Intracortical Remodeling and Growth of the Macaque Mandible

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The aim of this study is to consider preferential collagen fiber orientations resulting from Haversian and growth remodeling and any correspondence that such orientations might have with bone strain. There exists a substantial literature on the relation between biomechanical influences and skeletal development. Experimental studies illustrate that surface bone growth remodeling processes are influenced by genetic, epigenetic, and environmental factors, of which the latter two include mechanical stresses. In addition, studies also show local intracortical bone remodeling to be a response to the mechanical milieu.

The present study examined how the bone surface microstructure resulting from the bone growth remodeling processes reflects the biomechanical conditions under which it was formed, and whether the published data on macaque functional strain patterns relate to microstructural components of secondarily remodeled intracortical bone. Patterns of strain in the mandible during masticatory and incisal activities were described in detail by Hylander et al.

Two subadult female Macaca fascicularis mandibles were made superficially anorganic, replicated with high-resolution silicone-based dental impression material, and positive epoxy resin replicas were prepared from the negative impressions. The bone was then cut into plane parallel 100 μm sections for quantitative circularly polarized light (CPL) study. Bone growth remodeling patterns were obtained from secondary electron emission mode SEM images of the positive replicas.

The results of the SEM-based bone growth remodeling studies agreed with histology-based studies of macaque facial remodeling and with established interpretations of the mineralized surfaces of forming and resorbing bone. There was a uniformity of construction of the macaque mandibular corpus. Lateral cortices of periosteal origin were constructed of and subsequently secondarily remodeled with collagen lying in the long axis of the corpus. Parallel-fibered circumferential lamellae and compact cancellous bone of endosteal origin laid down on most medial corpus cortices were composed of collagen oriented parallel with the frontal plane, perpendicular to the long axis of the corpus. This general pattern contrasted sharply with the heterogeneous in vivo strain environment and is in sharp distinction from bones with more uniform strain distribution. Thus there cannot be a correspondence between the distribution of peak principal strains and collagen fiber orientation. However, the longitudinally oriented collagen within the greater volume of bone of periosteal origin would confer resistance to tensile stress along the long axis of the corpus.

The results suggest that both the bone growth remodeling and the secondary Haversian remodeling mechanisms coordinate the production of preferentially oriented collagen and, furthermore, that they coordinate with one another in this duty. Despite this, one cannot fully accommodate these results with current knowledge of mandibular strain within a single unifying working hypothesis.

The results suggest that there exists a compromise between rules governing the construction of bone and strain-mediated development and adaptation. They further indicate that one cannot generalize about the nature of the strain-mediated response at the microscopic level to all bones or even parts of the same bone (e.g., the mandible). Because the stresses and strains imposed upon a bone are so complex or variable, in cases such as this, there may be strong developmental constraints as to how the bone is remodeled. Constraints must be higher for bones that may not experience significant stress but that require a strict genetic determinacy over their growth and shape.

References