IMAGE-BASED TORSIONAL STIFFNESS OF SKELETAL ELEMENTS

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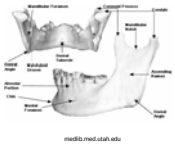
Introduction

Traditional measures of torsional stiffness in skeletal elements include geometry (i.e., the shape) but neglect heterogeneity in bone density. An image-based method was developed in this project that takes into account variations in density for determining the torsional stiffness. The method was then applied to computed tomographic (CT) images of the mandibular corpi of three species of great apes.



CT images → pixels with grayscale values

Density → $\rho \propto \Gamma^{1/\beta}$ ← Grayscale

Shear Modulus → $G \propto \rho^{b}$

$r \approx 1$

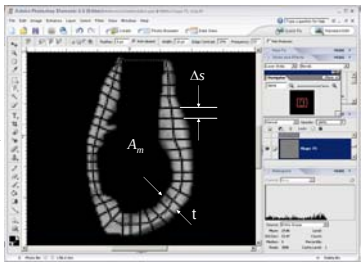
$$G \propto \Gamma^{b/\beta} = \Gamma^{r}$$

torsional stiffness, $$k \approx \frac{4A_m^2}{\sum \frac{\Delta s}{\Gamma(s)t(s)}}$$

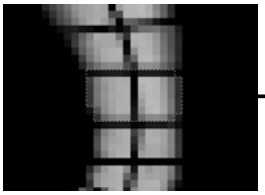
Discretization of Bredt's Formula

Three Stiffnesses Determined:
k - using *in situ* bone density variation
k_w - using 100% grayscale over cross section
k_{avg} - using grayscale averaged over cross section

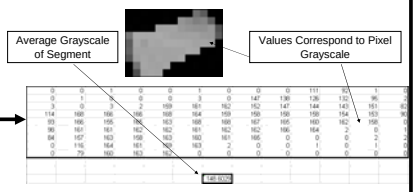
CT image (*Gorilla)*



Adobe Photoshop Elements
– Image segments and Midline

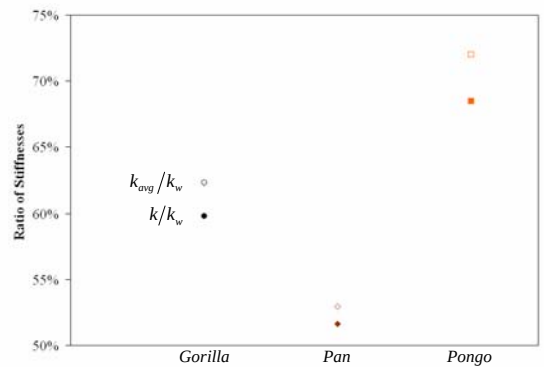


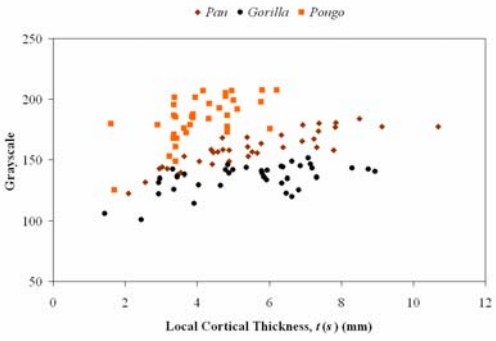
Individual Segment Analysis



Images Converted to Matrix Using MATLAB

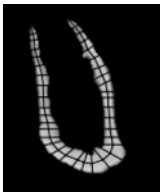
Results





Stiffness values are greater at thicker regions

Orangutan (*Pongo*)



Chimpanzee (*Pan*)

Summary and Conclusions

A method was developed in this project for determining an image-based weighted measure of torsional stiffness and applied to the premolar region of mandibles of three species of great apes. The method includes analytical results from the mechanics of torsion of thin-walled tubes and a discretization of Bredt's formula. The method can be applied readily to larger comparative samples.

Torsional stiffness computed using grayscale averaged over the entire cross section overestimated the stiffness and does not take into account the adaptive placement of bone mineral. Contrary to a prevailing belief in physical anthropology that this adaptation functions to produce similar strains throughout the cross section, bone tissue stiffness (as represented by grayscale) was found to be lower in thinner regions of the cross sections, that would only serve to increase strains in the thinner compared to the thicker regions. Therefore, this work supports the exploration of alternative hypotheses regarding remodeling in the mandibles of great apes.