OSTEOCONDUCTION AT POROUS HYDROXYAPATITE WITH CYLINDRICAL PORE CONFIGURATION

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Relevance to Musculoskeletal Conditions: Porous hydroxyapatite (HA) is biocompatible and osteoconductive. Optimal pore geometry for osteoconduction, however, has not been determined yet. This study shows different pattern of bone ingrowth to porous HA with cylindrical pores compared to random pore configuration.

Introduction: Porous HA has been used as artificial bone graft material in many experimental and clinical trials [1-6]. In these studies, it was claimed that a minimum pore size of 10μm is necessary for bone ingrowth into the porous implant materials [3]. Most of these studies were based on the results with implants of random pore geometry. Porous HA with random pore configuration (coral and other synthetic HA) has pores of various sizes with much smaller interconnecting fenestration. It is suspected that the size of interconnection was main rate limiting factor of osteoconduction rather than the pore sizes [4]. We have developed porous HA with parallel cylindrical pores without interconnecting fenestration between adjacent pores to evaluate the actual effect of pore size on osteoconduction. The objective of this investigation was to assess both the histological response and the reinforcing effects of bone ingrowth within porous HA implants depending on pore geometry.

Methods: Stoichiometric HA powder (Ca/P ratio 1.67) was synthesized by solid state reaction using CaP-O3 and CaCO3. Preforms of pores were nylon fibers for cylindrical type, polyurethane foam for sponge type and polyester net for cross type of porous HA. After coating with HA slurry, sheets of preforms were compacted into block shape, which were then burned out and sintered. Four kinds of cylindrical type (450, 100, 300, 500μm), one sponge type (15mm) and one cross type (500x120μm) of porous HA were selected for animal experiment. Eighty-four white rabbits weighing about 3.5Kg were divided into 6 groups according to the types of porous HA implants. 5x5x7mm sized porous block was inserted into the corticocancellous defect through medial cortical window (5x5mm) of proximal tibia. Four rabbits of each group were sacrificed at 4 weeks after implantation and remnants were killed at 8 weeks. Histomorphological changes were examined using light microscopy (Goldner’s modified Massen trichrome staining and hematoxyline & eosin staining) and scanning electron microscopy (Phillips, XL-20). Biomechanical compression test was performed using material test machine (Instron 5585, 5565, static mode, cross head speed 0.1mm/min) and comparisons were made among the six HA groups using Wilcoxon rank sum test and median test.

Results: HA implants appear to have no early adverse effects, such as inflammation and foreign body reaction. Osteoconduction through pores was found in all six implants and new bone was on the surface of pores with no histologically demonstrable intervening nonosseous tissue. At four weeks after implantation, the implants showed different histological changes depending on to pore geometry. In cylindrical type porous HA, new bone was arranged concentric pattern around vessel(s) (one for 50 and 100μm, multiple for 300 and 500μm) similar to cement. In sponge and cross type, irregular woven bone pattern was found. New bone formation through pores was most evident at 300μm sized cylindrical type porous HA. At 8 weeks, active osteoconduction was also found at 450μm sized cylindrical type porous HA. Evidence of remodelling of new bone and bone marrow formation within porous HA was found at larger cylindrical type (500, 100μm), sponge and cross type. In biomechanical study, ultimate compressive strength has significantly increased at 450μm cylindrical type, sponge and cross type after 8 weeks implantation compared to preimplantation (Table 1). Considering macroporosity of porous implants, 300μm cylindrical type showed best results in terms of increment of strength.

<table>
<thead>
<tr>
<th>HA type</th>
<th>Pre.(n)</th>
<th>Post.(n)</th>
<th>Inc.</th>
<th>Inc/MP</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>50</td>
<td>12.7(3)</td>
<td>14.5(3)</td>
<td>1.8</td>
</tr>
<tr>
<td>C</td>
<td>100</td>
<td>6.12(5)</td>
<td>8.65(3)</td>
<td>2.5</td>
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<tr>
<td>C</td>
<td>300</td>
<td>7.98(4)</td>
<td>15.8(3)</td>
<td>7.8*</td>
</tr>
<tr>
<td>C</td>
<td>500</td>
<td>10.3(4)</td>
<td>11.5(4)</td>
<td>1.2</td>
</tr>
<tr>
<td>Sponge</td>
<td>0.24(5)</td>
<td>4.3(5)</td>
<td>4.3*</td>
<td></td>
</tr>
<tr>
<td>Cross</td>
<td>0.19(3)</td>
<td>7.83(5)</td>
<td>7.6*</td>
<td>24.9</td>
</tr>
</tbody>
</table>

C: Cylindrical pore configuration
Pre.: Pre-implantation
Post.: Post-implantation 8 weeks
Inc.: increment of strength
MP: macroporosity

*statistically significant (Wilcoxon rank sum test and median test)

Discussion: Porous HA implanted into rabbit’s tibia showed biological fixation and osteointegration. It has been known that the optimal osteoconductive pore size for ceramics appears to be between 150 and 500μm [5]. In this study, a pore size of 300μm was most effective for bone ingrowth. At 50μm sized cylindrical pores, active osteoconduction was happened. But in porous implants with same sized random pore geometry, much smaller interconnections (less than diameter of capillary, 20-30μm) and lower rate of bone resorption of HA may delay or block osteoconduction [6]. In accordance to bone formation pattern, the pattern of new bone formation was different and it may have influence on biomechanical strength. All four cylindrical type porous HA showed greater compressive strength than normal cancellous bone (7-8MPa) at pre- and post-implantation. Porous HA with cylindrical pores would be one of the useful graft materials due to its strength, osteoconductivity and easiness of controlling pore geometry.

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References:

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