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Oral presentation

Bearing surface modeling of the talus and calcaneus

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Introduction

Precise talar in vivo motion is difficult to measure due to its inaccessibility to surface based measures. Thus, most measures of talar motion have been limited to cadaver based measures, typically under static conditions. Quantitative measures of the talar bearing surfaces and their ability to mesh with the calcaneal and malleolar bearing surfaces would provide an understanding of the envelope of movements available in both in healthy and pathological joints. Such measures could exploit the availability of 3D non-invasive imaging methodologies, making it available for large-scale healthy and pathological studies. Thus, the purpose of this work is to mathematically model the bearing surfaces of the talar and calcaneal bones in order to determine the allowable motions of a healthy joint.

Methods

A three-dimensional Faro-arm scanner was used to acquire a dense cloud of points depicting the shape of skeletal bones of a single human foot. The points on the subtalar joint bearing surfaces were then fit with continuous functions.

The functions were chosen from classes which provide the characteristics expected of the surfaces. The functions were relative to coordinate system defined such that the axes were parallel when the bones were assembled in a "natural" fit, with origin at the saddle point. Initial fits used bi-quadratics. The surface curve fits allowed the evaluation of several parameters. Among these, the relative curvatures of the mating surfaces was a primary measure of interest because it allows an examination of allowable motions of the surfaces relative to each other. For example, very different radii of curvature about a particular axis allows for a rocking motion, but very limited relative sliding of the surfaces.

Results

The quality of fit was good, but has not yet been compared with other possible functions. Figure 1.

The range of radii found along the y-axis (anterior-posterior) correlate well between the two bearing surfaces, allowing the surfaces to conform to one another. The overlapping radii range between the talus and calcaneus suggests that not only is the motion about the x-axis (medial-lateral) rotational, but the curvature radii is flexible. The motion about the x-axis in not confined to a specific moment arm distance, but can change throughout the ankle's range of motion.

In contrast, the x-axis curvature values were not found to coincide, and the values for the calcaneus were larger than any of the curvature values found for the mating surface. The large radius of curvature values likely allow the calcaneus superior articulation surface to provide translation instead of rotational joint motion about the y-axis. This motion is likely constrained by other aspects of the joint.

Conclusion

At the current time this work is ongoing. After bearing surface models have been fit to 4 new scans of cadaver bones
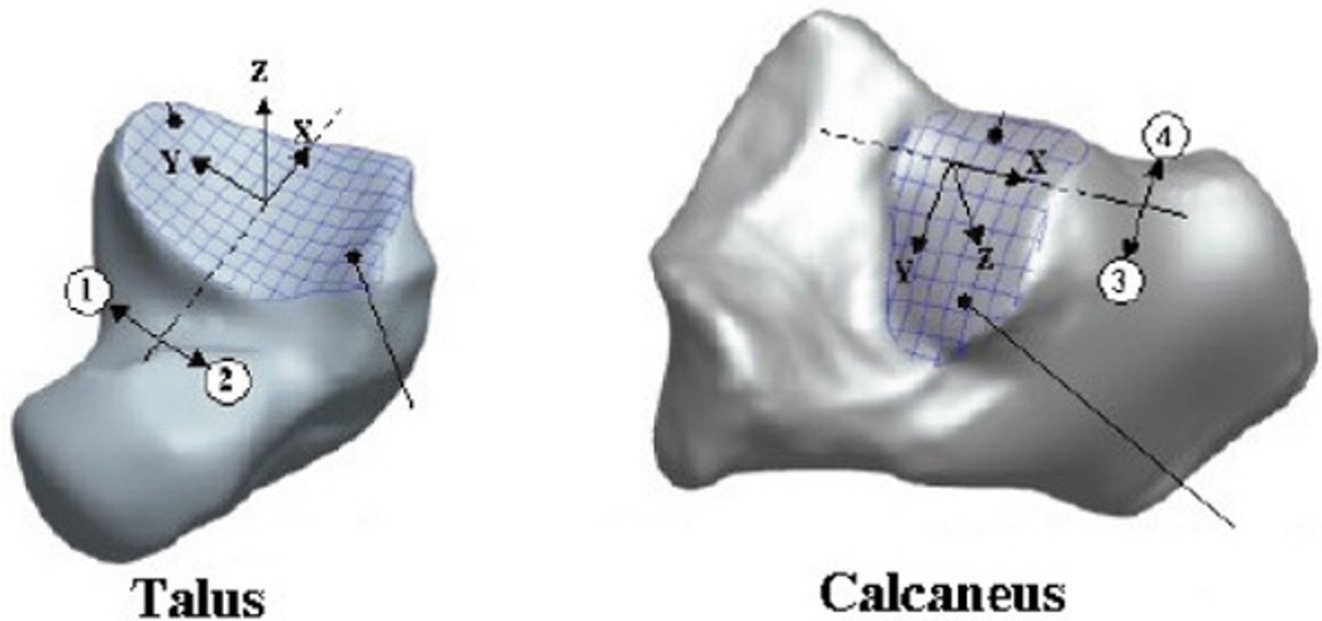
Figure 1
Talus and calcaneus bearing surfaces, hashed for curve fitting. Each surface is separated into two sections, and separate fits are found for each.

and 8 models acquired through segmenting high-resolution 3D MR images of healthy ankles, appropriate scaling factors will be investigated so that an average calcaneal and talar bearing surfaces can be created. Examination of all contact surfaces will provide further insight into allowable and expected motions of the joint.