Effect of particulate and putty-like tricalcium phosphate-based bone grafting materials on bone formation, volume stability and osteogenic marker expression after bilateral sinus floor augmentation in humans

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Introduction: Among the various techniques to reconstruct or enlarge a deficient alveolar ridge, augmentation of the maxillary sinus floor with autogenous bone grafts has become a well-established pre-implantology procedure for alveolar ridge augmentation of the posterior maxilla. Using synthetic biodegradable bone substitutes, however, is advantageous, since it avoids second-site surgery for autograft harvesting. Over the last decade, the use of tricalcium phosphate (TCP) particles as alloplastic bone graft material for sinus floor elevation procedures has received increasing attention in implant dentistry.[1] More, recently, the combination of tricalcium phosphate ceramics with polymeric scaffolds or carriers including natural polymers such as hyaluronic acid (HyAc) has been proposed in order to improve surgical handling properties.[2] In the current study the effect of a putty-like as well as a particulate TCP graft material on bone formation, volume stability and osteogenic markers expression was evaluated in biopsies sampled 6 months after bilateral augmentation of the sinus floor applying a split-mouth design. This was in addition to examining the biodegradability.

Methods: The study consisted of 7 patients (5 women and 2 men) ranging in age from 54-69 years. In all patients bilateral sinus floor augmentation was required in order to facilitate dental implant placement in the posterior maxilla. Since the residual alveolus was 1-3 mm in height, a staged approach was used. Test materials were two ß-TCP-based bone grafting materials. First pure, synthetic ß-TCP granules with a porosity of 65% and a grain size of 700 to 1400 µm (TCP-G). Second, a putty-like β -TCP-based material composed of pure ß-TCP granules, with a porosity of 63% and two types of grain size (125-250 µm and 500 to 700 µm) embedded in a fermented sodium HyAc hydrogel matrix (TCP-P). The β-TCP:HyAc ratio was 10:1. Sinus floor augmentation was performed using a combination (10:1 ratio) of TCP-G or TCP-P and autogenous bone chips. Dental implants were placed 6 months after sinus floor augmentation. At implant surgery when preparing the implant bed, cylindrical biopsies, 2.5 mm in diameter and 8 mm long, were sampled using a trephine drill. The tissue samples were fixed in an alcohol based fixative Histochoice (Amresco, USA). Subsequently the specimens were embedded in a resin composed of polymethyl-methacrylate (PMMA) and polybutyl-methacrylate (PBMA) as described previously.[3] This resin facilitated performing immunohistochemical analysis on hard tissue sections. 50 µm-sections were cut longitudinally using a Leitz 1600 sawing microtome (Leitz, Wetzlar, Germany). Sections were then deacrylized by immersion in toluene, xylene and acetone. Subsequently, immunohistochemical staining was performed using primary antibodies specific to collagen type I (Col I), alkaline phosphatase (ALP) (Sigma, USA), osteocalcin (OC) and bone sialoprotein (BSP) in combination with the DAKO EnVision+^{TM} Dual link System Peroxidase, AEC+ (DAKO, Denmark).[3] Mayer's haematoxylin was used as a counterstain. First, histomorphometric evaluation of the sections was performed. To this end, a rectangular area 6 mm^2 in size was defined in each section at a distance of 3 mm from the native alveolar crest. The bone area fraction (trabeculae), the bone marrow area fraction as well as the graft material area fraction was measured using a light microscope in combination with a digital camera (Colourview III) and SIS Analysis software (Olympus, Germany).[1] Second, semi-quantitative analysis of the immunohistochemical staining was performed. A scoring system quantified the amount of staining observed using light microscopy. A score of (+++), (++) and (+) corresponded to strong, moderate or mild, whereas a score of (0) correlated with no staining.[1] Cone-beam CTs (computed tomography) were recorded after sinus floor augmentation and at implant placement, i.e. 6 month later. The data sets were used for calculating the volume of the grafted area at these two time points.

Results: The TCP-P grafting material displayed more advantageous surgical handling properties. In the grafted sinus floors, in which TCP-P was used the mean bone area fraction (excluding marrow spaces) was 30.1 ± 8.1%, the mean particle area fraction was 29.5 ± 8.0% and the mean area fraction for marrow spaces was 40.5 ± 8.5%, whereas in the sites, in which TCP-G was used, a mean bone area fraction of 17.4 ± 8.7 %, a mean particle area fraction of 32.9 ± 6.4 %, and a mean area fraction for the marrow spaces of 49.7 ± 6.8 % were noted. Good bone bonding behavior was observed with both materials. This was accompanied by slightly greater expression of Col I, ALP, BSP and OC in the newly formed bone tissue in the TCP-P samples compared to TCP-G. The HyAc matrix was fully resorbed. The cone-beam CT data showed a less pronounced reduction in grafting volume with TCP-P (14.5 ± 10.3%) compared to TCP-G (28.4 ± 16.1%).

Discussion / Conclusions: Six months after implantation of both TCP-based graft materials bone formation and matrix mineralization were still actively progressing in the tissue surrounding the TCP particles. The TCP putty material displayed more favorable surgical handling properties compared to TCP-G without the Hyac hydrogel matrix having any adverse effect on bone formation, bone tissue maturation or graft volume stability. Consequently, TCP-P can be regarded as excellent grafting material for sinus floor augmentation in a clinical setting.

References:
[1] Knabe C. Biomaterials 2008;29:2249-2258.
[2] Bohner M. Mater Today 2010;13:24-30.
[3] Knabe C. Biotech Histochem. 2006;81:31-39.

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