

The ultrastructure and processing properties of Straumann Bone Ceramic[®] and NanoBone[®]

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The ultrastructure, fundamental chemistry, and processing modes of fully synthetic bone grafting materials are relevant to the reconstruction of osseous defects. Rapid progress in the profitable market of biomaterials has led to the development of various bone substitutes. Despite all these efforts, an ideal and full substitute of autologous bone is not yet in sight. With regard to anorganic calcium phosphate ceramics, Straumann Bone Ceramic[®] and NanoBone[®] are compared. These have a similar composition and are osteoconductive, which indispensably requires contact with well-vascularised bone.

Key words: Straumann Bone Ceramic[®], NanoBone[®], ultrastructure, fundamental chemistry

INTRODUCTION

During recent decades autogenous grafts, as well as human donor (allogeneous) bone grafts, have proved successful in the reconstruction of osseous defects of the human skeleton. Because of the biological activity which takes place after transplantation, defect reconstruction using autologous bone is considered to represent the gold standard which has to be met by all other procedures. The disadvantage of a second operation for graft harvesting and the limited availability of autogenous tissue have intensified the search for suitable bone graft substitutes. Extension of the indication of bone substitutes to dental implant surgery, periodontology, preprosthetics or orthodontics has led to the increased use of alloplastic materials of fully or semi-synthetic origin.

Since the general absence of a vital indication for bone grafting, especially in subcritical defects, hardly justifies the potential risk of disease transmission, fully synthetic materials from physically and chemically different material groups are frequently used. These materials are, at worst, mere

space maintainers with reduced mechanical stability or, at best, penetrated by bone. Two fully synthetic bone graft substitutes on a hydroxyapatite and β -tricalcium phosphate basis will be presented including their ultrastructure and processing techniques.

Structure and properties

Straumann Bone Ceramic[®] is a fully synthetic bone graft substitute available as granulate. It consists of biphasic calcium phosphate, a composite of 60% hydroxyapatite (100% crystalline) and 40% β -tricalcium phosphate sintered at temperatures of 1100 to 1500°C. Straumann Bone Ceramic[®] is 90% porous with interconnected pores of 100–500 microns in diameter (Fig. 1).

Likewise, NanoBone[®] is a fully synthetic bone graft substitute in granulate form. It consists of nanocrystalline hydroxyapatite (76 weight per cent) and silica (24 weight per cent). This bioceramic is produced using a modified technique at 200°C. Material porosity exceeds 80%, with pore sizes ranging from some nanometres to some 100 microns (Fig. 2).

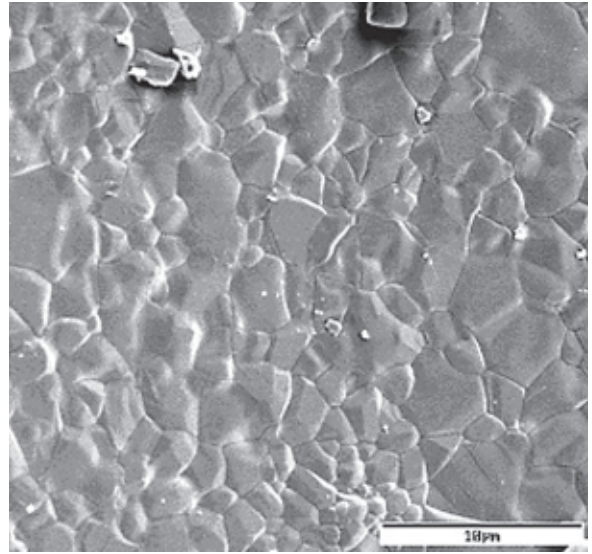
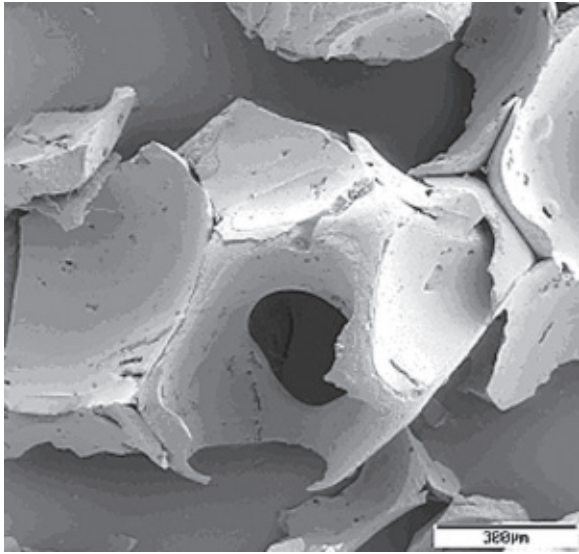


Figure 1. Straumann Bone Ceramic®.

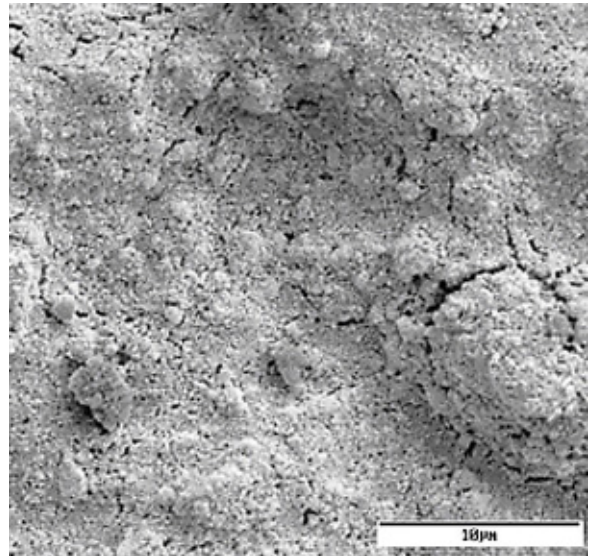
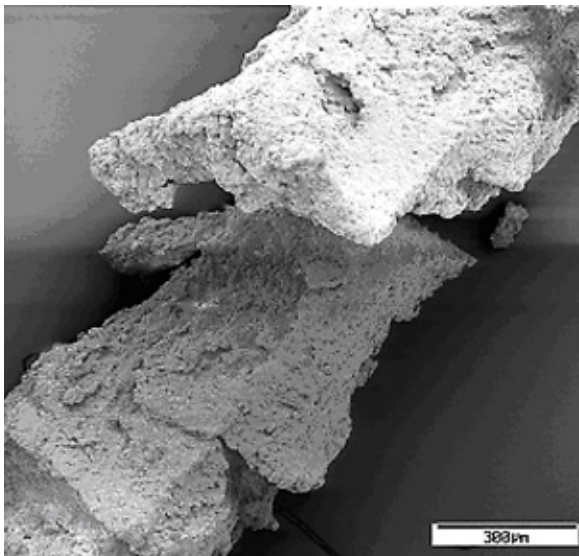


Figure 2. NanoBone®.

Both alloplastic bone graft materials have compositions similar to bone mineral and are osteoconductive. Owing to the structure and surface properties of the graft, namely the bone substitute material, osteoblasts are enabled to immigrate into the defect on a kind of guide rail. Starting from the defect margin, resorption and bony substitution of the grafting material occur, depending on the bone substitute and its material properties.

Processing

Prior to application Straumann Bone Ceramic® is to be mixed with sterile sodium chloride solution or

autologous bone material. Crushing of the granulate is to be avoided. The bony defect should be completely filled with Straumann Bone Ceramic®. The greatest possible contact with vital well-vascularised bone should be ensured.

Direct contact with bleeding vital bone is crucial to the function of NanoBone® as well. Thorough bone freshening is, therefore, obligatory before insertion of the material. In order to provide the proteins involved in bone regeneration, the granulate must be mixed with some autologous venous patient blood to form a homogeneous mass. Subsequently the bone defect is completely filled

with the compound. Both over-filling and condensation of the material are to be avoided. Complete and tension-free soft tissue coverage is obtained by both materials.

DISCUSSION

The abundance and variety of clinically applicable bone graft substitutes displaying different chemical, physical, biological, and processing properties and continuous new product approvals make it difficult for the user to keep track and to choose the best suited material according to the given indication. As an aid, materials may be classified using the orientating taxonomy after Rueger [3], where bone substitutes are assigned to respective categories for their origin and composition (organic, biological bone substitutes, composites, and anorganic, synthetic bone substitutes). The specific selection of an appropriate substitute material is made according to the given problem and type of surgical procedure with respect to the specific properties and risks of the material, defect formation and size, localisation and regional conditions (perfusion and mechanical stress) [1]. The user of bone substitutes has to realise that, despite intensive research on biomaterials, no ideal and full substitute of autogenous bone exists thus far and that any substitute has both advantages and disadvantages.

The rapid development of fully synthetic materials during recent decades has been partly encouraging and partly disillusioning. While at first fully synthetic materials such as silicon and polyethylene merely served as space maintainers in the defect area, calcium phosphate ceramics and glass

ceramics have yielded at least rudimentary penetration by the surrounding bone. Hydroxyapatite was increasingly used during the 1980s, not least for its good histocompatibility. However, this only partially fulfilled the demand for bone remodelling. The ingrowth of bone tissue was detected only at the direct contact interface with native bone, whereas more distant granula displayed connective tissue encapsulation, regardless of the type of hydroxyapatite applied. These granula show delayed or failing resorption, thus representing a potentially inflammation-promoting and biomechanical weak point. The recent hope, tricalcium phosphate, shows a more favourable resorption behaviour compared to hydroxyapatite. However, on the one hand dissolution occurs before cell adhesion is possible, while on the other a lymphocyte inflammatory reaction is evoked. Mere osteoconduction but as yet no osteoinduction has thus far been achieved using fully synthetic bone substitutes. Selection criteria for the user include resorption behaviour, osteoconductive behaviour, the temporal dynamics of the remodelling process and histocompatibility [2, 4].

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