Histological Study Of Newly Formed Bone In Novel Unidirectional Porous Hydroxyapatite Using As Spacers For Double-Door Laminoplasty

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Introduction: A hydroxyapatite (HAp) spacer is widely used in orthopaedic applications due to its osteoconductivity. Because of the benefits of no donor site pain, shorter operative time, and decreased blood loss, using HAp spacers for double-door cervical laminoplasty to keep the split laminae “opened” has become remarkably popular. However, there are a few reports of neurological complications because of dural laceration by dislocated HAp spacers couple of years after implantation. Thus, new bone and tissue ingrowth inside HAp spacer is crucial for long-term stability.

We developed a novel unidirectional porous HAp which has a purity above 99.9%, a porosity of 75%, and penetrating oval pores 100–300 µm in diameter and reported its advantages in migration for osteogenic and angiogenic cells inside HAp and in mechanical strength after implantation in the femur of rabbits at the 54th annual meeting of the Orthopaedic Research Society. In this study, we investigated histology of newly formed bone in HAp spacers using for double-door laminoplasty in beagles.

Materials and Methods: Four adult beagles (Body Weight: about 15 kg) were used in this study. Unidirectional porous HAp was obtained from Kuraray Co., Ltd. Under general anesthesia, we made skin incision between L1 and L6 in supine position, and exposed 6 spinous processes and 6 laminae. After resection of spinous processes at the bottom, we split in the middle of the laminae and made side gutters using 1mm high-speed drill. Then we performed double-door laminoplasty by opening the split laminae. We made a 1mm hole through the split lamina and fixed the HAp spacer between the split laminae by nylon suture. We randomized the level of implantation and used 2 unidirectional HAp spacers in each beagle. It has trapezoidal shape (top: 3mm, bottom: 5mm, height: 5mm) and 10mm in length. For suture fixation, 1 mm diameter hole was made in the center of side walls. The direction of the unidirectional pore was perpendicular to the axis of the spine. For comparison, we chose two other HAp porous spacers which have almost same porosity. (APACERAM® PENTAX, Tokyo, Japan and NEOBONE® COVALENT MATERIALS, Kanagawa, Japan), cut into the same size and used 2 of each at randomized levels. NEOBONE® has interconnective porous structure.

The animals were sacrificed 3 and 12 weeks (2 beagles respectively) after implantation. Lumbar spines were harvested in whole and fixed in 4% paraformaldehyde. We performed histological evaluation with hematoxylin and eosin staining after decalcification. Some of these samples were evaluated with Villanueva bone staining without decalcification. For evaluation of newly formed bone, we measured the length of direct bonding or bone ingrowth at HAp spacer wall and calculated the ratio to the length of bone-spacer. (Fig.1) We categorized the ratio in “zero”, “zero to 1/3”, “1/3 to 2/3”, and “2/3 and more” and counted the numbers of side walls. A HAp spacer has 2 side walls and each spacer was implanted 2 levels respectively in a beagle, so the numbers of spacer walls were 8 in each group. (Table 1)

Results: Two laminae broke during the study. One was in the 3 weeks group, APACERAM® was implanted, and the other was in the 12 weeks group, APACERAM® was implanted. These were excepted from evaluation. There were no other operative complications such as dural laceration, paraparesis, infection, or dislocation of HAp spacers.

In 3 weeks group, histological findings show that direct bonding was partly observed at the surfaces of unidirectional spacers, but fibrous tissue was mostly observed between spacer and lamina. On the other hand, osteogenic cells and newly formed bone were partly observed at the edge of the spacers. (Fig. 2 left) In 12 weeks group, direct bonding and bone ingrowth were increased compared with the 3 weeks group. Newly formed bone and capillary were partly observed inside the unidirectional spacers especially the dural side. (Fig. 2 right)

Discussion: Blood and bone marrow sink into the unidirectional pores by capillary phenomenon. And the unique pore size (100 – 300µm in diameter) is suitable for cell migration and angiogenesis. So we expected that the unidirectional HAp spacers had advantages to the other spacers in osteoconductivity. However, this study revealed that it has equal to the other. The laminae of beagles were so thin that there were not enough bleeding. We supposed that the spacer could not obtain enough blood supply to make advantages in osteoconductivity. It is considered that long term study using large-sized animal such as goats is necessary to clarify the osteogenesis deeply inside the spacers and the remodeling of HAp.

References:

<Fig. 1> Scheme of laminoplasty and method of osteogenesis evaluation

<Fig. 2> Histological image (Villanueva bone stain)

<Table 1>Summary of calculation of osteogenesis length

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