Animal Study of Various Types of Porous Calcium Phosphate Substitutes

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Introduction: Porous hydroxyapatite is one of the most extensively studied materials for alternatives to autogenous bone grafting. Although it is osteoconductive, biocompatible, and has good mechanical properties among the calcium phosphate compounds, it is relatively bioinert and remains in the host body for a long time. For this reason, many other calcium phosphate compounds such as tricalcium phosphate were studied. However, the comparative studies of aspects of bone ingrowth in bone substitutes of various chemical compositions are few. The purpose of the present study was to compare the osteoconduction in porous bodies made of various compositions of calcium phosphate compounds and other porous artificial bones.

Methods: Hydroxyapatite, β-Tricalcium phosphate, and β-calcium pyrophosphate were prepared by solid state reaction of high purity $Ca_2P_2O_7$(99.9%, Aldrich co. USA) and $CaCO_3$(99.99%, high purity chemical, Japan). Sponge type porous bodies were made using polyurethane foams having randomly interconnected pores and 60ppi size. Polyurethane foams were coated with each kind of calcium phosphates slurry. They were burned out and sintered at 1100 - 1300℃ for 2 hours. The resultant porous sintered bodies had 300-500mm pore size and 75% porosity. Single-level inter-transverse process spinal fusions were divided into nine groups (ten rabbits per group) by the type of bone graft materials: autograft(positive control); implantation of Lubboc, Calcium sulfate pellet(CSP), hydroxyapatite(HA), calcium pyrophosphate(CPP); no-graft after decortication(negative control). All animals were killed at 4, 8, 12 weeks after surgery. The extent of fusion was evaluated by radiography, manual palpation, uniaxial tensile strength measurement, light microscopy and SEM. Before tensile strength measurement, all soft tissue was removed from fused part to leave only the fused part. The tensile strength of the fused part was measured.

Results: Fifteen rabbits (17%) were excluded due to complications. Of the remaining seventy five rabbits, bone fusion was detected by manual palpation in all autografted group and of the CPP implanted group, six of seven of Lubboc implanted group, eight of ten of HA implanted group, six out of ten of the HA/TCP implanted group, three out of eight of the TCP group, five out of ten in the TCP/CPP implanted group, and none of the no-graft group and CSP group. The autografted and the CPP implanted group showed much more fusion ratio than the TCP implanted, the TCP/CPP implanted, and the no-graft group. From the radiological examination, the TCP implanted group seemed to show more rapid absorption of implant in rabbit body than the CPP and the HA group. The result of direct inspection and microscopic examination showed the TCP implants lost their porous structure, whereas the other implants did not. The mean values of tensile strength of the autografted and the CPP implanted groups were significantly larger than those of the Lubboc implanted, TCP implanted, the TCP/CPP implanted, and the no-graft group. SEM findings showed the tight bond between calcium sulfate graft and newly grown bone tissue.

Table 1. Comparision of fusion ratio and mean tensile strength(* & **: statistically significant by Kruskall-Wallis test, $P<0.05$)

Group	Solid fusion mass on manual palpation	Mean tensile strength(N)
No graft	0/9**	0**
Autograft	7/7*	138±9
Lubboc	6/7	102±43
CSP	0/10**	0**
HA	8/10	189±46
HA/TCP	6/10	128±54**
TCP	3/8**	120±10**
TCP/CPP	5/10**	140±53
CPP	7/7*	191±56*

Conclusions: Based upon the above observations, we concluded that the calcium sulfate pellet could not conduct the growth of new bone efficiently because lack of porous structure and excessively rapid biodegradation. The porous b-TCP grafts lost their porous structure 12 weeks after implantation in the living rabbit body, which caused in the poor osteoconduction when compared with b-CPP grafts and HA grafts. These results suggest that the maintenance of porous structure is considered to be indispensable for osteoconduction. The porous b-TCP implants showed the fusion ratio and the tensile strength of fusion masses similar to those of the porous HA implants, however, more rapid resorption than the porous HA grafts. These findings suggest that porous b-CPP grafts could be more desirable bone graft substitute.

References:

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