractures were created and the deltoid ligament complex was left intact to most closely simulate the injury condition encountered intraoperatively by surgeons. Intuitively however, the injury conditions and thus results are not generalizable to all scenarios. Second, all assessments were performed by a single, board certified (American Board of Foot & Ankle Surgery, ABFAS), fellowship-trained, podiatric surgeon. The original study protocol included other podiatric surgeons; however, for various reasons including airline/travel cancellations due to inclement weather on the day of the study, the decision was made to proceed with an alternate protocal, prepared in case of such occurences. The author is not a consultant or designer for the study sponsor (Fuse Medical LLC, Dallas, TX), and no monetary support was recieved for the completion of the study; ie no commercial biases. Ideally, future study(s) will involve multiple participants, a greater number of specimens, and randominization methods. Finally, the results of any invitro study cannot be directly extrapolated to the in-vivo condition(s). As with most research, additional research is warranted to lend credence to, or refute the findings of the present study.

In the present cadaveric model, direct visualization of the articular surface congruity between the anterolateral tibia and anteromedial fibula was the most reliable method for discerning syndesmotic injury. Discontinuity of the articular surface was readiy identified in all injury conditions; including isolated ventral injury. Arthroscopic assessment was reliable in 2 and 3-ligament injury conditions; while historically poplularized methods (CHT, ER) were reliable in 3-ligament injuries. Surgeons should be cognizant of the inherent subjectivity, and reliability of indirect syndesmotic assessment methods. The author recommends direct assessment of the syndesmosis (direct visualization, direct palpation, arthroscopic) intraoperatively for discerning syndesmotic injury.

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Ethics/Informed consent

Informed consent was not applicable for the in-vitro model.

Consent for publication

Not applicable for the in-vitro model.

Availability of data and material

All data generated or analyzed during this study are included in this published article

CRediT authorship contribution statement

Calvin J. Rushing: Writing – review & editing, Writing – original draft, Visualization, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

Design Surgeon, Royality Bearing. Fusion Orthopedics, Mesa, AZ 85212.

Patent US11,185,385- Issued November 30, 2021.

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