Adaptive plasticity in the masticatory apparatus: inference for form, function, and fossils

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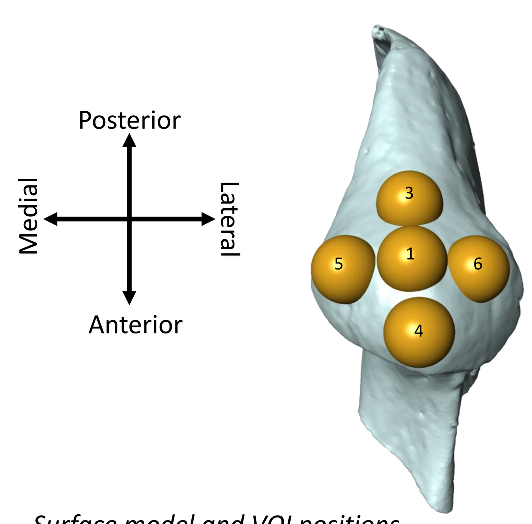
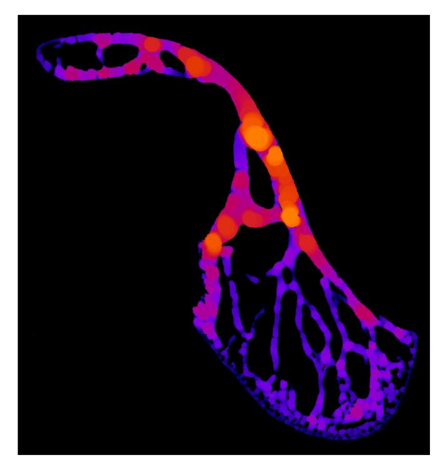
INTRODUCTION: Understanding bone functional adaptation is critical for reconstructing behaviors of, and inferring evolutionary relationships among, fossil species. Though form-function links are most frequently examined in an evolutionary framework, the mediating role of loading environment during ontogeny plays an important role in determining the expression of adult form. Moreover, different anatomical regions and analytical scales may reveal disparate patterns, reflecting a complex interplay of adaptive plasticity and evolutionary adaptation. In the masticatory apparatus, prior experimental manipulations of diet have induced changes in skeletal shape exceeding differences observed among primate genera**. Here we examine trabecular structure in the mandibular condyle in an experimental group of rabbits (*Oryctolagus cuniculus*), a mammal which shows similar masticatory patterns as primates. We hypothesize that rabbits raised on more mechanically challenging diets (pellets + hay) will exhibit thicker trabeculae, higher bone volume fractions, higher levels of anisotropy, and decreased trabecular spacing.**

MATERIALS AND METHODS:

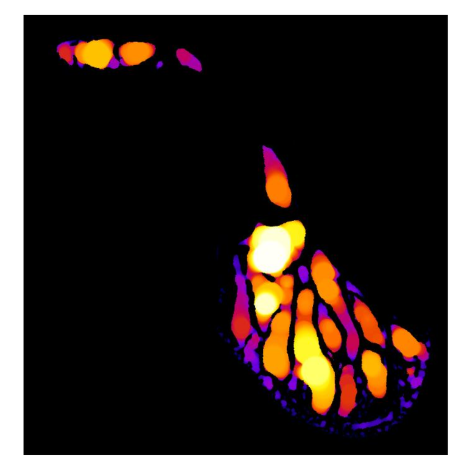


Surface model and VOI positions

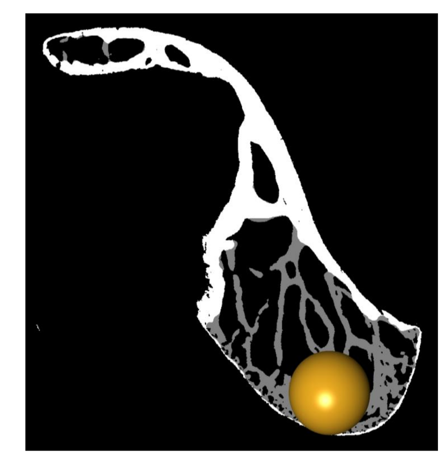
Segmented data



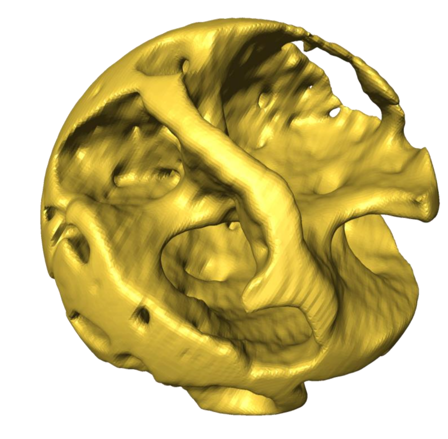
Bone thickness map (warmer colors=increased thickness)



Trabecular space map (warmer colors=increased spacing)



Cortical (white) vs. trabecular (gray) bone showing VOI position



Extracted VOI
1.5 mm

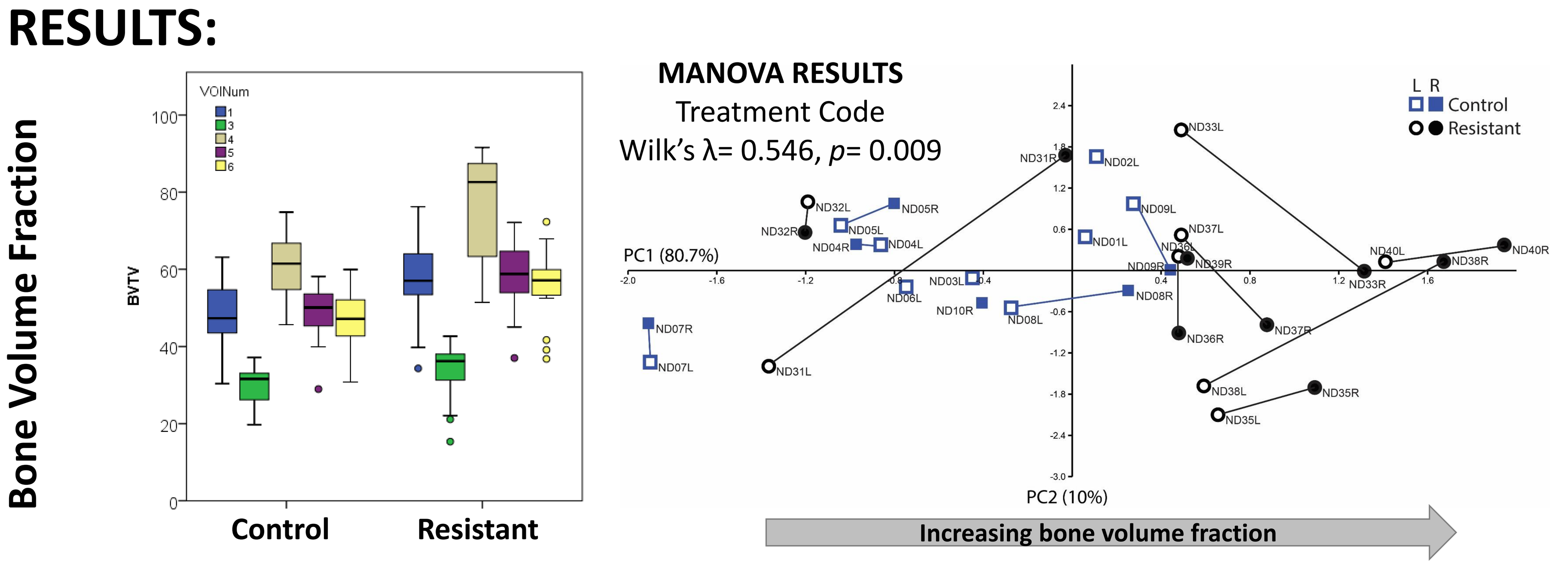
- 10 “control” rabbits raised (48 weeks) on rabbit pellets only
- 10 “resistant” or “over-use” rabbits raised (48 weeks) on pellets + hay cubes
- Left and right condyles for each rabbit
- µCT scanned at ~ 10µm voxel size

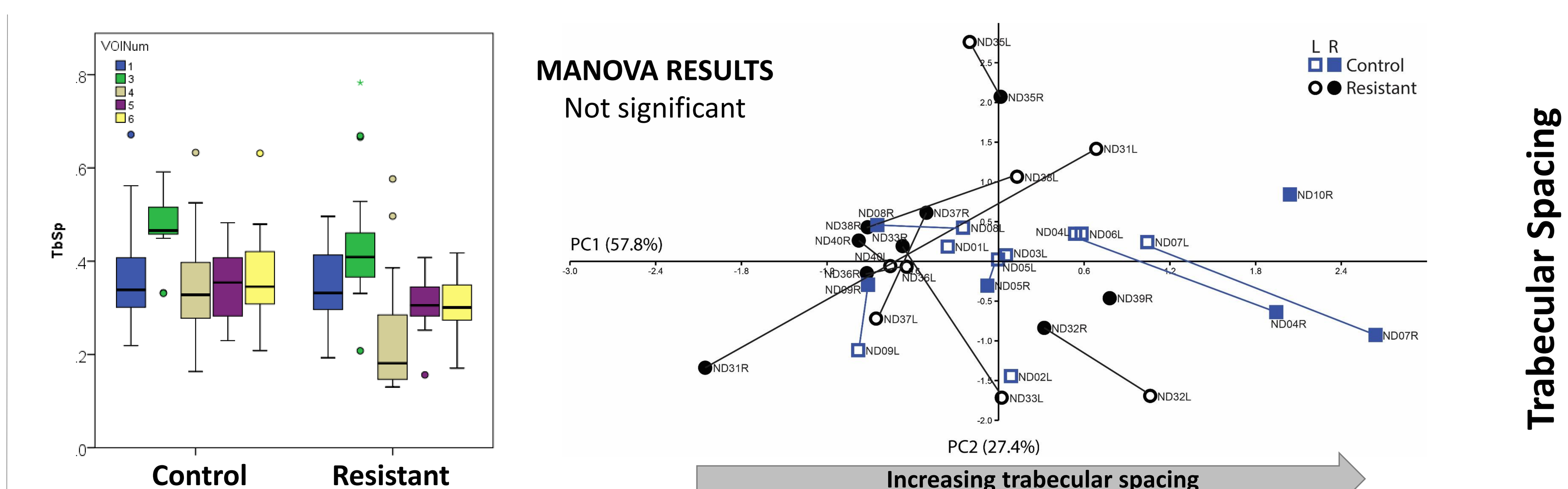
- Surface models generated in Avizo
- Image stacks segmented using BoneJ[1]
- Cortical and trabecular bone separated using algorithm of Pahr and Zysset[2]
- Trabecular thickness and trabecular spacing maps generated in BoneJ

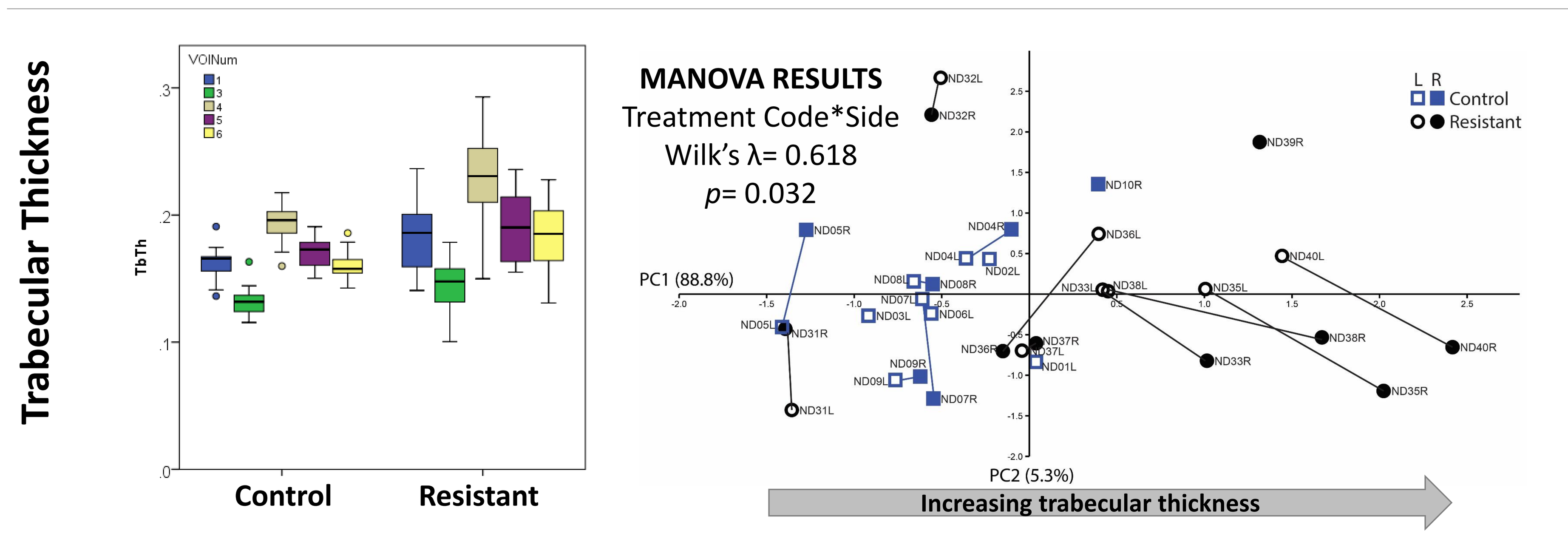
- 6 volumes of interest on condylar articular surface; VOIs slid down surface normal vector until embedded in trabecular bone[3]
- Bone volume fraction (BV/TV), trabecular thickness (Tb.Th), trabecular spacing (Tb.Sp), and anisotropy (DA) measured for each VOI

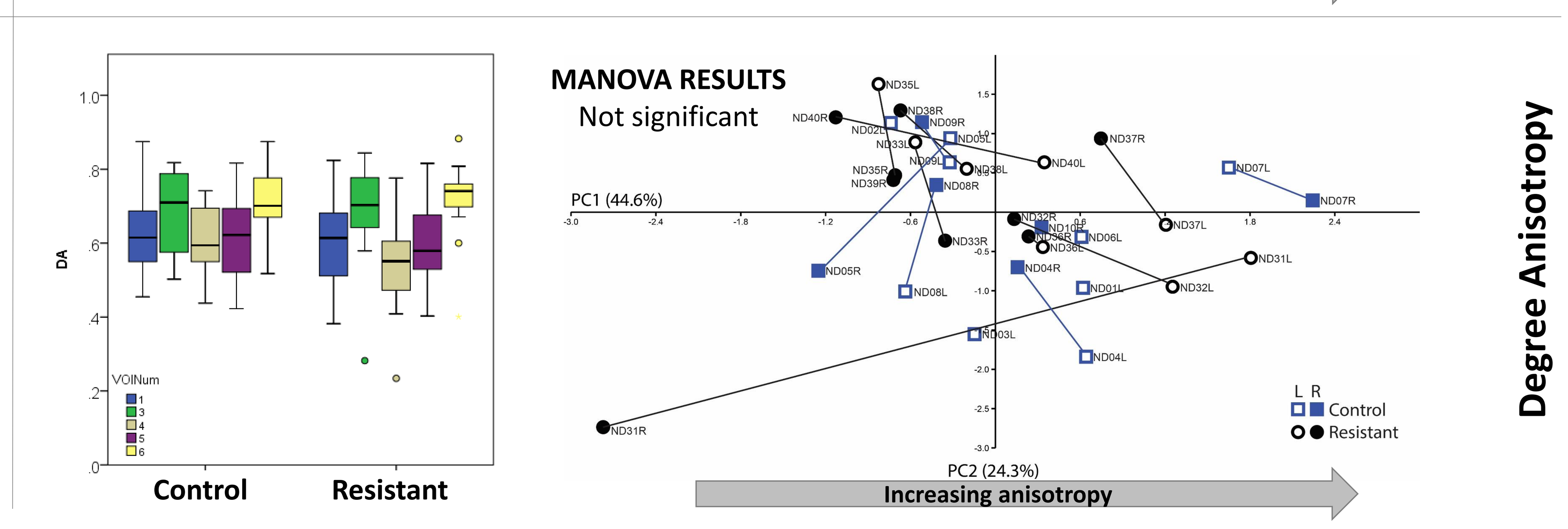
- Box plots, principal components analysis (PCA), and multivariate analysis of variance (MANOVA) (factors= treatment group, side, treatment*side) performed to examine and test for differences between groups

RESULTS:









DISCUSSION: We observe variation in trabecular properties across the condylar articular surface, between left and right sides of the same individual, and, as predicted, between treatment groups of rabbits. Results reveal that rabbits raised on a mechanically challenging diet (“resistant” rabbits; pellets + hay cubes), which results in greater cyclical loading[4], have significantly thicker condylar trabeculae and higher bone volume fraction relative to controls fed a pellet-only diet. These differences between rabbit groups are consistent with previous work demonstrating that these “resistant” rabbits have larger palatal, symphyseal, corpus, and condylar areas, as well as higher levels of biomineralization[5-7]. Importantly, these observed differences may exceed differences observed between different primate species[8]. These results suggest that adaptive plasticity is fundamental to consider when assessing fossil shape variation and may require reassessment of taxonomies and phylogenies, as well as a reconsideration of the form-function relationship in the masticatory apparatus.

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