PERMEABILITY OF CORALLINE HYDROXYPATITE

Introduction: Coraline hydroxyapatite (ProOsteon®500, Interpore International, Irvine, CA), is a clinically successful bone substitute that has been shown to allow bone integration while possessing similar ultimate strength and higher Young’s modulus values than human trabecular bone (1). Previous investigation of the fluid mechanics of trabecular bone grafts has shown that inter trabecular permeability and geometry is vital for vascularization (2), indicating that permeability is an important biomechanical parameter to consider for bone substitutes. The overall goal of this work was to determine the permeability of coraline hydroxyapatite and compare it to trabecular bone.

Methods: Cylindrical specimens (8 mm diameter, 15 mm long) of coraline hydroxyapatite with an apparent orientation of either 0, 15, 30, 45, 60, 75 or 90 degrees with respect to the cylinder axis, were cored from a single coral head. Trabecular bone (same dimensions as above) from the human vertebral body, femur, and bovine tibia were cored either parallel or perpendicular to their apparent trabecular orientation. The permeability, k, of coraline hydroxyapatite was measured using a constant flow-rate permeameter and Darcy’s Law (3). Volume fraction was then measured using Archimedes’ Principle. These properties were then compared to those previously measured for human vertebral and femoral and bovine tibial trabecular bone (3).

Results: Regardless of the orientation, permeability of coraline hydroxyapatite was 0.49 x 10^{-9} ± 0.12 x 10^{-9} m^2, ranging from 0.29 x 10^{-9} to 0.68 x 10^{-9} m^2 (n=9). The permeability of human and bovine trabecular bone ranged from 0.02–20 x 10^{-9} m^2, which was dependent upon anatomic location, volume fraction, orientation, and species. Mean volume fraction of coraline hydroxyapatite was 0.32 ± 0.02 ranging from 0.30–0.35. The volume fraction of the human and bovine trabecular bone ranged from 0.05–0.36, which was dependent on anatomic location, flow direction, and species. Correlation between the orientation and permeability of coraline hydroxyapatite indicated a negative but not significant (p=0.07) trend.

Discussion: Since previous work has shown the importance of permeability for vascularization, analysis of the pre-implantation permeability of bone substitutes may be an important measure of potential bone ingrowth. The comparison of permeability of coraline hydroxyapatite vs. trabecular bone (Figure 1) reveals that although the mean permeability values of coraline hydroxyapatite are substantially lower than those of vertebral trabecular bone, they do fall within the range of reported values for other sites and flow directions (3). Interestingly, the smaller pore size and higher volume fraction of coraline hydroxyapatite substantially decreased its permeability, though it still was within the physiological range of permeabilities found for human trabecular bone. Further, the mean permeability values for coraline hydroxyapatite were most similar to that of the transverse bovine tibia, which has a lower volume fraction and a largely plate architecture (Figure 2). Though there was not a significant correlation between the apparent orientation and permeability of coraline hydroxyapatite, there was a trend in this respect towards a negative correlation. Thus, it is likely that proper alignment of coraline hydroxyapatite with the direction of fluid flow in vivo may optimize bone integration.

References:

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