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Influence of bone elastic properties on the predicted stress distribution in the dental implant vicinity

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Abstract

Evaluation of stress distributions around dental implants via finite element method is an important task due to its implications over long-term survival of bone-implant assembly. However, the complexity of bone material implies approximations of elastic properties, which involve rough stress estimations. In this paper, we employed the procedure of generating Young moduli based on tissue radio density and compared the results, in terms of stress jump from implant to crestal bone, with the ones determined in the same points, but using homogenized Young moduli. It is shown that the homogenization procedure underestimates the stress jump in crestal bone.

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Keywords: Hounsfield units, finite element, computed tomography, bone Young modulus, bone density distribution, dental implant

1. Introduction

Dental implants are mechanical devices used to replace the roots of missing teeth of edentulous patients. Their long-term survival is usually determined by the bone-implant interface development, which is related to the stress level in the bone surrounding the implant. In the field of dental biomechanics, the finite element method (FEM) became popular due to its ability of assessing the mechanical interaction between the implant and bones. For such

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Nomenclature

HU	Hounssfield units
E	Young modulus of bone as a function of apparent density
ρ	bone apparent density

simulations however, the material elastic properties are essential in order to achieve reliable results. In the case of bones, due to the complexity of their structure, some studies [1, 2] employ a homogenous behavior by averaging the Young modulus as a global constant. When local stresses are relevant, such an approach may determine rough approximations.

Using the FEM on bone models determined from computed tomography (CT) scans, it is now possible to define different material properties per each finite element as function of local density. Such a procedure is available in MIMICS 13 software (Materialise, Belgium). In this paper, we employ this procedure for defining the Young modulus within the mandibular bone and compare the results with the case of homogenous material properties, for a 3D bone-implant model.

2. Methods

The studied model consists of a generic shape implant, taken from Piotrovski et al [2], inserted in a mandibular bone, which is obtained by 3D reconstruction from CT data, using MIMICS 13. Only a segment of the mandible was considered, as depicted in Fig.1. The two bone parts - cortical and trabecular – are modeled as different volumes. The purpose is to allow independent material properties definition. The interface between the implant and bone is defined as bonded, thus an osseointegrated implant.

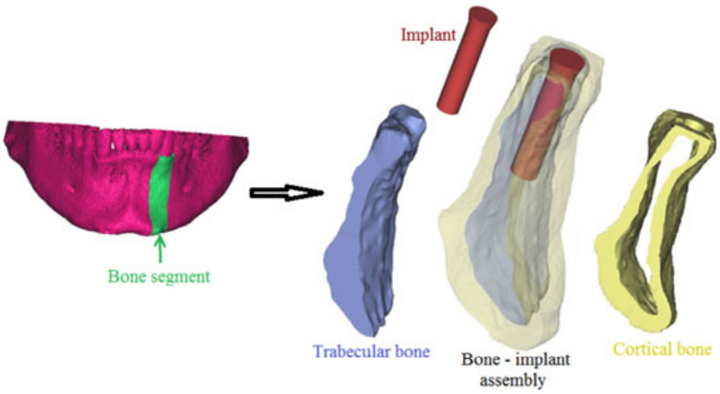

Fig. 1. The geometry of the bone-implant assembly.

We analyzed sixteen cases resulted from combinations of different values of Young modulus for bone and implant. For the implant, we employed four elastic moduli following Piotrowski et al [2]: 210 GPa for stainless steel, 110 GPa for CP titanium, 30 GPa for TiNb alloy and 15 GPa for dentine.

For bone, two cases are part of this study, where in case one the material properties are constant and in case two a relation between the Young moduli and apparent density is used to obtain the bone material for each finite element. The first case is also subdivided in three categories for the trabecular bone, to account for different bone quantities as defined for clinical applications [3]. In this respect, we defined the Young modulus equal with 2 GPa, 5GPa and 8GPa, for the low, medium and high bone quantities, respectively. The values were determined via expressions (1) and (2), starting from HU intervals presented by Norton and Gamble [3] for the three mentioned bone quantities.