Bert van Rietbergen
Eindhoven Universty of Technology, Eindhoven, Netherlands
e-mail: b.v.rietbergen@tue.nl

A theory for load-adaptive bone remodeling at the cellular level

It is well known that bone tissue can adapt its shape and density to the mechanical demands it is subjected to. However, how, exactly, this process is regulated is not well known. Over the last decade we have developed a theory for load adaptive bone remodeling that is based on the hypothesis that osteocyte cells in the bone tissue can sense local loading conditions and based on this information regulate the activity of bone forming cells (osteoblast) and bone resorbing cell (osteoclasts) [1]. We tested this hypothesis using computational models that included finite element models to represent trabecular bone architectures and to calculate loading conditions at the location of osteocytes, In the earlier of these studies [2], only the net result of bone formation and resorption was represented by changes in the model geometry. In these studies we demonstrated that this theory can explain many aspects of bone remodeling that could not be explained before. First, it was shown that this theory can explain the formation of typical trabecular architectures (osteogenesis). Second, it was shown that the theory can explain the adaptation and alignment of trabecular bone as the result of a local adaptation process. Third, it was shown that the theory could explain the development of osteoporosis as the result of changes in cell activity or loading magnitude. In later studies [3] we increased the resolution to also represent individual cells. In these studies we demonstrated that the theory can explain the coupling between osteoclast and osteoblast cells in basic multicellular units as the result of changes in local loading condition sensed by osteocytes. It could also explain the formation of osteons in cortical bone and why these are oriented in the loading direction. Finally, although the biochemical pathway by which the osteocytes regulate the other cells was never specified, we were ble to demonstrate that both a stimulatory pathway, in which inicreased loading leads to increased stimulation of osteoblast, and an inhibitory pathway, in which increased loading leads to decreased inhibition of osteoblast (typically for sclerostin) could work. Presently it is investigated if this theory can be transformed into a clinical tool to predict bone remodeling in patients as expected due to changes in cell metabolism or loading conditions.

References

[1] Huiskes R, Ruimerman R, van Lenthe GH, Janssen JD. Effects of mechanical forces on maintenance and adaptation of form in trabecular bone. Nature. 2000 Jun 8;405(6787):704-6.

[2] Ruimerman R, Hilbers PAJ, van Rietbergen B, Huiskes R. A theoretical ramework for strain-related trabecular bone maintenance and adaptation. J Biomech,2005;38:931-41.

[3] van Oers RFM, Ruimerman R, Tanck E, Hilbers PAJ, Huiskes R. A unified theory for osteonal and hemi-osteonal remodeling. Bone 2008;42:250-9.