" Strategies for Relating the Fracture Behaviour of Hard Tissues to Microstructure and Cell Function"

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Rather than describing the mechanical performance of biological hard tissues as primarily determined by their hierarchical nature, we take up the view that the structures are the result of specific actions of creation executed by cells (osteoblasts, osteoclasts, ameloblasts, odontoblasts, …), which have resulted in morphological characteristics that are in various ways optimal. In particular, those morphological characteristics that are commensurate with the cells that created them are known to be very important factors, if not dominant factors, in the mechanical performance of dental enamel, dentin, cortical bone, and trabecular bone. The creation of a tissue morphology can be posed as a purely mathematical problem, in which simple rules of generation govern the evolution of the structure from a set of initial conditions and result in a certain geometrical outcome. As a purely mathematical construct, such a rule-based generator can be an efficient method of creating a computational mesh that represents the morphology. However, the rules can also be interpreted in terms of the response functions of individual cells, providing a pathway from cell function to morphology and thence to mechanical performance. We illustrate these ideas by some preliminary and speculative work on dental enamel. We also argue the merits of embedding models of morphology in a top-down, rather than bottom-up, model of the overall mechanical behaviour of the tissue, with illustrations from fracture.