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Bone grafts' usage areas and β-TCP (tricalcium phosphate) mechanical strength properties

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Abstract

The process of completing the exposed areas with surgical procedures due to the deformation in the damaged bone for the purpose of repairing bone fractures is called bone grafting. With this invasive procedure, the grafts placed in the damaged bone area are absorbed by the living structure with the repair process in the bone. The healing process takes a few months, depending on the type of the graft used. With the precondition that the patients are not too old, the bone structure usually has the ability to completely regenerate. In order to activate the regeneration ability, the fracture area in the bone must either be very small or have a support structure that will act as a scaffold. Bone grafts can be evaluated in four basic groups; Autograft (contains structures taken from the patient's own body), Allograft (structures taken from another patient of the same type), Zenograft (taken from another living thing), Synthetic (Ceramic materials, materials in block, granule, injectable form produced from polymer materials). Bone grafts serve as scaffolding to regenerate the losses in the bone with their osteoconduction feature. Supporting the osteoconductivity in the area where the deformation occurs in the bone depends on the bioactive chemicals (Beta-Tricalcium Phosphate) of the implant used during the surgical procedure to support the regeneration. The graft used to repair (regenerate) the damaged bone should have osteoinduction, osteoconduction, and osteointegration properties. Although the allograft structure is observed to be more successful when evaluated in terms of these three features, it is observed that synthetic grafts are used at very high rates in surgical operations when the accessibility, cost, and applicability are evaluated. In this study we will review and evaluate synthetic bone grafts.

Introduction

Synthetic bone grafts, which are frequently used in surgical applications, are usually made from biomaterials due to their biocompatibility. The surface properties of these grafts are compatible with the surface properties of the implanted tissue. These properties are known as wettability, and surface adhesion and increase the proliferation and adaptation of the tissue it comes into contact with. Thanks to its 3D structure, its pore widths support cell transport and development. Porosity and pore width are other important features but are critical for vascularization and colonization. The mechanical properties of bone grafts should be both similar and compatible with the properties of the region to be used. Mechanical properties are also important in terms of being a parameter that shows the suitability of the quality control processes of the implant. Viscoelasticity, shear strength, and resorb ability are the most critical evaluation parameters in bone grafts [1].

When the features of bone grafts are evaluated in terms of their contribution to the healing of the defects, the reasons for their preference are summarized. A graft with osteoconduction is important because it supports osteoprogenitor cell growth and the completion of the lost parts. The osteoinduction feature has undertaken the task of sending a warning for the regeneration by enabling the transformation of the osteoprogenitor cells into osteoblasts. Thanks to its osteogenicity feature, the bone graft used helps the living bone cells to be reshaped by sending warning signals. The characteristics of four different graft types are given in Table 1 comparatively. Autografts seem to have the highest compatibility naturally. However, it is known that synthetic grafts in the table are widely used because of their osteoconductive properties and their reparative role in bone loss [2].

Table 1. Bone grafts (Autograft, Allograft, Xenograft, Synthetic) evaluation of conformity [2]

	Osteoconductive	Osteoinductive	Osteogenic
Autograft	+	+	+
Allograft	+	+/-	-
Xenograft	+	-	-
Synthetic	+	-	-

Ceramics are the most commonly used biomaterials with inorganic structures, and the most preferred calcium phosphates in tissue engineering are Hydroxyapatite, Tricalcium Phosphate, and a combination of these two. β-TCP (tricalcium phosphate) exists in alpha and beta phases, in forms with two different crystallographic properties. Autografts leave their place for products with high bone compatibility due to their superior properties as well as the difficulty of obtaining them. Especially β-TCP + SiO2, β -TCP + HA, Bioglass, β -TCP + HA + Hydroxypropyl methylcellulose (HPMC), β -TCP + Poly (L-lactide-co-ε-caprolactone), which is defined as Synthetic Bone Graft, are the most common of the materials used.

Material and Method

β-TCP Production methods are listed in Figure 1 β-TCP Precipitation Method and Figure 2 Sponge Impregnation Method. The final control tests to be done for the finished products are listed in Table-2 β-TCP Beta Tricalcium Phosphate (β-TCP) Quality Control Tests [3].

Table 2. Beta Tricalcium Phosphate (β-TCP) Quality Control Tests [3]

No	Quality Control Test Parameters
1	1 PH control
2	Appearance – color, matte
3	XRD - β -TCP ratio > 95%
4	FTIR - % β TCP 723 cm-1 β -TCP Peaks
5	Elemental Residue ICP/MS (ISO 13175-3)
6	Particle size and shape - Laser diffraction
7	Ph-Solution Test (ISO 13175-3)
8	Sieve Control – Powder
9	Porosity – Mercury porosimetry
10	Mikropar-Macropar Dimension Control – SEM
11	Compressive strength - 1-16mpa
12	LAL Test Endotoxin Ratio <0.25 IU/ml

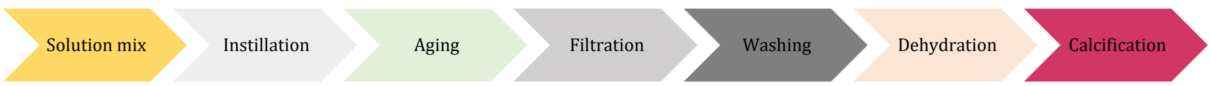

Figure 1. Beta Tricalcium Phosphate (β-TCP) production technology by precipitation method [3]

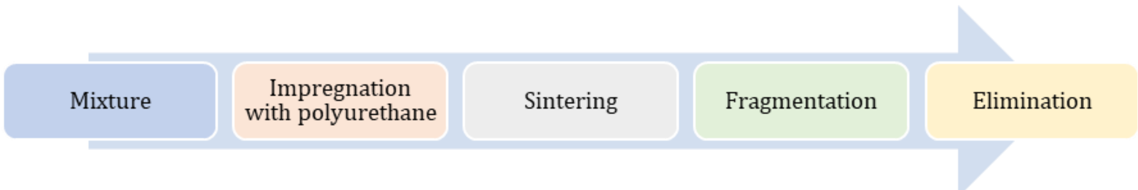

Figure 2. Production technology of Beta Tricalcium Phosphate (β-TCP) with sponge impregnation method [3]

After the production is completed, specific tests of the product should be recorded and special processes (water system-TCP production, mixing, drying, sintering, screening, shaping, filling, sterilization, packaging) should be regularly validated by the manufacturer [4].

Results

Like all implants produced, bone grafts are expected to meet legally determined requirements and international standards for the relevant product. In order to control the reliability of the product and the repeatability of the production technology at the same quality, the defined tests should be recorded and reported. The instructions for use of these products, which are defined as medical implants, should contain the necessary information (contraindications, warnings, and precautions). In addition, instructions should be established for proper placement and storage in the desired treatment area. The warning not to implant the device in a patient with a pre-existing calcium metabolism disorder (e.g., hypercalcemia) should be included in the relevant guidelines. A precaution against overfilling the defect area, a warning against its use in infected areas. Methods for cutting and shaping block-form grafts should be determined and shared with consumers. In addition, for grafts in injectable form, there should be warnings against sending them with excessive pressure [5]. Beta Tricalcium Phosphate (β-TCP) production technology, which is one of the lower-cost products developed as an alternative to allograft bone grafts, has successful results when evaluated in terms of its reliability, its suitability for GAMMA sterilization after production, its high histocompatibility ability, and mechanical strength test results. It is preferred in surgical interventions due to its widespread use and preference [6].

Conclusion

Synthetic implants should be biocompatible to enable proper tissue remodelling and repair. In this proceeding we discussed several synthetic materials that can be used in bone grafts. These should be studied in more depth to develop more compatible and repair inducing materials.

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