Mechanical Environment Differentiate New Bone Formation through Unidirectional Porous Hydroxyapatite Implanted in a Tibial Bone Defect of a Rabbit

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INTRODUCTION:
Porous hydroxyapatite (HAp) has been used as a bone substitute instead of autogenous bone grafts because of no donor site morbidity, fewer complications, as well as osteoconductivity. Previously, we reported a novel unidirectional porous hydroxyapatite (UDPHAp) with a porosity of 75% and a microstructure consisting of cross-sectional oval pores (diameter, 100–300 μm) that penetrate through the material [1]. UDPHAp exhibits good osteoconductivity and capillary formation implanted in the femoral intramedullary cavity in a rabbit [2, 3].

The objective of this study was to investigate the effect of mechanical loading condition on long-term bone remodeling in UDPHAp implanted into a tibial bone defect of a rabbit.

MATERIALS AND METHODS:
UDPHAp substitutes were obtained from Kuraray Medical Inc. (Fig. 1). A cortical bone defect (4.5 mm × 7 mm) was created at the proximal tibia of a Japanese white rabbit (body weight, approximately 3.5 kg), and HAp shaped in the form of an isosceles trapezoidal prism (Fig. 1) was implanted into the cavity (Fig. 2). The direction of the unidirectional pore was parallel to the long axis of the tibia. The tissue samples were harvested at 6 (n = 4), 52 (n = 2), and 104 weeks (n = 3) after implantation, and undecalcified ground sections stained with Villanueva Goldner stain were used for histological evaluation. Furthermore, the new bone area inside the HAp substitute was calculated using the image-analysis software MacScope® ver. 2.59. The mean percentages of new bone area in 3 fields per cortical side and 3 fields per medullary side were calculated (Fig. 3). For statistical analysis, the Welch’s t test was used, and significance was set at p <0.05.

RESULTS:
Histological findings revealed that osteogenesis inside the HAp substitute occurred at 6 weeks, increased at 52 weeks, and was maintained at 104 weeks (Fig. 4). The new bone was present along the wall of the HAp. Moreover, cortical bone and the new bone inside the pores were directly connected. The mean percentage of new bone area on the cortical side was 36.0%, 43.3%, and 36.9% at 6, 52, and 104 weeks, respectively. The mean percentage of new bone area on the medullary side was 27.7%, 31.0% and 28.3% at 6, 52, and 104 weeks, respectively (Fig. 5). Statistically significant differences were observed between the new bone areas at 6 and 52 weeks after implantation and between the cortical side and medullary side at all time points.

DISCUSSION:
This study revealed that UDPHAp showed good osteoconductivity and supported bone ingrowth for up to 2 years. New bone inside the HAp substitute was located to a greater extent at the cortical side than medullary side. These results suggest that the mechanical load from surrounding cortical bone or interaction between osteogenetic cells controls osteogenesis inside HAp bone substitute. UDPHAp has a unique micro-structure consisting of 100-μm to 300-μm pores penetrating through the material. This structure may be appropriate to maintain the structure of medullary canal due to the environmental interaction.

The cortical bone defect created in this study was similar to those often encountered by surgeons in clinical situations. UDPHAp can be used as a bone substitute for the treatment of cortical bone defects under weight-bearing conditions.

CONCLUSION:
UDPHAp offers an advantage with regard to bone formation and remodeling in the HAp substitute, especially under mechanical loading conditions for at least 104 weeks.

REFERENCES:

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