Novel re-entrant porous composite structure: a potential for orthopaedic applications

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It was hypothesized that the nonlinear load-displacement relationship displayed by bone could be conferred on an implant by tailoring its structure, yielding an enhanced mechanical stimulation of the tissues. Composite structures would feature piezoelectric properties that could also stimulate osteogenesis. Preliminary mechanical and electromechanical investigations of such porous structures are presented. Initial trial bowtie specimens with various aspect ratii were made from Nickel powder via a solid free form process and from stainless steel shim stocks. Poled Barium Titanate plates were sandwiched between stainless steel bowtie cells to create composite structures. Results: Under quasi-static compression, the Nickel structures displayed a nonlinear mechanical behavior at small strains and an overall strain-stress relationship similar to bone. Under cyclic compressive tests to 0.6 percent strain, all structures presented a repeatable nonlinear strain-stress behavior. The curves were fitted by a second-order polynomial whose coefficients are function of the relative density of the structure to a power n. Composite stainless steel/BaTiO3 bowtie structures confirmed that their electromechanical properties can be tailored. Discussion: Certain patients present metabolic degeneration that hamper bone healing. A ductile and tough structural material with piezoelectric properties such as the new composite structures in development presents the potential to overcome those limitations. They could have the advantages of existing devices without some of the drawbacks. Those porous implants may reduce the needs, costs, and risks linked to the additional use and implementation of an electrical stimulator and BMPs. Furthermore, the solid free form technique gives control over the mechanical properties of the structure. Thus, the mechanotransduction activity of biologic cells can be fully exploited to trigger a faster implant-tissue bonding, which could lead to reduction of surgical cost and time.