A Comparative Study of Synthetic Bone Grafts in a Canine Metaphyseal Defect
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Introduction: Over 800,000 bone grafting procedures are performed in the U.S. each year (1). Autograft, usually taken from the iliac crest, is considered the gold standard for these procedures. There are, however, several disadvantages to using autogenous tissue, the first of which is an inherently limited quantity. Harvesting the bone also requires increased operating time and creates the potential for various complications which can lead to longer recovery times, prolonged disability and even chronic pain (2). The high cost and additional risks associated with autograft have led medical researchers to search for an alternative. Allograft, or donor bone, is an obvious choice but it also has many drawbacks including high cost, potential for disease transmission and variable clinical performance.

Several ceramic materials have shown promise as synthetic alternatives to autograft and allograft. Calcium phosphate ceramics have been used in medicine and dentistry for over 30 years (3). The most notable of these ceramics include tricalcium phosphates (TCP) and hydroxyapatite (HA), both of which have shown the ability to support the ingrowth of bone.

There are three essential elements which are necessary to facilitate the generation of new bone tissue: an optimized scaffold for osteoconduction, signals or growth factors for osteoinduction and progenitor cells for osteogenesis. An effective bone graft substitute needs to provide for all three of these requirements.

Materials and Methods: Four different synthetic bone graft substitutes were studied in the same skeletally mature canine model: An HA scaffold derived from natural coral (Pro Osteon® 500R), an HA material in which silicate ions have selectively replaced phosphate groups in the calcium phosphate lattice (Actifuse™), a β-TCP scaffold with 90% open and interconnected porosity (Vitoss®), and an HA/β-TCP composite scaffold (Mastergraft™).

Figure 1. SEM images of each of the study materials

Each material was implanted and filled a drill hole defect, approximately 10mm in diameter and 25mm deep, in the metaphyseal region of the proximal humerus. Healing was evaluated at 3, 6, 12, 24 and 52 weeks. At each time point a 5mm section was cut orthogonal to the long axis of the cylindrical defect. A Faxitron X-ray Cabinet was used to obtain a radiograph of each section. Histology slides were prepared by an outside vendor.

Results: The results of this study suggest that all of the materials tested support bone growth into a canine metaphyseal defect. There was no evidence of foreign body reaction to any of the products in this study. At 12 weeks quantitative histomorphometry shows that Vitoss Scaffold is 86% resorbed and the ratio of bone in the defect to adjacent bone is 1.2, demonstrating a high degree of bone remodeling at the defect site (Figure 3). By 52 weeks there was almost no Vitoss remaining and the amount of bone in the defect site was well within the range of average cancellous bone. For all 3 of the other synthetic bone grafts a significant amount of implanted material remains in the defect site at 52 weeks (Figure 2).

Figure 2. High resolution radiographs of the defect sites 24 weeks after implantation. Vitoss(a), Pro Osteon 500R(b), Mastergraft(c), Actifuse(d)

Figure 3. Implant resorption and bone formation curve for Vitoss.

Discussion: This study shows that HA and TCP materials are biocompatible and have the capability to support bone ingrowth. What sets Vitoss apart from the other products studied is the physical structure and porosity of the scaffold. Previous studies have presented the positive effect of porosity on bone healing (4). Vitoss has interconnected pores measured from 1-1000microns. This broad size range supports all of the biological processes associated with healing: Haversian bone ingrowth, revascularization, cell infiltration and fluid, nutrient and oxygen flow. The chemistry and porous structure of the Vitoss scaffold are optimized for osteoconduction. The pure β-TCP crystal phase resorbs at a clinically relevant rate, matching the rate of new bone ingrowth permitting proper diagnosis of the rate of bone formation by physicians.

References: