Abstract (Program Number: 612.13)

Analyses of bone microstructure based on single volumes of interest (VOIs) are limited in their ability to quantify variation in trabecular properties across a joint. Geometric morphometric methods can overcome these limitations by utilizing sliding semilandmarks to locate multiple VOIs within a trabecular structure. Variation in the placement of semilandmarks, however, may change collected bone parameter values. Here we quantify the effect of intraobserver error in delineating the articular surface on sliding semilandmark placement and sampled trabecular properties.

Proximal tibiae of 12 individuals that are part of the Texas State University Donated Skeletal Collection were scanned using micro-computed tomography at the Forensic Anthropology Center at Texas State. Original grey scale image stacks were converted to binary images, and surface models of the exterior bone surface were created. Medial condyles were trimmed from their full surface models three times over a period of weeks. Sliding semilandmarks (n=141) were distributed on the condyle surfaces and then slid to minimize the bending energy of the thin-plate spline function relative to the updated Procrustes average. Each sliding semilandmark was then used to locate a single VOI just deep to the cortical shell. To investigate the effect of landmark placement on trabecular bone parameters, each VOI was moved 0.5-1.5 mm to one of 10 neighboring positions. Bone volume fraction (BV/TV) and trabecular thickness (Tb.Th) were calculated for each VOI at each of the 11 positions. VOIs that moved outside the trabecular structure were removed from further analyses. 10,000 randomized combinations of the 11 positions of each VOI were created and correlations between bootstrap samples were calculated.

Sliding semilandmark placement differed by 0.27 mm on average. Landmarks most affected by intraobserver error were those placed along the edge of the condylar surface (mean = 0.38 mm), while those on the interior portion of the condyle were affected less (mean = 0.21 mm). Sampled BV/TV and Tb.Th vary with VOI position, although there is a strong correlation among the 11 sampled values for BV/TV (r=0.83) and Tb.Th (r=0.80). These results suggest that VOI positions calculated from sliding semilandmarks provide consistent information about bone microstructure even when VOI placement is forced to deviate beyond average variation in sliding landmark position.

Sensitivity of Trabecular Mapping to Sliding Semilandmark Placement

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Introduction

Analyses of bone microstructure based on single volumes of interest (VOIs) are limited in their ability to quantify variation in trabecular properties across a joint. Geometric morphometric methods can overcome these limitations by utilizing sliding semilandmarks to locate multiple VOIs within a trabecular structure. Variation in the placement of semilandmarks, however, may change collected bone parameter values.

Sample

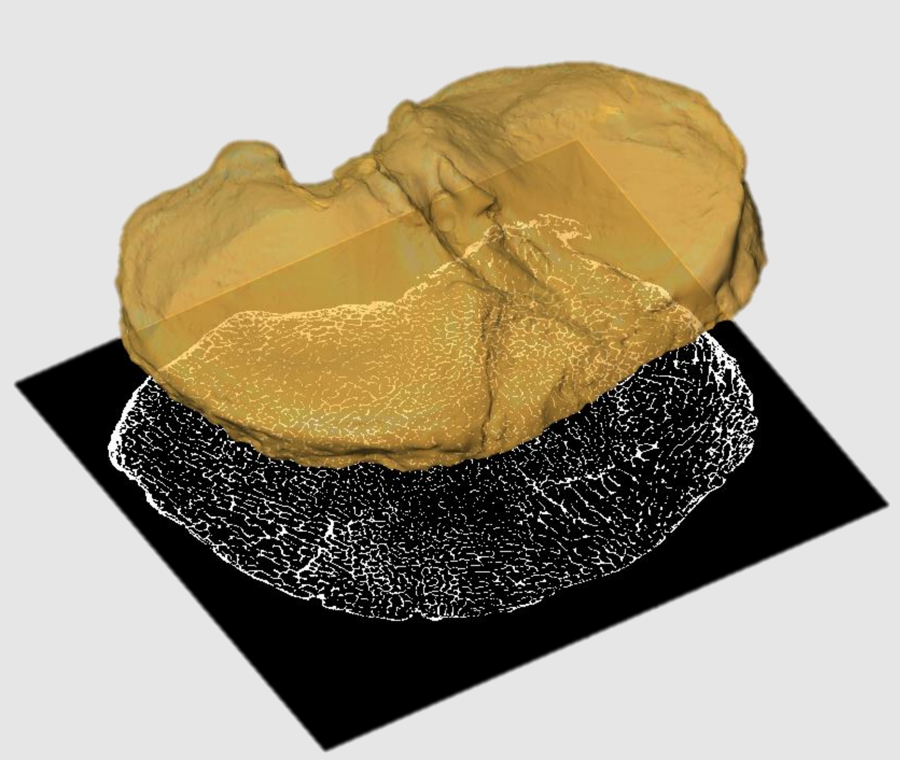
Proximal tibiae of 12 individuals that are part of the Texas State University Donated Skeletal Collection were scanned using micro-computed tomography at the Forensic Anthropology Center at Texas State.

Objectives

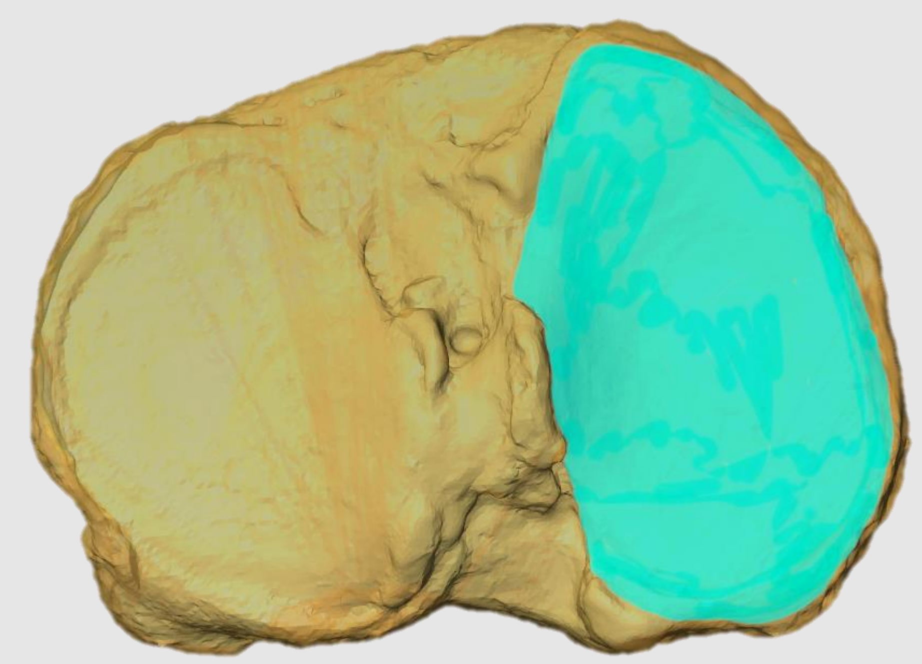
1) How does intraobserver error in articular surface delineation affect the placement of sliding semilandmarks?
2) How does error in VOI placement affect collected bone properties?

Intraobserver Error & Placement of Sliding Semilandmarks

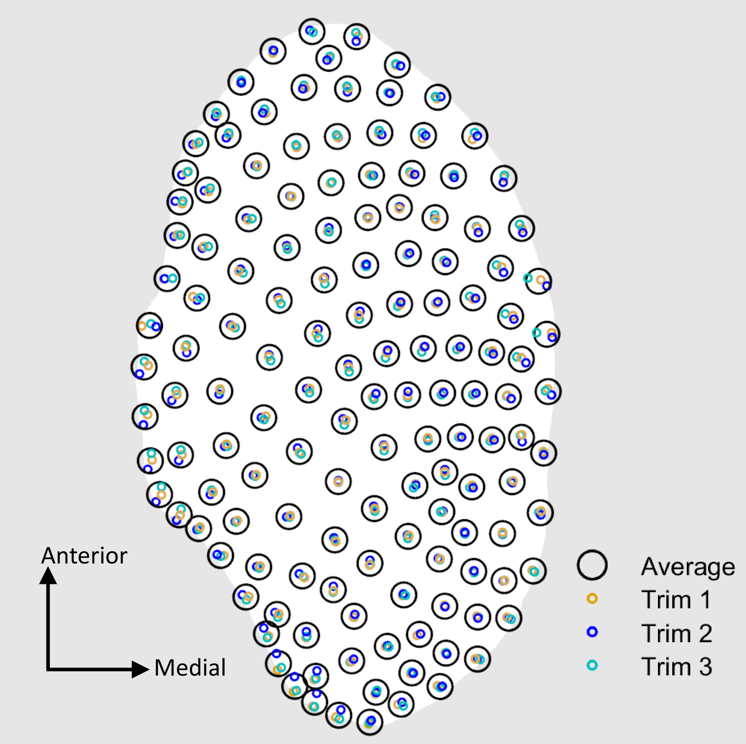
Methods



Original grey scale image stacks were converted to binary images, and surface models of the exterior bone surface were created.

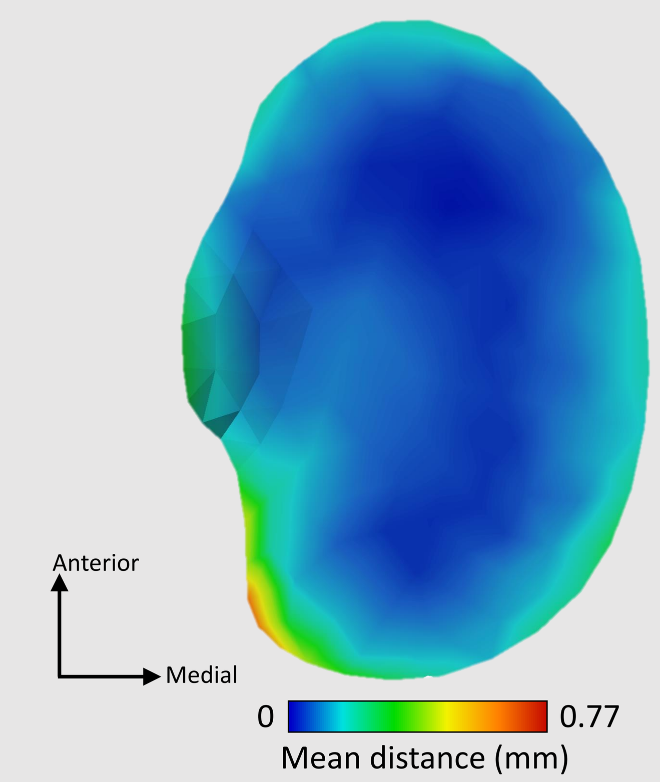


Medial condyles were trimmed from their full surface models by the same observer three times over a period of weeks.



Sliding semilandmarks (n=141) were distributed on the condyle surfaces and then slid to minimize the bending energy of the thin-plate spline function relative to the updated Procrustes average.[1]

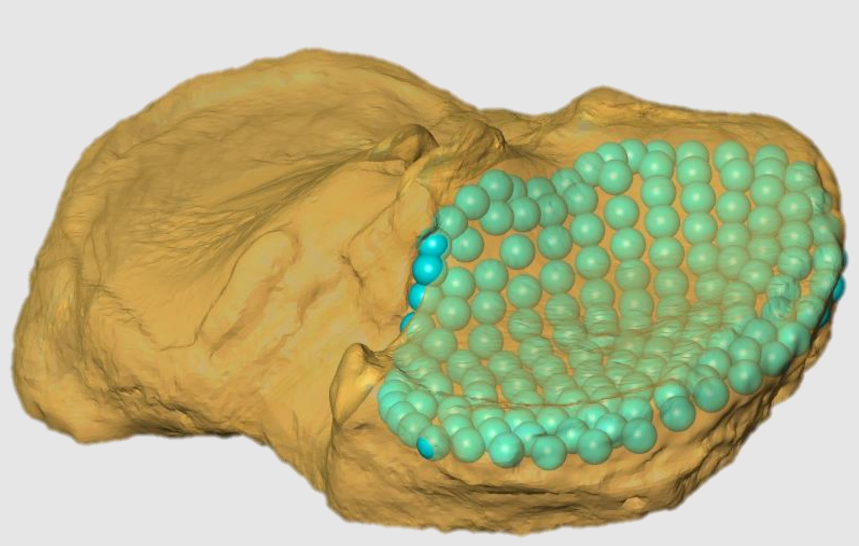
Results



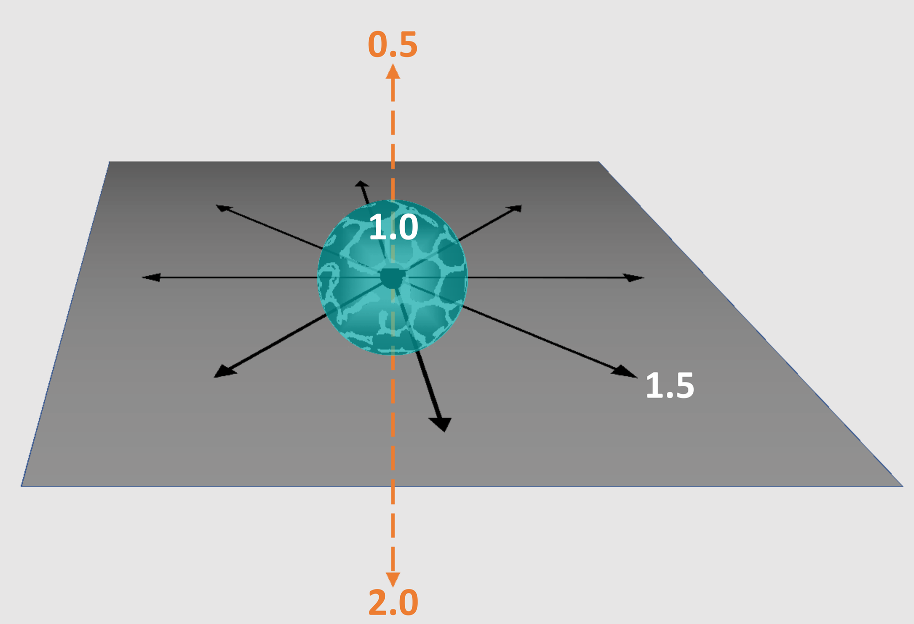
Sliding semilandmark placement differed by 0.27 mm on average. Landmarks most affected by intraobserver error were those placed along the edge of the condylar surface (mean = 0.38 mm), while those on the interior portion of the condyle were affected less (mean = 0.21 mm).

VOI Placement & Collected Trabecular Properties

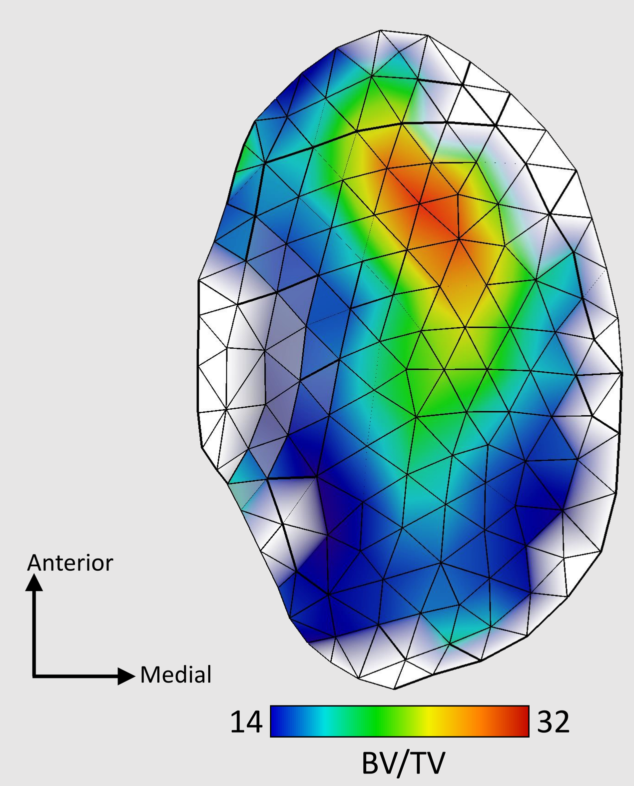
Methods



To investigate the effect of landmark placement on trabecular bone parameters, each sliding semilandmark was used to locate a single spherical VOI (3.5 mm radius) just deep to the cortical shell at a distance of 1 mm from the surface.[2]

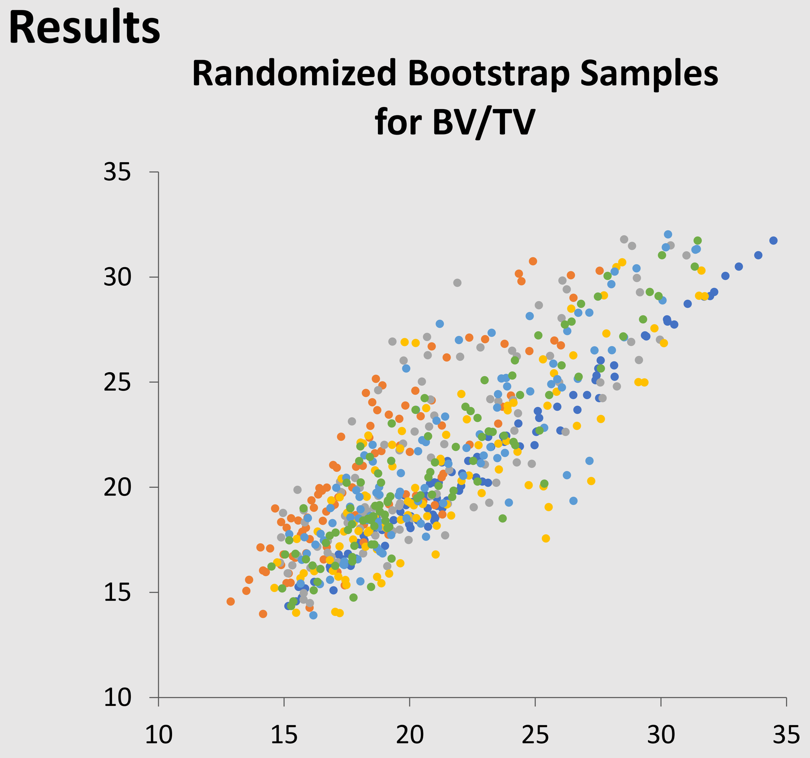


Each VOI was moved to 10 neighboring positions. Two positions varied in depth along normal vectors from the condylar surface (0.5 & 2 mm). Eight positions were determined by translating the VOI at 1 mm depth 1.5 mm along vectors in an orthogonal plane.



Bone volume fraction (BV/TV) and trabecular thickness (Tb.Th) were calculated for each VOI at each of the 11 positions. VOIs with any positions more than 10% outside the trabecular structure were removed from further analyses (101 of 141 VOIs retained).

Results



10,000 randomized combinations of the 11 positions of each VOI were created per individual and correlations between bootstrap samples were calculated (six comparisons are plotted here). Though BV/TV and Tb.Th vary with VOI position, there is a strong correlation among the 11 sampled values for BV/TV (r=0.83) and Tb.Th (r=0.80).

Conclusions

These results suggest that VOI positions calculated from sliding semilandmarks provide consistent information about bone microstructure even when VOI placement is forced to deviate well beyond average variation in sliding landmark position. Assessment of intraobserver error and VOI quality should be incorporated into future trabecular analyses utilizing sliding semilandmarks for VOI placement.

Acknowledgements

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References

1. Sylvester AD, 2013. A geometric morphometric analysis of the medial tibial condyle of African hominids. *Anatomical Record* 296(10):1518-1525.
2. Sylvester AD & Terhune CE, 2017. Trabecular mapping: leveraging geometric morphometrics for analyses of trabecular structure. *American Journal of Physical Anthropology* 163(3):553-569.