

# A DIGITAL TEMPLATE OF CARTILAGE THICKNESS VARIATION IN THE ANKLE

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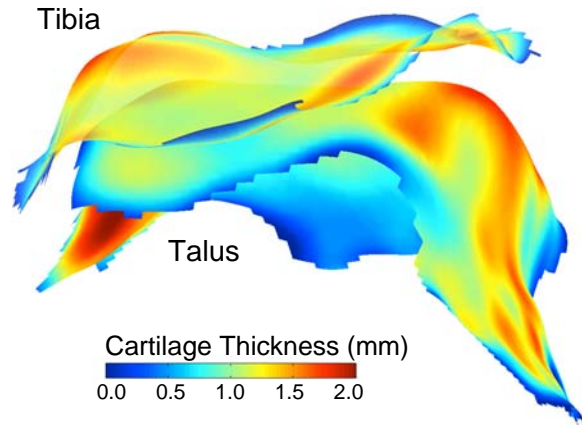
## INTRODUCTION

Patient-specific modeling of the ankle has provided a unique opportunity to study the relationship between altered articular surface anatomy and elevated contact stress, to help elucidate the mechano-pathology of post-traumatic osteoarthritis [Anderson et al., 2006]. The source medical images for these fracture patients have been CT, rather than MRI, because of the presence of metallic hardware. Thus, cartilage layers have been modeled as of constant uniform thickness.

This abstract describes the derivation of a digital template of cartilage thickness variation in the normal ankle working from MRI datasets, to allow projection of non-uniform cartilage thicknesses upon patient-specific models derived from CT datasets.

## METHODS

Bone and cartilage boundaries of the distal tibia and the proximal talus were previously segmented from high-resolution MRI scans of eight human cadaveric ankles [Millington et al, 2005]. In the present study, these data were fitted using fourth order B-spline least-squares surface-fitting techniques [Ateshian, 1993], implemented in MATLAB. Cartilage thicknesses (defined as the length of the three dimensional vector originating on, and normal to, the subchondral bone surface and terminating at the cartilage surface) were calculated for both the tibia and talus at between 15,000 and 20,000 points across the entire subchondral bone surfaces (Figure 1).



**Figure 1.** Mapping of cartilage thickness distribution upon tibia and talus for a single cadaveric ankle specimen.

In order to create thickness maps that were averages of those measured in the 8 different ankles, the three-dimensional topographical and thickness data were scaled and aligned into a parametric space [Cohen et al., 2003] based on an anatomical coordinate system. The foundation of this approach was the highly accurate fitting of a cylinder to the superior surface of each talar dome.

This parameterization of the ankle cartilage thickness mappings was selected to allow later projection of a generic normalized cartilage thickness distribution upon CT-segmented bone surfaces from fracture patients enrolled for study.

## RESULTS AND DISCUSSION

Cartilage thickness values varied gradually over the surfaces of the tibia and talus (Figure 1). Peak values were observed

anteriorly on the tibia, and at the junction between the medial malleolus and the rest of the articular surface. On the talar dome, peak cartilage thicknesses were noted along the primarily AP-directed ridges.

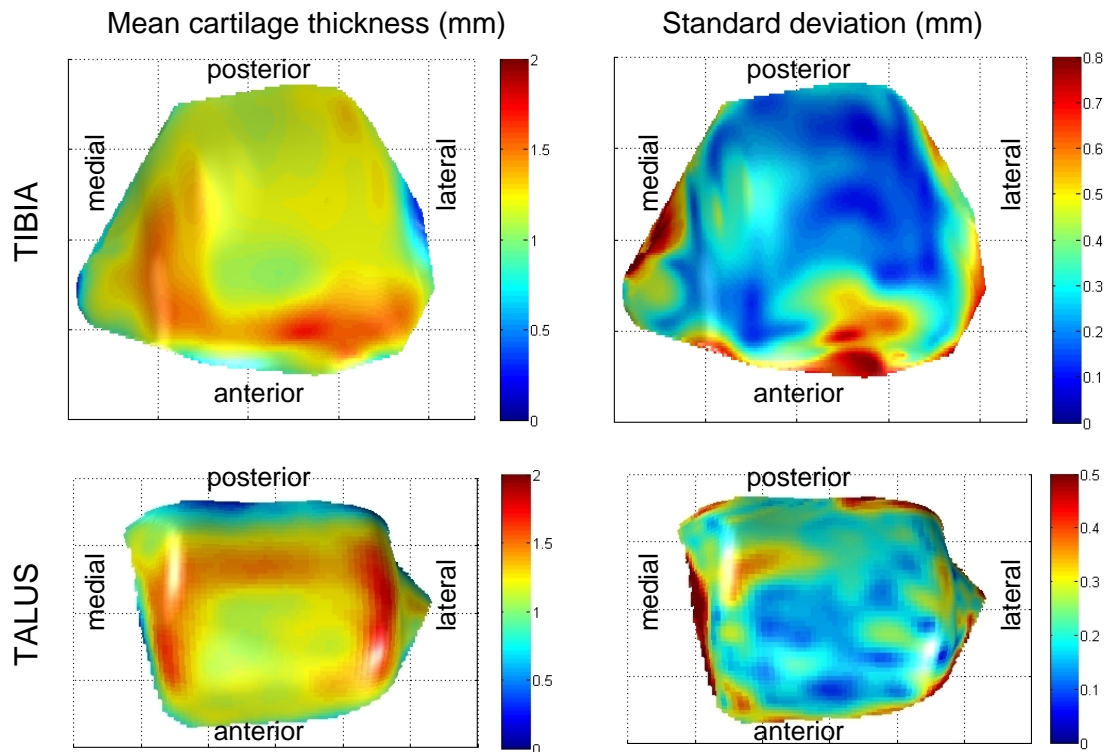
The parameterization of the tibial and talar surfaces allowed averaging over the eight specimens (Figure 2). Standard deviations were relatively small over most of the surface, although individual specimen variability at the periphery resulted in larger values there. These digital templates of cartilage thickness variation in the ankle provide a valuable basis for incorporation of non-uniform cartilage thickness in patient-specific computational joint models derived from source CT datasets.

## REFERENCES

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## ACKNOWLEDGEMENTS

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**Figure 2.** Mapping of cartilage thickness in parametric space (values are scaled in a specimen-specific manner), averaged across the eight cadaveric ankle specimens. All surfaces are visualized from superior viewpoint.