

# 3D Printing and the Future of Trabecular Bone Grafts

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## Introduction

We are witnesses to the third industrial revolution that began with the creation of 3D printers at the beginning of the 80's which is about to change standards in transplantology and leave its mark on bone grafting- the second most frequent worldwide type of tissue transplant after blood transfusion [1,2].

Currently the autograft is the "gold standard" for bone grafts but there are a number of complications that are related to the donor site of bone autografts, including arteriovenous fistula, urethral damage, massive blood loss, deep infection, chronic pain, and abdominal hernia [3-5].

An alternative to bone autografts are bone allograft. They are distributed through regional tissue banks and hospital banks but the mandatory quality control of the banked bone- one an undisputed advantage- makes the procedure more expensive [6,7].

Along with the use of allograft and autografts, the number of bone substitutes increases- especially in traumatology, revision prosthetic surgery and spine surgery [8-10]. Brydone noted that around 4,000,000 operations involving bone grafting and bone substitutes are performed around the world annually [11].

Kinaci research tendencies in using bone grafts among more than 2 million patients between 1992 and 2007 in the USA, as they found a slight increase in the use of bone substitutes than bone allograft [12]. Trabecular bone is the most commonly used form of autologous bone grafting because it has good osteogenic potential and large surface which helps revascularization and incorporation at the recipient site [13].

The creation of a scaffold of a trabecular bone through 3D printing is an attractive goal but not every three dimensional lattice could perform the function of autologous bone graft. According to Hollister et al. approaches in scaffold design must be able to create hierarchical porous structures to attain desired mechanical function and mass transport properties, and to produce these structures within arbitrary and complex three-dimensional anatomical shapes [14].

The trabecular bone is anisotropic material which has a hierarchical porous structure with five levels of hierarchical

organization: mineralized collagen fibril, single lamella, single trabecula, trabecular bone, whole bone [15].

Because of this reason, the creation of substitute bone graft should be preceded by the creation of a mathematical model of human trabecular bone to analyze its structure. The beginning is when Hamed used bone samples extracted from proximal tibia (near knee joint) of an 88-year-old male. Although this research sets a framework for multiscale modelling of materials with hierarchical structures, the use of bone samples from a larger group of people in different age and different bone density it is still necessary [16].

The bone consists of organic phase, inorganic phase and water. The organic phase is composed of collagen type and non-collagenous proteins. The inorganic (mineral) phase is made of calcium phosphate, which is similar to hydroxyapatite:  $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$  [17]. To create bone graft substitutes, various synthetic materials are used: metals, polymers- polylactides, polyglycolides, polyurethanes, or polycaprolactones; and ceramics- silicate based glasses, calcium sulfate hemihydrate and dehydrate and calcium phosphates that are among the most attractive [18].

Currently two phase implants of calcium phosphate and type I collagen have been created using two technologies of additive manufacturing- inkjet 3D printing and low temperature additive manufacturing [19-21]. The thickness of the building layers and the geometry of the structures in no way bring them closer to the parameters of the trabecular bone. However, it is encouraging that the authors report good osteoconductivity of the implants and preservation of the natural properties of the biomaterials used. Undoubtedly, 3D printing is linked to the future of bone grafts because it will be able to create "personal graft on demand", but at this stage creating a trabecular bone structure remains a challenge to additive manufacturing technology.

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