Preferential Orientation of Biological Apatite Crystallites in Bone and Regeneration of Anisotorpic Bony Tissue Surrounding Metal Implants

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The bone mechanical property depends on both bone quantity and quality corresponding dominantly to bone mineral density (BMD: density of biological apatite) and the integrity of the internal architecture, respectively. BMD is correlated with bone strength, but is not a index accounting for all of bone mechanical properties. Thus, new indeces representing the bone quality have been investigated so far because bone is a well-organized hierarchical composite at various scale levels. It was proposed by the National Institutes of Health in 2000 that bone strength should be represented and analyzed by bone quality as well as bone mass and bone mineral density (BMD). Microstructure organization, bone turnover rate, micro-crack occurrence, and cellular properties are important bone quality parameter candidates. Since BMD refers to the density of BAp, but the crystallographic orientation of BAp crystallites corresponds to the rotated degree of BAp crystallite, these two parameters are independent. In other words, BAp orientation is a possible bone quality parameter. Thus, our group is focusing on the preferential alignment of BAp *c*-axis orientation as a bone quality parameter under normal, pathological, and regenerated bones using the microbeam X-ray diffraction system.

The preferential degree of the BAp *c*-axis strongly depends on the bone position, *in vivo* stress distribution, bone growth, degree of pathology and regeneration, activity of bone cells, gene defect, etc[1-3]. We are challenging to clarify the BAp preferential alignment formation mechanism and to control the degree of BAp orientation by using an anisotropic biomaterial design to develop suitable distribution of the BAp *c*-axis orientation[4-6].

Correlations became clear among *in vivo* stress distribution, anisotropy of the BAp/Col alignment and the mechanical property in the original intact, regenerated and pathological hard tissues including mandible. Since BAp orientation distribution is essential microstructure for exerting mechanical, chemical and biological functions, technique for controlling the BAp orientation should be developed, especially in relation to tissue engineering technique in the lost bone tissue.

Because of the anisotropy of bone microstructure based on the BAp/collagen orientation distribution, development of implants for bone substitute should be considered by structural anisotropy. The Teflon implant with a unidirectional-elongated-through, for example, was implanted so that the elongated pore direction was parallel or perpendicular to the longitudinal axis of rat tibia with one dimensional orientation of BAp *c*-axis. As a result, the degree of calcification and the subsequent orientation of BAp are larger in the elongated pore parallel to the longitudinal axis than those in the pore perpendicular to the axis, indicating that BMD and BAp orientation of the newly formed bone can be controlled by the elongated pore direction closely relating to the anisotropic bone microstructure and principal stress distribution *in vivo*.

We aimed at the following three topics about the preferential alignment of BAp *c*-axis: (1) evaluation of the degree of BAp orientation; (2) control of BAp orientation based on metal biomaterial design; (3) and clarification of the mechanism for producing the BAp orientation *in vivo* or *in vitro*. In this study, our results regarding these three topics are introduced.

References

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