

Trabecular Symmetry and Pathology in the Primate Temporomandibular Joint

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INTRODUCTION

While the dense outer shell of cortical bone comprises most of a bone's mass, the internal trabecular structure of bone serves the important function of redirecting and distributing the stresses placed on the articulating surface of the cortical shell. This trabecular bone is made up of interconnected struts and its morphology, sensitive to these loading patterns, responds to changes in loading environment throughout an individual's lifetime (Wolff, 1892). In the temporomandibular joint (TMJ), the mandibular condyle experiences joint reaction forces that then must be distributed through the skeletal element via the trabecular structure of the condyle. As a result, this trabecular structure should be responsive to variations in masticatory loading. However, previous studies have been equivocal in their findings regarding trabecular structure of the condyle and how it corresponds to Wolff's law (e.g., Ryan et al. 2010). Here we examine a sample of sooty mangabey (*Cercocebus atys*) crania with the goal of assessing condylar structure as it varies across the articular surface and in relation to left/right symmetry and pathology.

RESEARCH QUESTIONS

- 1) Are trabecular properties homogeneously distributed across the articular surface of the mandibular condyle of the TMJ?
- 2) Are trabecular properties symmetric between left and right condyles of an individual?
- 3) What role, if any, does pathology play on the trabecular structure?

MATERIALS AND METHODS

- μ CT scans of six male and six female *Cercocebus atys* (sooty mangabey) skulls (~68-81 μ m voxel size).



Analytical methods follow Sylvester and Terhune (in press)

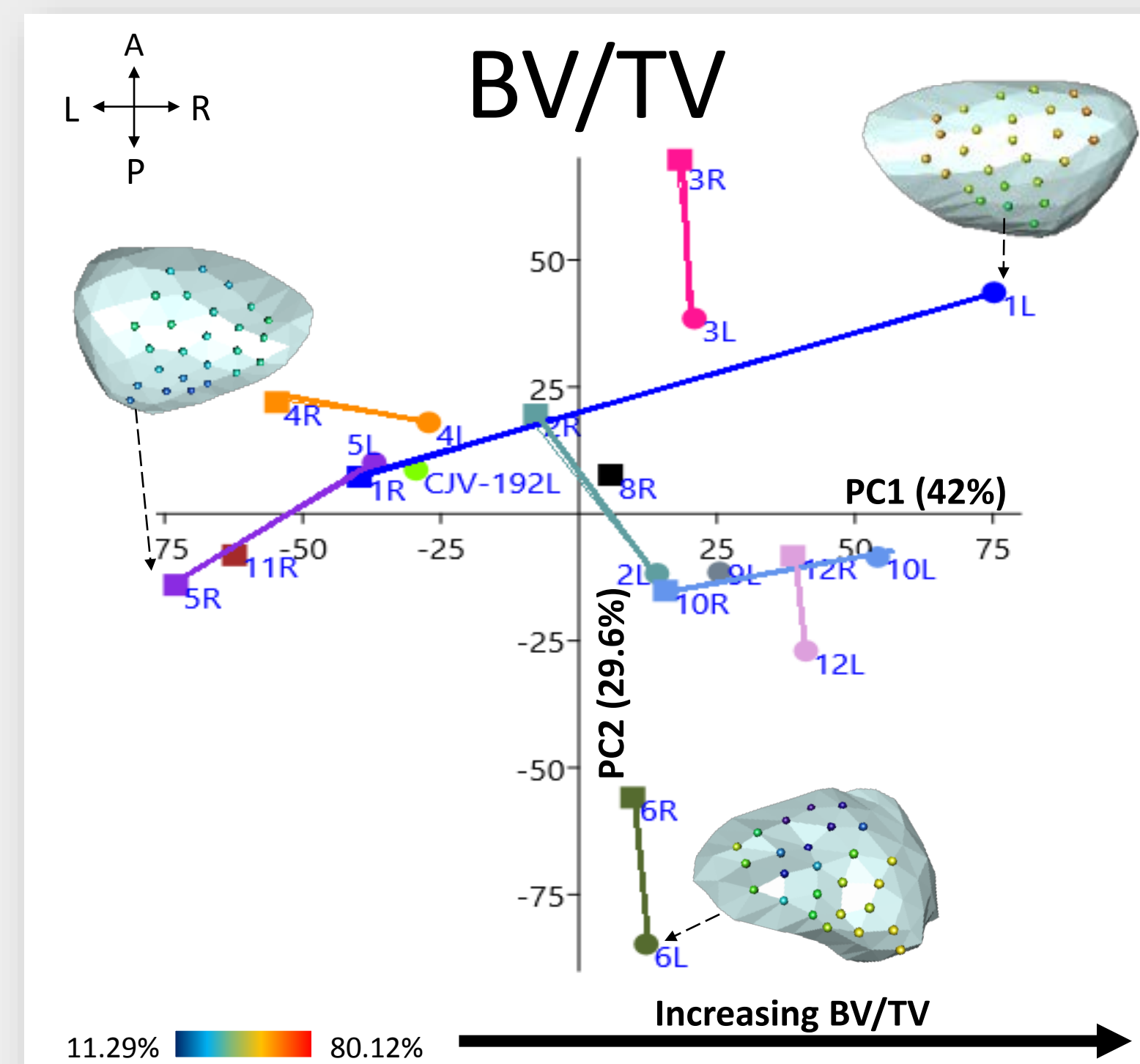
- Full image stacks trimmed to include only the TMJ segmented in Bone1 (Doube et al., 2010), and cortical/trabecular bone separated following Pahr and Zysset (2009)
- Condylar surface models trimmed to just articular surface, then used to place 83 sliding semilandmarks
- Spherical volumes of interests (VOIs) (~3mm diameter), corresponding to landmarks were slid down surface normal vector, perpendicular to condylar surface, until fully embedded in trabecular bone
- For each VOI we sampled the following parameters: BV/TV, Tb.Th, Tb.Sp, and DA
- 26 out of 83 VOIs used for analysis (only those with >80% of volume inside trabecular structure)

Name	Abbrev.	Units	Definition
Bone Volume Fraction	BV/TV	%	Percent mineralized bone in given volume of interest (VOI).
Trabecular Thickness	Tb.Th	mm	Average thickness of trabecular struts in VOI.
Trabecular Space	Tb.Sp	mm	Space between trabecular structures in VOI.
Degree of Anisotropy	DA	0=isotropic, 1 = anisotropic	Orientation of trabecular struts in VOI.

LITERATURE CITED

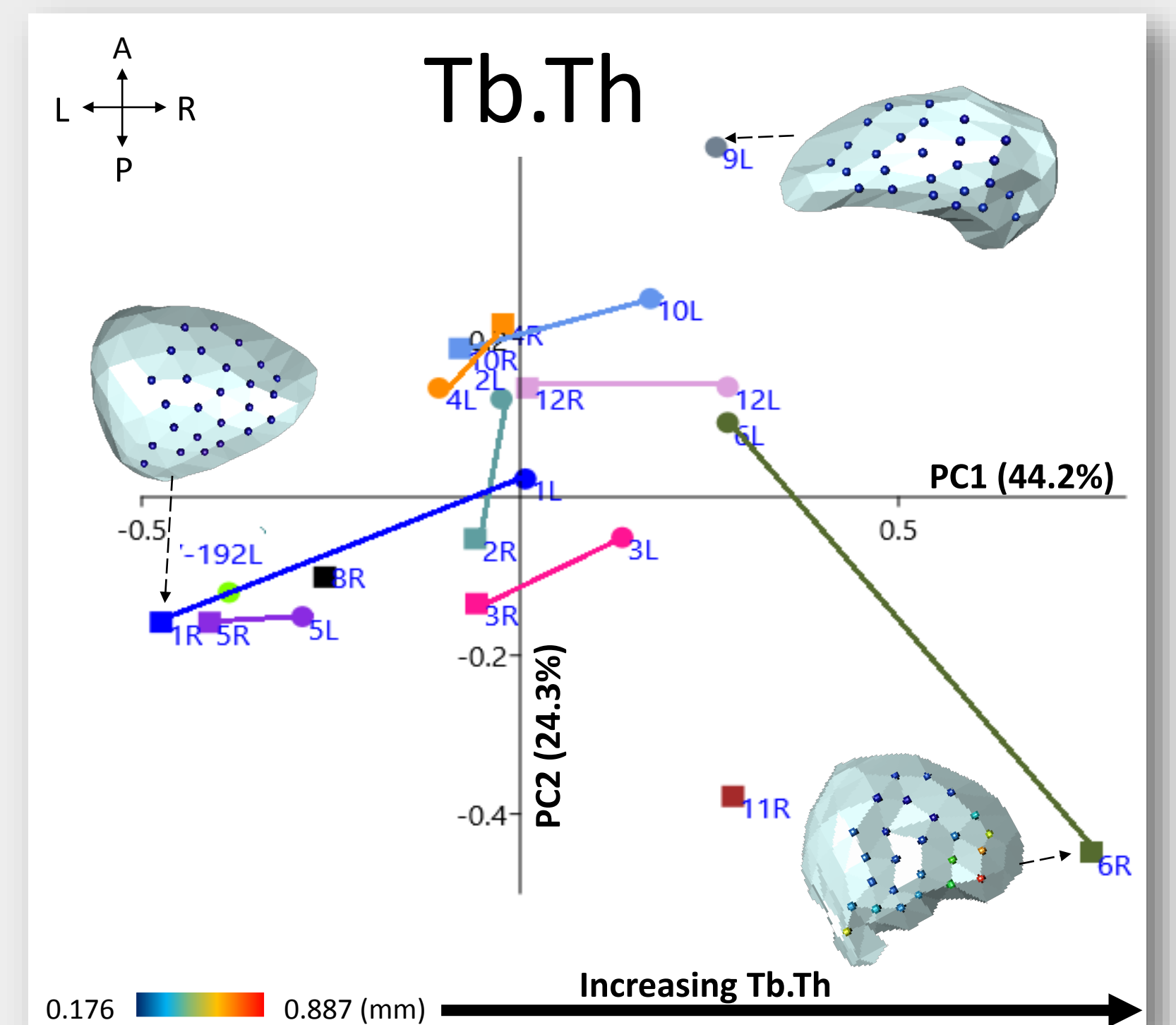
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RESULTS



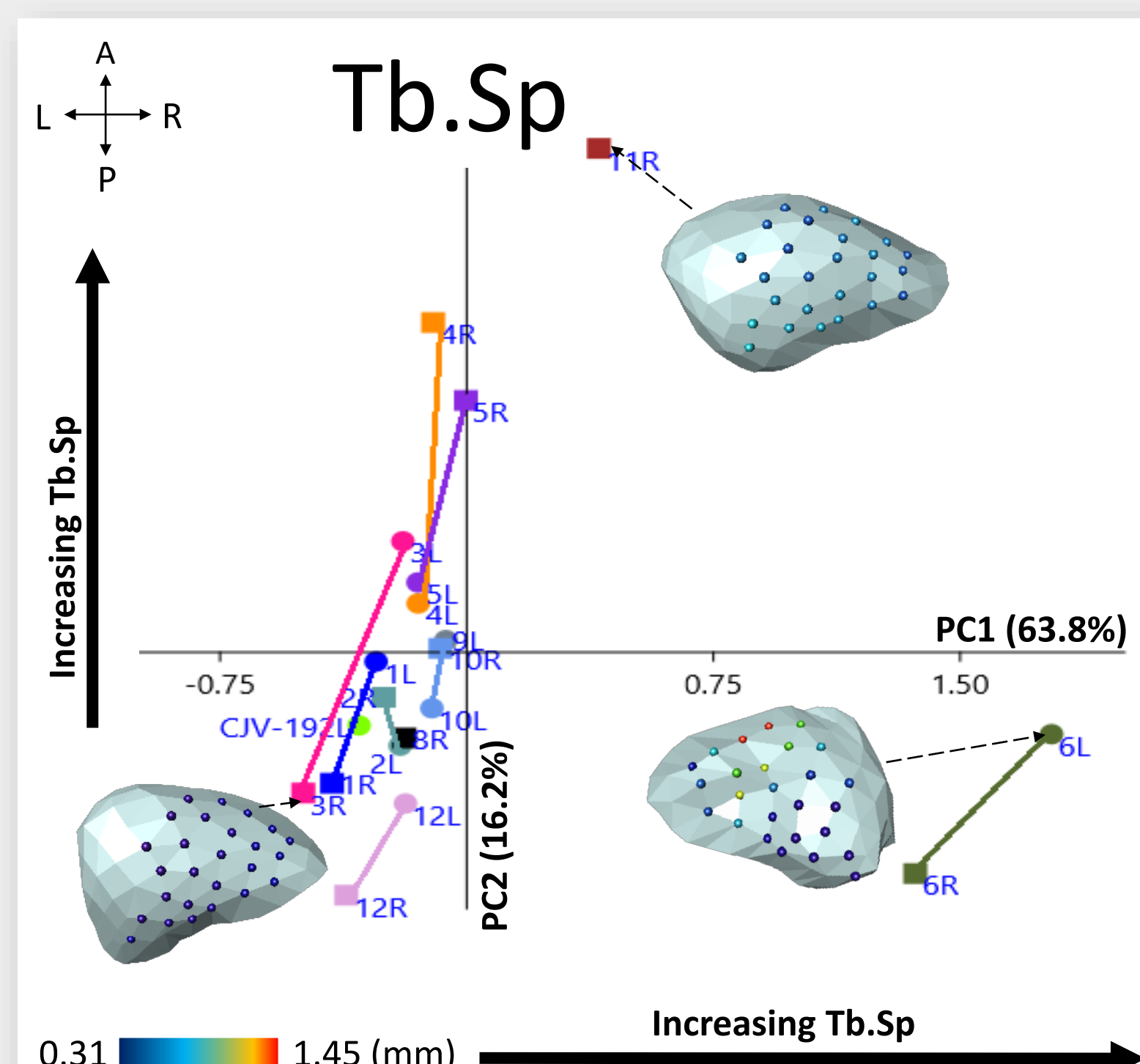
Bone volume fraction

- PC plot of BV/TV shows increasing values (for all VOIs) moving positively along PC1
- BV/TV is variable across specimens and L/R sides
- Pathological specimen ABT6 is clearly separate from other individuals



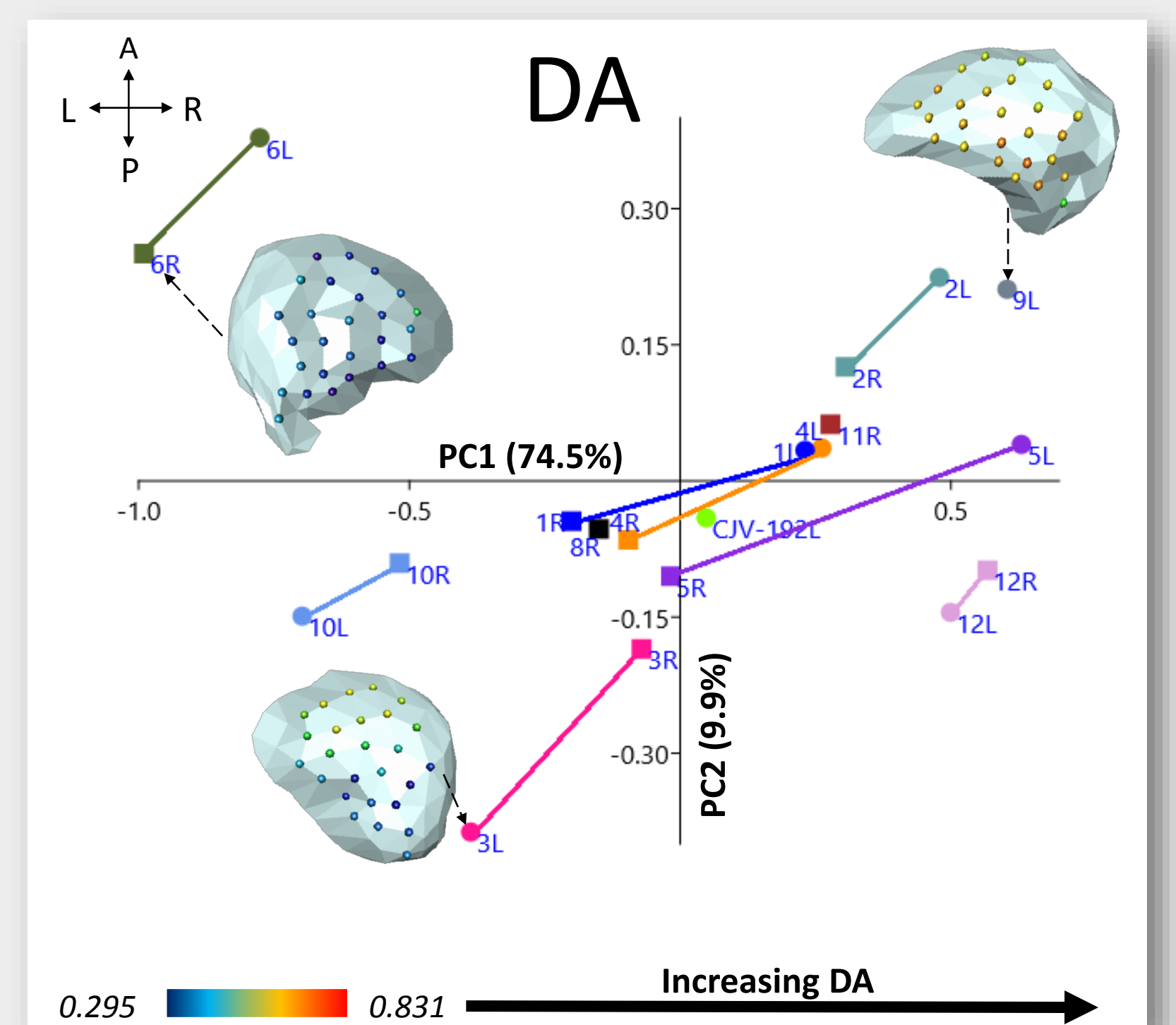
Trabecular thickness

- Tb.Th for all VOIs increases positively along PC1
- Higher values of Tb.Th on the medial and lateral aspects of the condyles
- Major deviations from the sample group by pathological individuals ABT6 (right) and ABT9 (left)



Trabecular Spacing

- Tb.Sp increases both on PC1 and PC2, though in different VOIs
- Nearly all specimens load on the negative end of PC1, except ABT6, which is highly pathological
- PC2 represents differences in Tb.Sp between L/R sides



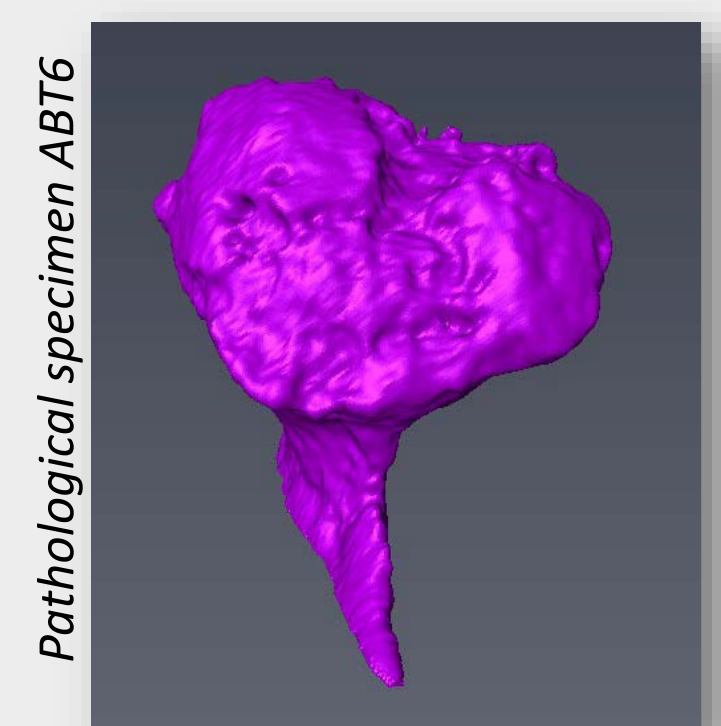
Degree of Anisotropy

- DA increases positively along PC1 for all VOIs
- Higher DA values on antero-lateral portion of condyles
- High levels of asymmetry between L/R sides demonstrated by PC1

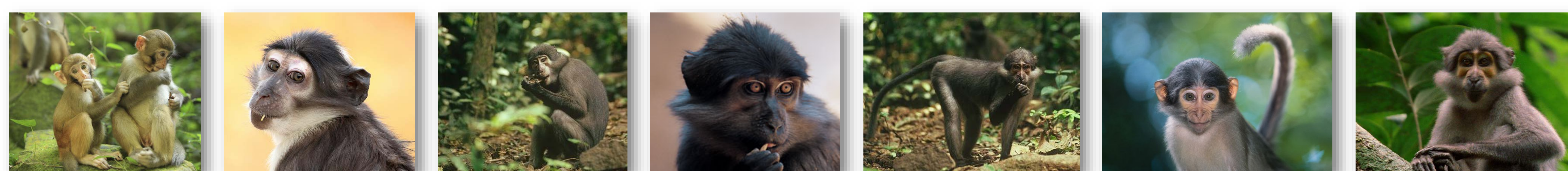
CONCLUSIONS

- We observed a clear lack of homogeneity in trabecular parameters across the articular surface of the mandibular condyle.
- Asymmetry between left and right condyles of an individual was evident. This corresponds to questions posed by Moffitt et al. (1964) and Hylander (2006) regarding unilateral chewing and its effect on force distribution between working and balancing sides.
- Pathological individuals frequently deviated from the larger sample (e.g., ABT6). This was true across all parameters. For example, the most pathological specimen in the sample, ABT6, demonstrated decreased bone volume fraction, increased trabecular spacing, and a lower degree of anisotropy corresponding with characteristics of a weakening bone structure.

These findings suggest that trabecular parameters vary substantially across the articular surface of the mandibular condyle, between left and right condyles of the same individual, and in relation to TMJ pathology. Documenting these sources of variation are critical for beginning to address questions related to reconstructing diet, behavior, and understanding disease processes from bone microarchitecture. Continual research with these techniques, especially employing geometric morphometrics to examine variation in trabecular structure across a joint surface (Sylvester and Terhune, in press), can allow for further inferences into understanding fossil hominins and comparing trabecular bone functional morphology across different species.



Pathological specimen ABT6



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