# Bimodal porosity in bone scaffold materials: dual function of enhancing both biological function and fracture energy?

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**Abstract**

The biological community recognizes that the bimodal pore architecture of natural bone (which includes populations of large and small pores, Figure 1) serves a biological function. Relatively independently, a few researchers working with structural ceramic materials have investigated improvements in purely mechanical properties that can be associated with bimodal pore distributions.[1-6] Interesting and useful synergisms concerning biological function and fracture energy in ceramics and bioceramics having bimodal porosity may be potentially exploitable, but only through the careful evaluation, application and extension of the available knowledge base. Currently, the literature on bimodal porosity in ceramic materials is viewed disjointedly in these occasionally isolated intellectual communities (namely, bioceramics and structural ceramics). Boosting the mechanical properties (such as fracture energy) represents a potential avenue for optimizing the fracture energy of bone scaffolds materials while simultaneously providing the bimodal porosity required for biological function.

Studies of structural ceramics such as silicon nitride[5,6] silicon carbide[2] and alumina[1,3,4] have shown that bimodal porosity distributions can result in up to roughly an order of magnitude increase in fracture energy. In contrast, unimodal porosity distributions (Figure 2) lead to a decrease in fracture energy as a function of increasing volume fraction porosity.[7,8] Model porosity/crack studies involving arrays of holes in polymethylmethacrylate (PMMA) sheets also show a drop in fracture properties with an increase in the area density of pores than are of a uniform size while bimodal distributions of holes boost the effective fracture energy.[3] Bone scaffold design criteria based on an idealized biomimetic bone scaffold material seek to duplicate the pore size distribution in natural bone. However, it is in fact extremely difficult to produce pores in synthetic bone materials that appropriately reproduce the complicated pore architecture of natural bone. However, the goal need not be to duplicate the complex pore structure of natural bone. In this presentation, we suggest that a paradigm shift may be in order, in that there may be many different bimodal pore architectures that yield comparable mechanical properties. A crucial advantage of investigating the general category of bimodal pore distributions (rather than attempting to duplicate bone structure) is that such an adequate pore architecture may in fact be much easier to fabricate than materials with bone-like pore distributions, while retaining the mechanical and biological functions of natural bone.

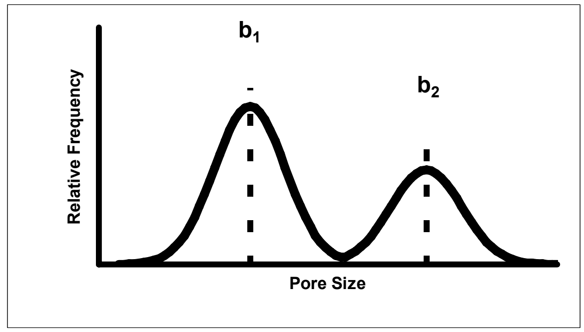


Figure 1 Pore size distribution for bimodal pore distribution. The parameters $b_1$ and $b_2$ are the mean pore sizes for the smaller and larger pore populations, respectively.

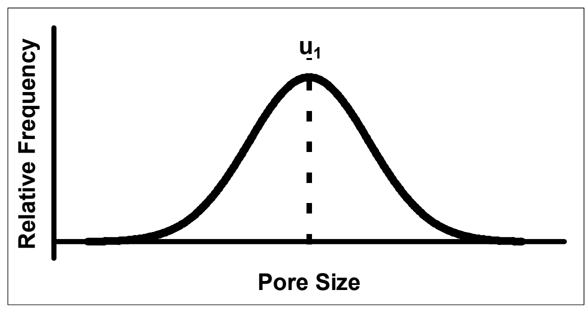


Figure 2 Pore size distribution for unimodal pore distribution, where $u_1$ is the mean pore size.

## References

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