Ankle Distraction Arthroplasty: How Much is Enough?

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INTRODUCTION

Distraction arthroplasty has gained popularity as an alternative to arthrodesis or traditional arthroplasty for tibiotalar arthritis[1-8]. This procedure uses external fixation to apply traction (distraction) across the ankle joint thereby expanding the narrowed joint space. Unloading is believed to create favorable conditions for cartilage repair and/or regeneration[7-9] (**Figures 1 and 2**); however, complete separation is required for optimal regenerative potential and clinical outcomes[1,2,7]. Additionally, the resultant stress shielding of the subchondral bone allows for regression of arthritic changes in that bone[2,10]. The desire for optimal unloading must be balanced against the need to protect neurovascular structures and avoid sacrificing ankle range of motion by increasing tension on the ankle ligaments.

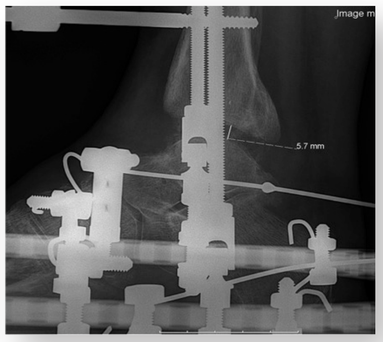
This presents an obvious question: what is the minimum, and thus morbidity minimizing, distraction necessary to fully unload the articular surface during full weight bearing? Good clinical results have been reported using 5 mm of additional joint space as measured on a weight bearing x-ray of the ankle[2,4-6,11]; however, this suggested distraction has not been studied in and of itself. The purpose of this study was to rigorously measure this minimum critical joint distraction using a cadaveric model.

Figure 1a – Preop lateral clinical x-ray

Figure 1b – One year post op lateral clinical x-ray

Figure 2a – Baseline joint space prior to distraction

Figure 2b – An additional 4.1 mm of joint space from distraction (5.7 mm measured, less 1.6 present initially)



MATERIALS AND METHODS

We mounted RAD frames (Small Bone Innovations, Morrisville, PA; **Figure 3**) on nine fresh-frozen cadaver ankles using three tension wires in the hind foot and two half-pins in the tibia12. We fitted the talotibial joint with a pressure sensitive film (Tekscan, South Boston, MA), and used a specially designed press (**Figure 4**) to apply 0N (no weight), 350N (half body weight/bipedal x-ray), 700N (full body weight/standing) loads while serially distracting the ankle in 1mm increments. At each load (0, 350, 700N) and distraction (0, 1, 2 … mm) a lateral radiograph was used to measure joint space (**Figure 5**). We continued this process until the intra-articular pressure readings under 700N of load equaled that ankle's 0N intra-articular pressure readings (**Figures 6 and 7**). We considered this the moment of full unloading and the distraction required to reach it was recorded as the minimum critical joint distraction.

Figure 3 – SBI RAD frame

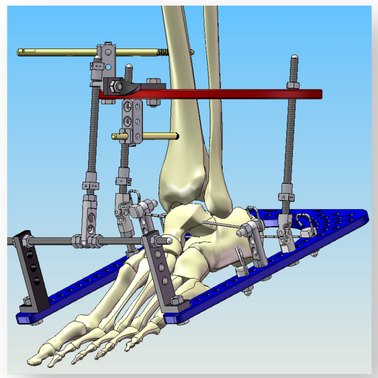


Figure 4a – Ankle specimen mounted in loading chamber and instrumented with Tekscan surrounded by fluoroscope.

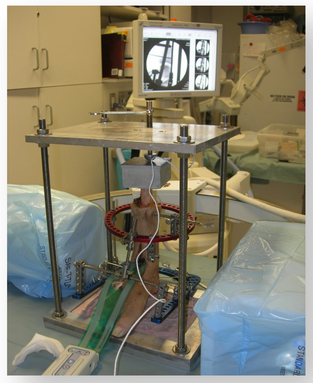


Figure 4b – Posterior view of specimen in testing apparatus.

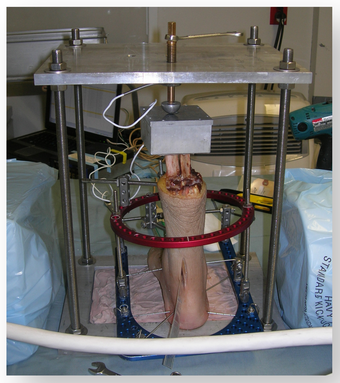


Figure 5 – x-ray measurement of joint space scaled using the additional k-wire in the distal tibia.

Figure 6 – Tekscan reading under 0N load with 1mm of distraction

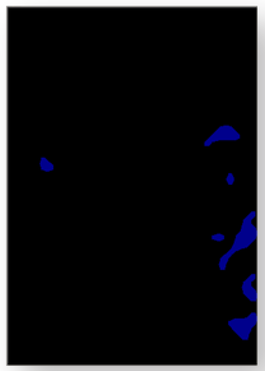


Figure 7a – Tekscan under 700N load at 1mm of distraction

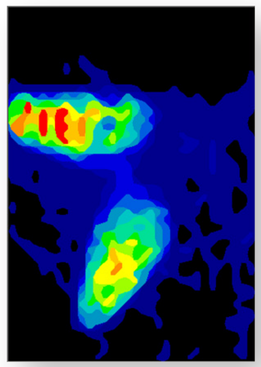


Figure 7b – Tekscan under 700N load at 2mm of distraction

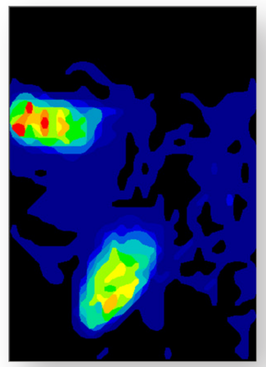
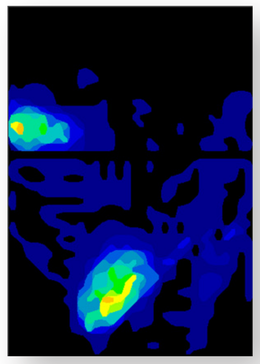


Figure 7c – Tekscan under 700N load at 3mm of distraction



RESULTS

The average joint space at which articular surfaces did not contact despite 700N of applied load was 2.4 (SD, 0.8; range, 1.6-4.0) mm. The average critical joint distraction was 4.4 (SD, 0.7; range, 3.7-5.8) mm at 350N of load and 4.9 (SD, 0.7; range, 3.7-7.0) mm at 0N of load (**Figure 8**).

Figure 8 – Mean (with SD) joint distraction required for articular surface unloading by applied load

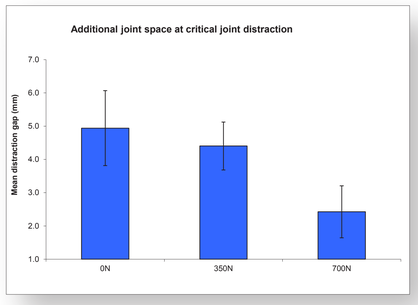


Figure 7d – Tekscan under 700N load at 4mm of distraction

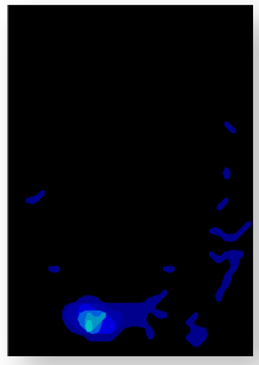
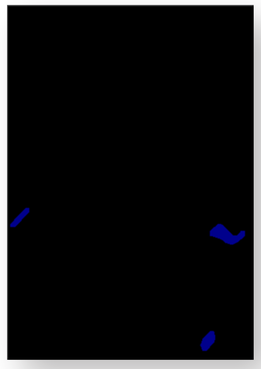


Figure 7e – Tekscan under 700N load at 5mm of distraction



DISCUSSION AND CONCLUSIONS

The goal of distraction arthroplasty is to apply the minimum joint distraction at which no load is transferred across the articular cartilage despite full weight bearing loads. As this goal cannot be directly measured in routine clinical practice, we use a minimum additional joint space target on bipedal radiographs. This target, or critical joint distraction, is the additional joint space needed, above the joint space present on an undistracted film, to unload the articular surfaces despite application of 700N of axial load.

The additional joint space required depends on the load under which the radiographs are made. If bipedal films are used, the critical distraction is 4.4 mm. If nonweightbearing films are used, the critical distraction is 4.9 mm. If clinical radiographs were made standing on one leg, 2.4 mm of additional joint space would be required. Although much of the joint surface is unloaded at a minute increase in joint space under these conditions, the additional 2.4 mm are required to ensure the whole irregular surface of the joint is unloaded.

We believe these numbers give insight into the least morbid distraction that will achieve the therapeutic goals of distraction arthroplasty. In order to ensure all patients have an opportunity for maximum response, our therapeutic target will be 6mm on bipedal radiographs moving forward. This would provide adequate additional joint space to fully unload the articular surface of even the most difficult to distract subject (maximum critical joint distraction was 5.8 mm) based on these data.

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