

Quantification of Porosity, Connectivity and Material Density of Calcium Phosphate Ceramic Implants Using Micro Computed Tomography

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Introduction: Calcium phosphate ceramics have been widely investigated in orthopaedic tissue engineering and surgery as bone extensor. Attention has been given to manufacturing of a porous ceramic that mimics the trabecular bone structure for better osteoconduction. Although different methods have been applied to manufacture the porous structure, it was unable to quantify the pores and their interconnection within the ceramics. With the advance of biomedical imaging technologies, the study attempted to quantify the pore structure of different ceramics using a high-resolution micro-computed tomography (microCT).

Materials and Methods: Three kinds of ceramic blocks with product names, BSC, ChronOS, and THA, respectively, were synthesized by three methods from three different manufactures and evaluated in the study. The specification claimed the porosity of the ceramic ranged from 40% to 80%. Six blocks of each ceramic were evaluated by conventional water immersion method and μ CT. The pore size and connectivity of the pores were evaluated with standardized protocols. By the water immersion method, the porosity of three ceramic was ranged from 60% to 78%. The three-dimensional analysis of the pores by μ CT showed that the porosity of the ceramics was 26.2% for BSA, 59.9% for ChronOS, and 67.7% for THA. The pore connectivity was 2.7 for BSC, 39.7 for ChronOS, and 7.1 for THA. The ChronOS had more functional pores (200-400 μ m in diameter) than that of the BSC (52.8%) and THA (43.2%) ($p < 0.05$).

Discussion and conclusions: It was shown that the distribution of the pore size of three different ceramics has different characteristics. We speculated that different combination of structure parameters may have different in vivo property in osteogenesis while the chemical property of the ceramics cannot be neglected in the in vivo performance. Providing objective information on the functional pores, the microCT evaluation serves as a good standard for specification of the ceramic-related implants in the future characterization of scaffold biomaterials for orthopaedic and related medical applications.

Significance of the study: The results and methods developed above have been adopted into our ongoing studies, including the one on 'Cocktail Therapy Developed for Repair of Steroid-induced Osteonecrosis', which evaluates the potential of a combination of biological (autologous bone marrow mononuclear cells), biomaterial (ChronOS), and biophysical (low-intensity pulsed ultrasound) intervention for improvement of prognosis of core-decompression in steroid-associated osteonecrosis.