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Compression Across the Posterior Facet Comparing Two Extraarticular Screw Orientations: A Cadaveric Study

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Introduction

Subtalar Joint Arthrodesis (SJA) is commonly utilized for a variety of foot and ankle pathologies, including trauma, reconstruction, and arthritic conditions. Originally described by Grice et al., this procedure can be performed in isolation or in conjunction with other procedures for the lower extremity [1]. The nonunion rates of subtalar joint arthrodesis can vary with reported nonunion rates ranging from 0%-44% [2-10]. Given the large range of nonunion rates, several authors have discussed various fixation techniques including different screw configurations and number of screws [11-18]. Additionally, other studies have evaluated the biomechanical properties of varying fixation techniques to optimize the arthrodesis success rates [19-27]. While single screw fixation for isolated arthrodesis of the STJ has been shown to be successful, there is still the possibility of rotational forces occuring across the arthrodesis site, thus hampering fusion consolidation.

Two-screw or three-screw fixation can add an anti-rotational component but can offer its own challenges. One of the challenges that surgeons face is the potential difficulty with placement of multiple screws is the close proximity of the screws across the posterior facet of the subtalar joint. Increased screws across the posterior facet could also lead to less fusion consolidation. Thus, a second screw may be needed to be placed outside of the articular surface of the posterior facet. The purpose of this study is to evaluate the compression across the posterior facet of the STJ with two different screw placements that are adjacent to the posterior facet.

Materials and methods

Three fresh frozen below the knee cadaver specimens were utilized for this study. The limbs were stored at -20̊C and subsequent preparation and testing was done after specimens had been thawed to room temperature. The specimens were examined for any indications of previous surgeries that could affect testing and none were identified. Soft tissue dissection was performed to remove the superficial structures of the rearfoot and ankle and to assist in placement of the super-low film and the compression screws. The medial and posterior ligamentous structure were preserved as best as possible. None of the specimens were found to have any degenerative changes of the subtalar joint or any anatomic pathology that could affect testing (Figure 1).

For each specimen, the testing consisted of cutting fujifilm prescale super low film to the approximate shape of the specimen's posterior facet of the STJ. The film was then carefully sealed to ensure no liquid would contact the film per the manufacturer's instructions. For each of the specimens, two 6.5 mm compression screws would be placed separately. The first screw would be placed outside of the posterior facet from the posterior-inferior calcaneus to anterior-superior talar neck. After testing, the first screw would be removed, and the second screw would be placed extraarticular from the plantar calcaneus to the superior talar neck (Figure 2).

The posterior calcaneal to interior tailor 6.5 mm cannulated partial-threaded compression screw was inserted by the following surgical technique. A 3.2 mm guide wire was placed from the posterior inferior aspect of the calcaneus. Direct visualization of the posterior facet confirmed that the guidewire did not penetrate the posterior facet. The film was then carefully placed and secured within the posterior facet. The guide wire was advanced into the superior aspect of the talar neck region. The tip of the guide wire was directly visualized to ensure proper positioning. A small incision was made adjacent to the guide wire at the posterior aspect of the calcaneus. Dissection was deepened to the cortex and a depth gauge was used to determine the proper screw length. The guide wire was advanced slightly so a clamped hemostat could ensure the guide wire was not removed with drilling for the screw. The specimen was secured in place and the under drill was performed. A 6.5 mm partially threaded compression screw was placed along the guidewire. The screw was tightened to 4.5 N/m using a torque screwdriver. The compression screw and the guidewire were removed. The film was carefully removed from the posterior facet, labeled, and set aside in a clean and dark cabinet.

Next the plantar calcaneal to superior-talus 6.5 mm cannulated partial-threaded compression screw was inserted by the following surgical technique. A 3.2 mm guide wire was placed from the plantar aspect of the calcaneus just anterior to the posterior facet. Direct visualization of the posterior facet confirmed the guidewire did not penetrate the posterior facet. The film was then carefully placed and secured within the posterior facet. The guide wire was advanced into the superior aspect of the talar neck region. The tip of the guide wire was directly visualized to ensure proper positioning. A small incision was made adjacent to the guide wire at the plantar aspect of the calcaneus. Dissection was deepened to the cortex and a depth gauge was used to determine the proper screw length. The guide wire was advanced slightly so a clamped hemostat could ensure the guide wire was not removed with drilling for the screw. The specimen was secured in place and the under drill was performed. A 6.5 mm partially threaded compression screw was placed along the guidewire. The screw

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was tightened to 4.5 N/m using a torque screwdriver. The compression screw and the guidewire were removed. The film was carefully removed from the posterior facet, labeled, and set aside in a clean and dark cabinet. After testing of each specimen was complete, each of the Super Low films were scanned into a PC using an Epson Perfection V370 Scanner. The films were analyzed for average pressure, maximum highest pressure, and pressed area using fuji film FPD-8010E Version 2.5.0.2 software for windows.

Figure 1: Exposure of the posterior facet of the subtalar joint.

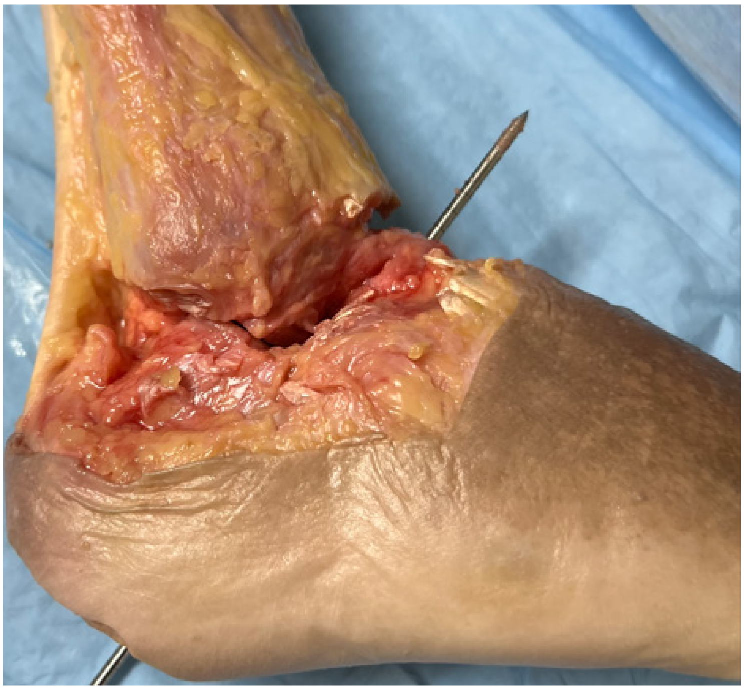

Figure 2: Example of the location of the guide wire for the placement of the posterior-inferior to talar neck screw.

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Results

The results of the study are listed in Table 1. The average MPA for the posterior-inferior to dorsal superior screw was 0.71 mpa (range 0.60-0.81). This converts to 71 N/cm². The average MPA for the plantar-inferior to dorsal superior screw was 0.73 mpa (range 0.71 mpa-0.75 mpa). This converts to73 N/cm2. Two-tailed P-value is 0.8185 showing no statistical significance between the two screws (Figure 3).

The highest maximum pressure across the posterior facet of the subtalar joint for the posterior inferior calcaneal screw was 1.53 mpa (range 1.16 mpa to 1.99 mpa). While the highest maximum pressure was 1.41 mpa across the posterior facet for the plantar inferior calcaneal screw (range 1.38 mpa-1.46 mpa). Two-tailed P-value is 0.6886 show--ng no statistical significance between the two screws.

The average pressed area for the posterior screw was 55.0 mm² of the posterior facet of the subtalar joint (range 4 mm²-77 mm²). The average pressed area of the posterior facet for the plantar screw was 22.6 mm² (range 1 mm²-69 mm²). The posterior screw resulted in a 43.6% increase in pressed area of the posterior facet compared to the plantar screw (Figures 4 and 5).

Second screw placement location	Average pressure (mpa)	Highest max pressure (mpa)	Pressed area (mm²)
Posterior-inferior calcaneus to talar neck (specimen 1)	0.81	1.99	77
Posterior-inferior calcaneus to talar neck (specimen 2)	0.72	1.16	33
Posterior-inferior calcaneus to talar neck (specimen 3)	0.6	1.43	55
	Average pressure (mpa): 0.71	**Average max pressure (mpa): 1.53**	**Average pressed area (mm²): 55.0**
Plantar calcaneus to dorsal talus (specimen 1)	0.71	1.4	69
Plantar calcaneus to dorsal talus (specimen 2)	0.75	1.38	13
Plantar calcaneus to dorsal talus (specimen 3)	0.72	0.46	31
	Average pressure (mpa): 0.73	**Average max pressure (mpa): 1.41**	**Average contact area (mm²): 37.7**

Table 1: Scanned super-low fujifilm comparing the results of the five cadaveric specimens with two different screw fixation techniques.

Figure 3: Example of the location of the guide wire for the placement of the plantar calcaneal to dorsal talus screw.

Figure 4: Location of the dorsal screw on the talus.

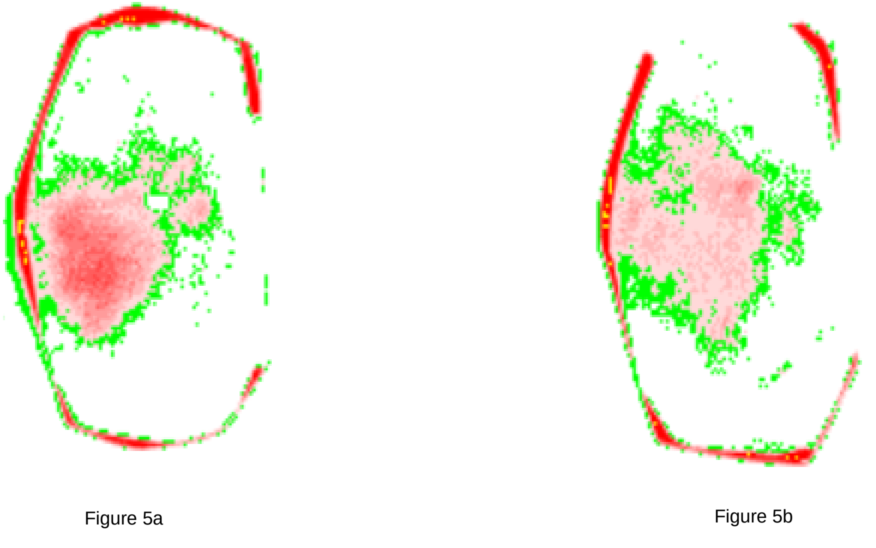

Figure 5: Super-low film testing of the compression of the posterior facet. 5a: Posterior-inferior to talar neck screw. 5b: Plantar calcaneal to dorsal talus screw.

Discussion

Subtalar joint arthrodesis is a common procedure for a multitude of foot and ankle pathology. Whilst a common procedure, there are some technical variations for the surgeon that can include the number of screws and location of screw placement.

Decarbo et al., performed a retrospective to determine if single-screw fixation is a predisposing factor to nonunion of a STJ arthrodesis [8]. They reported on isolated STJ arthrodesis performed in 113 patients. Single screws were used in 78.8% of the fusions and two screws were used in 21.2% of the fusions. Nonunion rates were found in 14.6% of the single-screw and 25.0% of the 2-screw fusions. The authors concluded that single-screw fixation does not predisposes STJ fusions to nonunion and that the motion occurring from single-screw fixation may not be significant enough to directly affect the rate of union. Haskell et al., showed similar success with their single screw fixation technique [13]. One hundred-one isolated subtalar arthrodesis using a technique of single 7.0 mm lag-screw fixation and the use of autograft. The reported union rate was 98% and other factors, including smoking, revision surgery, patient age, and patient gender, did not affect time to fusion.

Boffeli and Reinking retrospectively reviewed a 2-screw construct on higher risk patients for a nonunion [2]. The high-risk patient cohort included diabetics, smokers, and those undergoing revision of failed fusion. There 2-screw approach consisted of a primary compression screw placed through the posterior facet and a secondary stability screw is placed from the plantar lateral aspect of the anterior calcaneus into the head or neck of the talus. Of their fifteen high-risk patients, 10 weeks postoperatively radiographs identified a 100% fusion rate and no significant complications. They authors believe that one of the advantages of their fixation technique is to optimize the bone surface of the posterior facet to incorporate into an osseous union.

Wirth et al., performed a retrospective analysis of 113 patients with an isolated subtalar fusion comparing 2-screw versus 3-screw fixation [21]. The revision rate was required in six of the 36 (8%) 3-screw-fixation and thirty-five of the 77 (38%) for the 2-screw fixation. The 3-screw fixation non-union rate was observed in 14% compared to 35% with the 2-screw fixation. The authors concluded that the use of three screws increases the likelihood of successful arthrodesis of the STJ.

Given the continued debate of the number of screws used for surgical procedures, there have been several biomechanical studies to evaluate the variety of surgical procedures. Chuckpaiwong et al., simulated multiple screw fixation techniques for a STJ arthrodesis in 42 cadaveric speciemns [24]. The various fixation techniques included a single talar neck screw, a single talar dome screw, double parallel screws, or double diverging screws. As an aside they also isolated the location of the single talar dome screw with placement of the tip of the screw in the anteromedial, posteromedial, anterolateral, or posterolateral dome. Biomechanical properties that were studied included joint compression, construct torsional stiffness, and joint angulation under torsional load. The results showed an increased compressive force, torsional stiffness, and joint rotation resistance with double screw fixation compared to single screw fixation. Double diverging screws torsional resistance was twice as high compared to parallel screws in internal rotation. The single talar neck screw showed greater internal rotation and when looking at the specific locations of the single screw into the talus, there was greater external rotation with an anterolateral talar dome screw compared to the other single-screw orientations. Additionally, an increase in rotation in both directions was noted with the single screw tip located in the posterolateral talar dome. The authors concluded that double diverging screws confer the highest compression, the greatest torsional stiffness, and the least joint rotation and in the case of a single screw, placement of the screw tip in the talar neck or lateral talar dome should be avoided.

Hungrerer et al., evaluated various methods of fixation for STJ arthrodesis in an artificial bone model and cadaver model [25]. The authors' evaluated different screw configurations in terms of their rotational and bending stability in an artificial bone model and cadaver bone. Regardless of the screw alignment, two screws were utilized for the arthrodesis. The screw configurations that the authors' tested included parallel, counter-parallel, and a delta configuration. The parallel screw configuration involved two screws placed from the posterior aspect of the calcaneus into the dorsal-anterior talus. The counter-parallel screw configuration placed one of the screws from posterior to superior and the second screw from the dorsal talus into the posterior calcaneus. The delta configuration fixation involved one screw placed from the posterior calcaneus across the posterior facet into the dorsal talus and the second screw placed from the dorsal talus into the plantar calcaneus but anterior to the posterior facet. The also evaluated various screw sizes and types of screws, however, increasing the screw diameter from a 6.5 mm to 8.0 mm showed no additional stability. The delta configuration was found to provide the greatest biomechanical stiffness and the lowest degrees of deflection of the arthrodesis. The authors concluded that the delta configuration for arthrodesis results in the greatest construct stiffness and lower relative deflection between the talus and calcaneus in the positions assessed.

Matsumoto et al., studies the 2-screw versus 3-screw concept with ten cadavers as well as different 2-screw orientation. The subtalar joints were fixated with three different screw orientation. The first pattern consisted of two diverging posterior screws in which one screw was directed into the talar dome, the other screw into the talar neck. The second pattern was two parallel posterior screws both ending in the talar dome. The third pattern was the 3-screw fixation with two parallel screws with an additional anterior screw inserted from the plantar calcaneus into the talar neck. The reported mean compression of the two diverging posterior screws was 246 N, two parallel posterior screws 294 N, and augmentation of that construct with a third, anterior screw increased compression to 345 N.

The purpose of the current study was to evaluate the contact pressure across the posterior facet of the subtalar joint when the second screw is placed outside of the posterior facet. The authors of the current study advocate the use of 2-screw fixation and have often utilized the plantar calcaneal to superior talar screw especially for high-risk patients. There is no statistiacal significance will the pressure across the posterior facet with either screw. While the posterior-inferrior to talar neck showed an increased overal pressed area, the plantar-calcaneal to dorsal talus screw was more consistent with average pressure and maximum pressure. Our initial hypotheses were that the plantar calcaneal screw would increase the compression across the posterior facet of the STJ, while not statistically signifiant, is more consistent with the compression. . The postioer-infereior to talar neck screw is more perpedicular to the posterior facet which would likely be the reason the compresse area is larger. Given the surgical difficulty at times with a compression screw through the posterior facet and placing the second screw in close proximty, the plantar calcaneal screw apprears to offer another viable option.

Given the cadaveric nature of this study, there are some limitations that can influence the results of the present study. The authors directly visualized the placement of the guided wire and cannulated screws but did not use radiographs to confirm the placement. The same cadaver was utilized for each of the two screw configurations. While the authors directly visualized that the second screw did not exit near the first screw placement on the talus, there is still the possibility that the second screw may not have had maximum purchase. The cartilage was not resected for preparation of the joint which would occur with a subtalar joint arthrodesis. There can be variations among cadavers and cadaveric testing cannot simulate an actual performed arthrodesis in the surgical setting with quality of bone.

Conclusion

The author's report on a cadaveric study on the placement of two distinct locations of a second screw for a subtalar joint arthrodesis. This second screw was intentionally placed extra-articular to the posterior facet to see the amount of compression that occurs at the posterior facet of the STJ. The results show that the plantar-calcaneal to dorsal talar screw increases the amount of pressure, however the posterio-calcaneal to talar neck screw allows for an overall compressed area across the posterior facet compared to the plantar calcaneal to superior screw. None of the three were statistically signifigant. As there are multiple fixation techniques and implants available, further studies are recommended on this procedure.

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