TRANSVERSE PLANE MISALIGNMENT OF ANKLE ARTHRODESIS MINIMALLY CHANGES RANGE OF MOTION OF DISTAL FOOT JOINTS IN CADAVERIC GAIT SIMULATION

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INTRODUCTION

An estimated 27 million people in the United States have symptomatic osteoarthritis [1]. For patients with end stage ankle osteoarthritis, tibiotalar arthrodesis surgery is a common treatment. Post-operatively, patients with previously healthy distal foot joints have been shown to develop osteoarthritis due to changes in bone kinematics [2]. Additionally, a misaligned ankle arthrodesis can cause pain and eventually require revision surgery [3]. The objective of this study is to quantify the effect of transverse plane rotational misalignment of ankle arthrodesis on distal foot bone kinematics.

METHODS

Nine fresh-frozen cadaveric foot specimens (age 61.3±19.2 years) were obtained for this study. An orthopaedic surgeon examined each specimen to screen out anatomic deformities. A custom two-plate fixture was designed to fuse the ankle of each specimen and allow for misalignments to be imposed in the transverse plane (Figure 1A). The fixture was implanted by an orthopedic surgeon using the instrumentation of the Salto Talaris ankle arthroplasty (Integra LifeSciences, Plainsboro, NJ) to remove bone from the talus and tibia to the exact size of the fixture. Eight obliquely-directed bone screws were then driven into the tibia and talus to secure the two-plate fixture and fuse the ankle in neutral position (Figure 1B). Five and ten degree misalignments of both internal and external rotation were tested for each specimen.

Specimens were tested on the robotic gait simulator (RGS) [4]. The RGS consists of a force plate mounted on a six-degree-of-freedom robot that simulates the ground moving relative to the foot in walking. Actuators are connected to nine extrinsic foot tendons to simulate muscle forces. The input tibial kinematics and target ground reaction forces were taken from gait lab data of ten patients tested one year after ankle arthrodesis surgery. Specimens were tested in a walking stance phase simultation at 25% body-weight and one-sixth *in vivo* speed to avoid fixture damage. An 8-camera Vicon (Vicon Motion Systems, Oxford, United Kingdom) system tracked bone kinematics using a ten-segment model [5]. Reflective marker clusters secured to rigid wires were attached to bone screws inserted into each bone of interest in the model (Figure 1C). A pliance pressure mat (novel, Munich, Germany) was placed in series with the force plate.

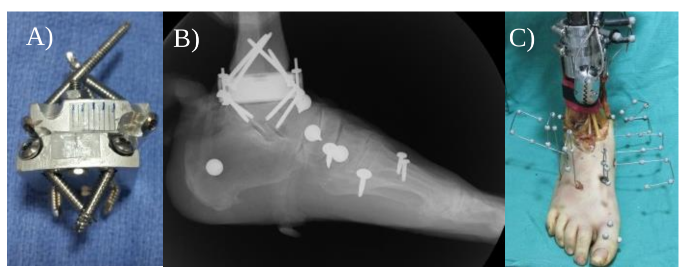

Figure 1: A) Anterior view of fusion fixture in misaligned position, B) lateral radiograph of fusion fixture implanted in specimen, C) reflective marker clusters connected to bone screws.

Using MATLAB (Mathworks Inc., Natick, MA), a repeated-measures one-way ANOVA detected significant changes in bone kinematics measured in ten foot joints. Differences in range of motion and in initial joint angle of each misaligned condition relative to the neutrally aligned condition were evaluated.

RESULTS AND DISCUSSION

Accurate *in vitro* simulation of ankle fusion and transverse plane misalignments were achieved with the RGS. The system matched the target vertical ground reaction force to an RMS error of 9.23%. The target misaligned arthrodesis conditions were achieved, as the initial transverse plane rotation angle of the ankle joint showed a significant difference from neutral ($p<0.001$) for all misaligned conditions. No significant differences were detected between misalignment changes in either range of motion or initial position relative to neutral for the distal foot joints. Mean differences in range of motion for the distal foot joints were small–all less than three degrees for each joint in each plane (Figure 2). A mean increase in transverse and sagittal plane range of motion at the calcaneocuboid joint was observed across all misalignments, suggesting a trend showing neutrally aligned arthrodesis causes the least hybermobility at this joint. Additional kinematic analyses that quantify the shift in joint motion over stance phase are being conducted. Plantar pressure analysis of both center of pressure and peak pressure beneath specific locations of the foot is also on going.

CONCLUSIONS

Successful simulation and misalignments of ankle arthrodesis surgery were achieved using a cadaveric gait simulation model. Significant changes in range of motion of joints were not found between the various transverse plane misalignments. Further analyses will be performed to further quantify differences in kinematic data due to misalignment and to understand the effect on plantar pressure.

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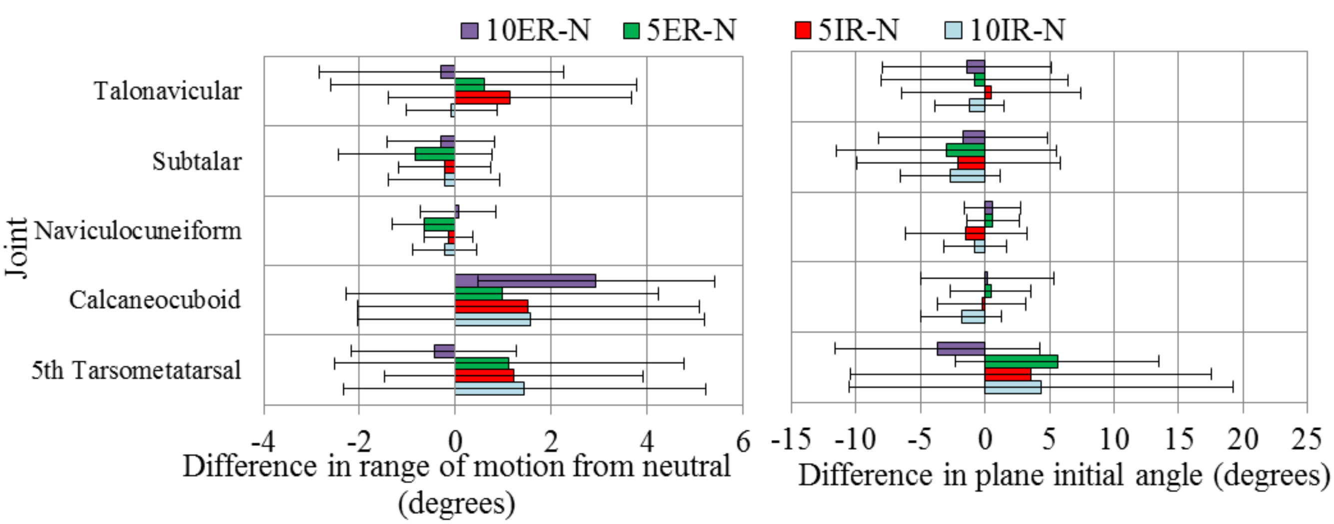

Figure 2: Transverse plane differences in range of motion and differences in initial angle from neutral for distal foot joints (average changes ± standard deviations). Comparison from neutral (N) for 10º external rotation (10ER-N), 5˚ external rotation (5ER-N), 5˚ internal rotation (5IR-N) and 10˚ internal rotation (10IR-N).