The effects of disuse- and overload-enhanced-resorption-characteristics on trabecular architecture

THE EFFECTS OF DISUSE- AND OVERLOAD-ENHANCED-RESORPTION-CHARACTERISTICS ON TRABECULAR ARCHITECTURE.

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INTRODUCTION

It is believed that osteocytes in the bone matrix serve as mechanosensors. The mechano-transduction of the signals goes through the osteocytic canalicular network (Burger, 1999). We assume that supernormal osteocyte signaling, from increased bone strains, stimulates osteoblastic formation. It is unknown what stimulus initiates the cascade of signaling processes that make osteoclasts resorb bone at particular sites on the trabecular surface. We hypothesize that micro-cracks and mechanical disuse may lead to subnormal osteocyte signaling, which may both stimulate osteoclastic resorption. This hypothesis may create a contradiction, as the locations of damage are those likely to be frequently high stressed in daily activity. Thus, osteoclasts would remove from the trabecular structure that material it needs most for maintaining strength. In this study, we investigate how alternative strain-based local stimuli for osteoclasts to resorb bone would affect remodeling and adaptation of architecture and mass at large. To investigate this, a computer-simulation model that earlier related trabecular morphogenesis and remodeling to mechanical load transfer was used (Huiskes et al., 2000).

METHODS

The simulations were performed on a piece of bone of 2x2 mm using a 2D FEA model. Five different resorption characteristics were studied in the model: (I) resorption occurs spatially random, (II) resorption is enhanced where there is disuse, (III) resorption is strongly enhanced where there is disuse, (IV) resorption is enhanced where there are high strains, and (V) resorption is strongly enhanced where there are high strains. The model was loaded by distributed stresses of 2 MPa, cycling at 1 Hz. To investigate the effects on remodeling, the stresses were applied to a morphological homeostatic model (fig. 1). To investigate the effects on adaptation, the stresses were applied at a different angle to the surface (fig. 2).

RESULTS

We found that the rates of remodeling, and structural adaptation to alternative loading, were higher for disuse-controlled resorption than for overload-controlled resorption. However, architecture and mass remained intact for all cases except (V) (Fig 1, 2). In the latter, strongly overload-enhanced process, the structure deteriorated as in osteoporotic bone; trabeculae became progressively thinner, and some were lost.

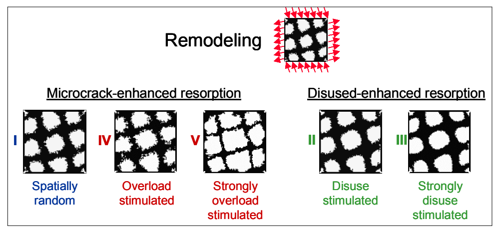

Figure 1: The effect of the five different resorption characteristics on remodeling.

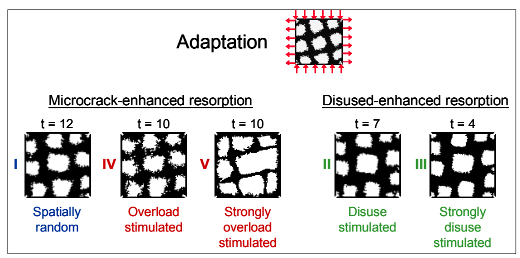

Figure 2: The effect of the five different resorption characteristics on adaptation.

DISCUSSION

We conclude that, given the potential of osteoblasts to form bone in highly strained areas, based on signals from osteocytes, osteoclastic resorption can be compensated for. The architecture remains stable within a wide margin of resorption characteristics, even when resorption is enhanced at locations where high strains are frequent. This explains the above contradiction. We hypothesize, however, that micro-damage in osteoporosis is likely to accelerate the process of architectural deterioration by enhanced osteoclast stimulation, creating instability in the control of the metabolic regulatory process. This may explain the occurrence of spontaneous vertebral fractures in the elderly.

REFERENCES

Burger *et al,* FASEB J 13:101-112, 1999.
Huiskes *et al*, Nature 405:704-706, 2000.