COMPARISON OF CALCIUM-BASED CERAMIC GRANULES IN A RABBIT TIBIAL DEFECT MODEL

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Introduction

Synthetic biodegradable bone graft substitutes are used increasingly to replace or extend autologous bone in the repair of bony defects. By the process of creeping substitution, biodegradable bone graft materials are expected to degrade by osteoclastic resorption and to be gradually replaced by osteoelastic bone formation. Two new biomaterials have been developed as granular, biodegradable bone graft substitutes (OsteoStim™ granules, EBI, Parsippany, NJ (CPG-1) and BioCement-D, Biomet-Merck, Darmstadt, Germany (CPG-2)). The purpose of this study was to compare these two bone graft substitutes to Interpore 500R™ (ProOs), in an established animal model for healing of bony defects.

Materials and Methods

CPG-1 granules are composed of pure CaNaPO$_4$, and CPG-2 granules are composed of calcium deficient hydroxyapatite (61% α-tricalcium phosphate, 26% dicalcium phosphate, 9.7% calcium carbonate, and 3.3% precipitated hydroxyapatite). ProOs is comprised of a calcium phosphate, 26% dicalcium phosphate, 9.7% calcium carbonate, and different biomaterials. The means (Avg.) and standard deviations (S.D.) given for each data set [all values are volume %].

Materials and Methods

Quantitative histomorphometry was performed on undecalcified tibial (n=3) and biomechanics (n=12). Quantitative histomorphometry was performed on undecalcified tibial cross-sections stained with tri-color Villanueva Mineralized Bone Stain. Volume fractions of new bone ingrowth, residual graft, and soft tissue were calculated within the margins of the cortical defect. Biomechanical torsion tests were used to measure maximum torsional load to failure, angular deformation, torsional rigidity and energy absorbed to failure. Biomechanical properties of healed defects were compared to non-defected (intact) tibias as well as fresh-cut defects (fenestrated). ANOVA and pairwise t-tests (Bonferoni) were performed on the quantitative histomorphometry and biomechanical data, respectively.

Results

New bone ingrowth for CPG-1 and CPG-2 was not significantly different than ProOs new bone ingrowth at any time point. CPG-1 resorption was significantly larger than that of ProOs at 12 and 24 weeks (p<0.05). CPG-2 resorption was significantly less than ProOs at 12 weeks (p<0.05), but not significantly different at 24 or 48 weeks. At 48 weeks, 2% of the initial CPG-1 graft material remained, 71% of the initial CPG-2 graft material remained, and 59% of the initial ProOs graft remained, showing all three biomaterials are resorbing. CPG-1 soft tissue was significantly larger than that of ProOs at 12 and 24 weeks (p<0.05); however, CPG-2 soft tissue was not significantly different than ProOs at any time point. There were no significant differences between biomechanical properties at 48 weeks of tibias healed with CPG-1, CPG-2, or ProOs. None of the biomechanical properties of the healed tibias, except for torsional rigidity, were significantly different than the intact controls. Torsional rigidity of all healed defects was significantly larger than the intact control torsional rigidity (p<0.005). Fracture patterns of all grafted defects resembled fracture patterns of the intact positive controls.

Discussion

All three graft materials facilitated bone defect healing by creeping substitution leading to complete biomechanical healing. CPG-1 underwent nearly complete osteoclastic resorption accompanied by new bone formation that led to complete bone healing. CPG-2 and ProOs were also resorbed, although to a lesser extent than CPG-1, and also resulted in satisfactory bone healing.

References


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Table 1. The quantitative histomorphometry data for the three different biomaterials. The means (Avg.) and standard deviations (S.D.) are given for each data set [all values are volume %].

Table 2. The biomechanical data for the control groups and the three different biomaterials. The means (Avg.) and standard deviations (S.D.) are given for each data set.

Figure 1. Photomicrographs of undecalcified histology slides prepared from tibial cortical defects grafted with CPG-1, CPG-2, and ProOs. Mineralized bone appears green, unmineralized new osteoid seams are dark red or magenta, and synthetic granules stain dark brown or black.

Figure 2. Fracture patterns at 48 weeks post-op for the controls (Fenestrated and Intact) and defects grafted with the three calcium based granules (CPG-1, CPG-2, and ProOs). Fracture patterns of all grafted defects resembled fracture patterns of the intact positive controls.