

THE CONTRIBUTION OF ARTICULAR SURFACE GEOMETRY TO ANKLE STABILIZATION

Yuki Tochigi, M. James Rudert, Charles L. Saltzman, Annunziato Amendola, and Thomas D. Brown
University of Iowa, Department of Orthopaedics and Rehabilitation
Email: yuki-tochigi@uiowa.edu, web: <http://poppy.obrl.uiowa.edu/>

INTRODUCTION

Passive stability of the ankle under weight-bearing conditions is thought to rely substantially on the role of the articular surfaces[1,2]. Ligament-sectioning paradigms previously utilized to study the relative contribution of ligamentous vs. articular restraints have not allowed direct study of the mechanism by which surface resistance contributes to ankle stabilization. This study hypothesized that ankle stabilization by surface resistance involves specific contact stress changes that plausibly explain the contribution of articular surface geometry to passive ankle stability.

METHODS

Six cadaver ankles with the significant peri-ankle ligaments intact were subjected to an experiment to explore articular contact pressure changes associated with various external loads. The loads were anterior/posterior (A/P) shear forces (40 and 80 N), inversion/eversion torques (150 and 300 N-cm), and internal/external rotation (IR/ER) torques (150 and 300 N-cm); these magnitudes are similar to those occurring during gait. An MTS-based custom fixture held a specimen at a predetermined ankle position (15° dorsiflexion, neutral, 15° plantar flexion, or 30° plantar flexion) under 600N axial force. At each position, one of the three external loads was applied for all load increments, while motion associated with the two remaining loads was unconstrained.

Contact stress on the superior tibial plafond surface was recorded by a purpose-designed transient stress transducer (Tekscan Inc., Boston, MA, USA), which reported local stress at each of the 1472 (32x46) sensing units (sensels). For each load/position, the pressure changes due to the applied external load were calculated from the recorded pressure map by subtracting the corresponding axial-load-only map obtained at that position, on a sensel-by-sensel basis.

Plafond geometry was modeled as two adjacent spherical sectors (Fig.1). The force at each sensel, assumed to act normal to the surface, was resolved into three components: axial, A/P, and medial/lateral (M/L). The sum of the A/P components was assumed to represent the surface resistance to the applied external A/P load. Version and IR/ER torques about the zero-load center of pressure were calculated from the appropriate force components and were assumed to represent the surface resistance to the corresponding external loads. Frictional forces were assumed negligible.

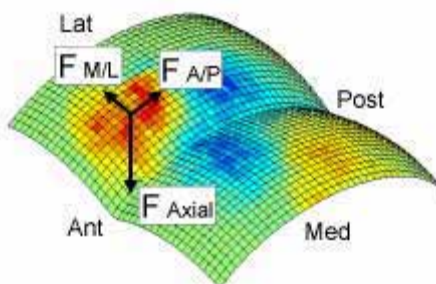


Fig.1 Ankle geometric model with a pressure change map (external load = 300 N-cm IR torque). The plafond geometry consists of two partial spheres (radius = 25mm, separation b/w centers = 20mm). The force is regarded as applied from the tibia to the talus. Pressure change is converted to the corresponding force perpendicular to the sensel surface. The axial, A/P, and M/L components of the force are utilized to estimate the magnitude of the surface resistance associated with the external load.

For each of the three external loading conditions, and at each position, the resisting force/torque was linearly regressed against the magnitude of the externally applied force/torque (Fig.2). The slope was considered to represent the contribution of the measured pressure changes to restraining the ankle. (A slope of 1.0 would indicate that articular surface engagement provided 100% of the resistance). This analysis was individually applied to each specimen.

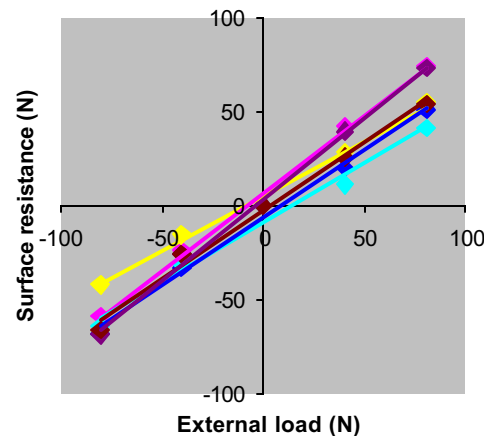


Fig.2 External load vs. surface resistance in the A/P force test at the neutral position (n=6). Each specimen has five data points (plotted for the four external-load magnitudes and the axial-load-only condition) and a trend line based on linear regression. In this case, correlation coefficient (R) is greater than 0.99 in every specimen, and the slopes range from 0.61 to 0.98.

RESULTS AND DISCUSSION

In the neutral position, the pressure changes on the tibial plafond accounted for $73 \pm 11\%$ (average \pm standard deviation) of the external AP force, $39 \pm 14\%$ of the version torque, and $30 \pm 14\%$ for the IR-ER torque. Significant effect of ankle position was revealed only in the version test ($p = 0.01$, single factor ANOVA), in which the contribution linearly decreased in the plantar-flexed positions.

The results indicate that the superior-inferior tibial-talar surfaces play the primary role in A/P stabilization under weight-bearing conditions. Contribution of these surfaces in helping to resist version and IR-ER torque was also evident, even without counting the effect of the lateral and medial ankle “gutter” surfaces (a subject inviting future investigation).

CONCLUSION

Ankle stability under weight-bearing conditions appears to be substantially dictated by the ankle surface geometry.

REFERENCES

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2. Watanabe K, et al. *49th ORS abstract*, #0119, 2003.

ACKNOWLEDGEMENTS

AOFAS Research Grant and NIH Grant AR48939