

BIOMECHANICAL BEHAVIOUR OF A JAWBONE LOADED WITH A PROSTHETIC SYSTEM SUPPORTED BY MONOPHASIC AND BIPHASIC IMPLANTS

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SUMMARY

Modern implantology is based on the use of endosseous dental implants and on the study of osseointegration processes. The loss of marginal bone around a dental implant can be caused by many factors; the proper distribution of the masticatory loads is important and is closely dependent on the quality and quantity of bone tissue surrounding the implant. In fact, bone has the ability to adapt its microstructure, through processes of resorption and neoformation of new bone matrix, as a result of the mechanical stimuli that are generated during the chewing cycles.

The purpose of this article is to redefine in a modern key and in light of current industrial and engineering technology, clinical and biomechanical concepts that characterize the monophasic implants, in order to assess proper use by evaluating the biomechanical differences with the biphasic implants.

Key words: monophasic implants, biphasic implants, biomechanics, FEM analysis.

Introduction

Modern implantology is based on the use of endosseous dental implants and on the study of osseointegration processes. The criteria that define the clinical success of implant therapy are several, but the main requirements are the bone stability shown by each implant, associated with the absence of bone lesions visible with radiological analysis (1). The maintenance of crestal bone is an important clinical requirement in evaluating the success of a dental implant. The loss of marginal bone around a dental implant can be caused by many factors; the proper distribution of the masticatory loads is important and is

closely dependent on the quality and quantity of bone tissue surrounding the implant. In fact, bone has the ability to adapt its microstructure, through processes of resorption and neoformation of new bone matrix, as a result of the mechanical stimuli that are generated during the chewing cycles (2).

The ideal condition would be a homogeneous distribution of the masticatory loads along the entire bone-to-implant surface: this managing of masticatory forces, however, is in direct relation with the geometry of the dental implant and with the chemical-physical characteristics of the implant surface (3). Studies based on the finite element analysis (FEA) performed on different types of implants, showed specific areas where stresses are concentrated as a result of mastication.

tory loads: in such areas, it is more frequent to see bone resorption. Typically, the areas showing increased bone resorption are those close to the neck of dental implant (4, 5).

This article analyzes the biomechanical behavior of a virtual model of jawbone loaded with monophasic and biphasic implants.

Materials and methods

In this research article, the Authors evaluated the biomechanical behavior of a portion of the mandibular bone, where the dental implants have been inserted (Immediateload SA, Lugano, Swiss), and these facilities have been subsequently loaded with a dental prosthesis.

In detail, the biomechanical analysis studied the distribution of the forces in two different cases:

1. mandibular bone and 2 monophasic implants (Immediateload type “Power”), with diameter of 4mm and height of 11.5 mm (case A);
2. mandibular bone and 2 biphasic implants (Imme-

diateload type “Immediate”), with diameter of 4 mm and height of 11.5 mm (case B).

The virtual jaw has been achieved through a process of analysis, DICOM files obtained from CT. It was virtually reconstructed using the program Rhinoceros 4-SP9, in WINDOWS 7_x64-SP0. The size of the implants, of the abutments and of the dental prostheses were drawn, in 3D mode, by the program Solidworks 2014-SP5, working in WINDOWS 7_x64-SP0, as showed in Figure 1.

The entire process of “mesh” and “calculation” performed by FEA was conducted using the software NeiFusion 1.2 - 9.1 NEiNastran, working in WINDOWS 7_x64-SP0 with a workstation DELL 690.

The important variable to be considered in the biomechanical analysis with the FEM method is represented by the materials which characterize the different elements analyzed. All the materials used in this study and their chemical-physical characteristics have been reported in Table 1.

The abutments and screws between abutment and fixture have been considered in Titanium grade 5. The biphasic “Immediate” implants and the monophasic “Power” implants have been considered in Titanium

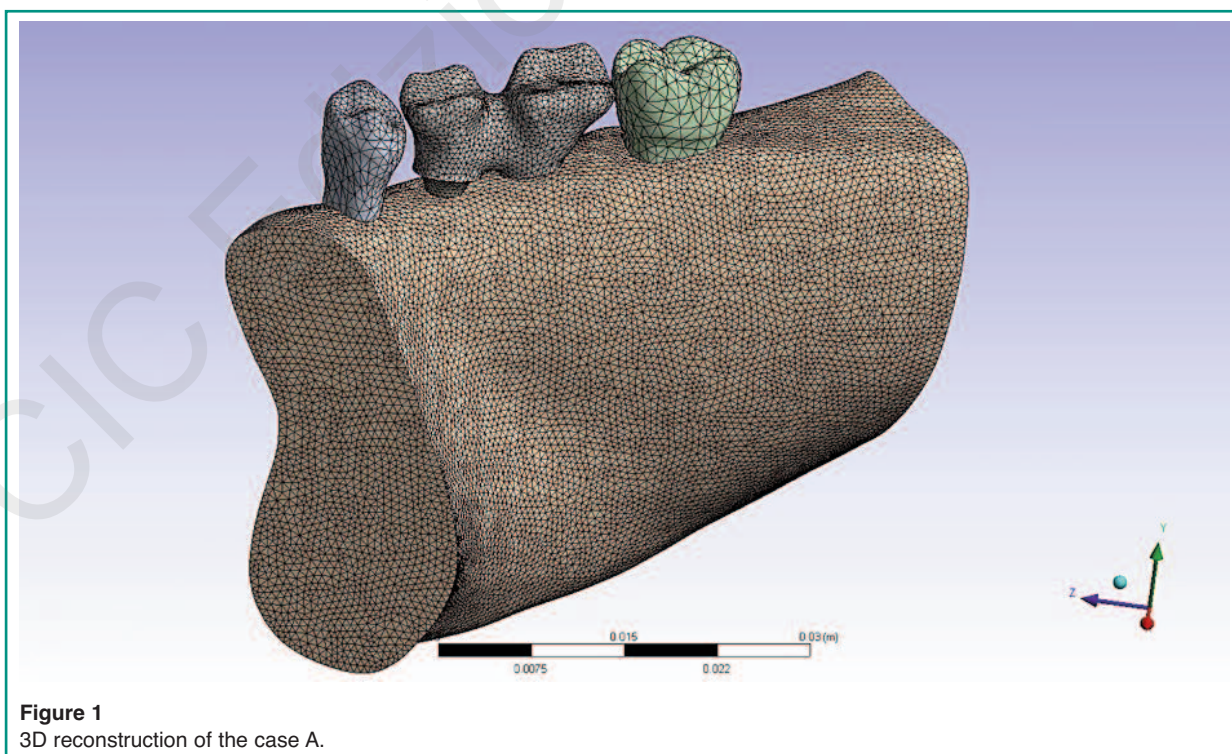


Figure 1
3D reconstruction of the case A.

Table 1 - Mechanical properties of materials used in biomechanical simulation.

Material	Modulus of Elasticity (E) Shear Modulus (G)	Poisson coefficient
Cortical bone	$E_{xx}1=9.6E9Pa$ - $E_{yy}2=9.6 E9Pa$ - $E_{zz}3=1.78 E10Pa$ $G_{xy}4=3.097 E9Pa$ - $G_{xz}5=3.51 E9Pa$ - $G_{yz}6=3.51 E9Pa$	$V_{xy}7=0.46$ $V_{xz}8=0.30$ $V_{yz}9=0.30$
Ti grade 5	1.1E11 Pa	0.33
Ti grade 4	1.05E11 Pa	0.37
Tooth	4.1E10 Pa	0.3
CoCrMo alloy	2.75E11 Pa	0.3

grade 4. The two natural teeth were considered made from enamel, pulp and dentin, and placed in contact with the jawbone through the periodontal ligament. The prosthesis was considered made in a cobalt-chromium-molybdenum alloy. Finally, the mandibular bone was considered as D1 bone (cortical bone); moreover, between the implant and the prosthesis, an acrylic cement was considered as warranty of perfect contact. The set-up look of the biomechanical study, of constraints and of related forces has been inserted. The load acting on the pre-molar is of 440N, while the load acting on the molar is of 880N: such loads are the mean masticatory values assessed in the adult patient, obtained with a frequency between 60 and 80 bites/min (6) (Figure 2).

Results

The FEM mandibular bone biomechanical analysis, observed following loads applied on the prosthesis, supported by 2 monophasic implants (case A), or by 2 biphasic implants (case B), have shown interesting concepts. In Figure 3 and in Figure 4 has been represented the trend of the bone deformation, assessed according to the von Mises theory.

Observing the Figures 3 and 4, it is possible to observe that the stress distribution on the bone crest is different according to the implant geometry used, and these changes in response to stress, affect the biomechanical behavior of the prosthetic component (7-10).

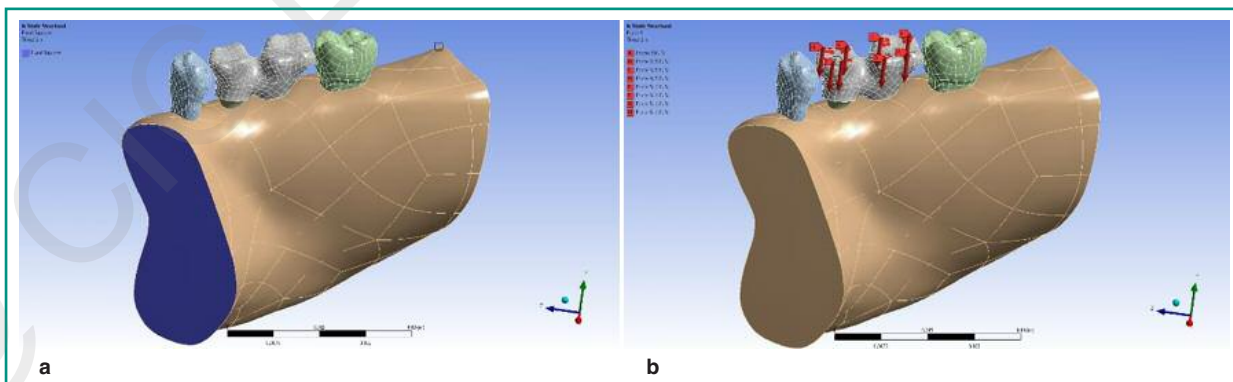


Figure 2
a) Constraints used to fix the bone during the biomechanical analysis; b) loads acting on the premolars and molars, in relation to the contact points.

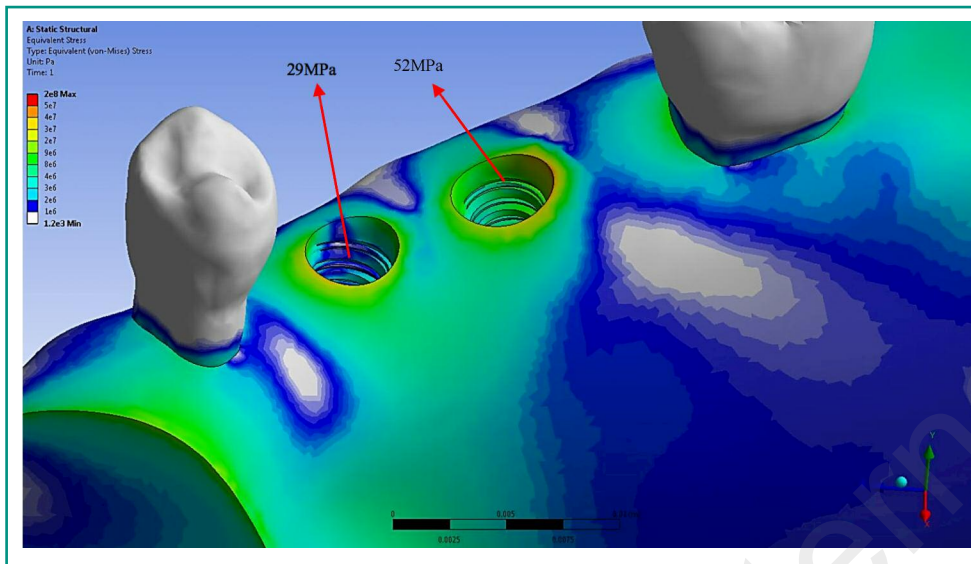


Figure 3
Trend of stress on the bone crest, in the configuration of Case A; it is possible to observe, in the areas of color between yellow and red, the peaks of maximum stress.

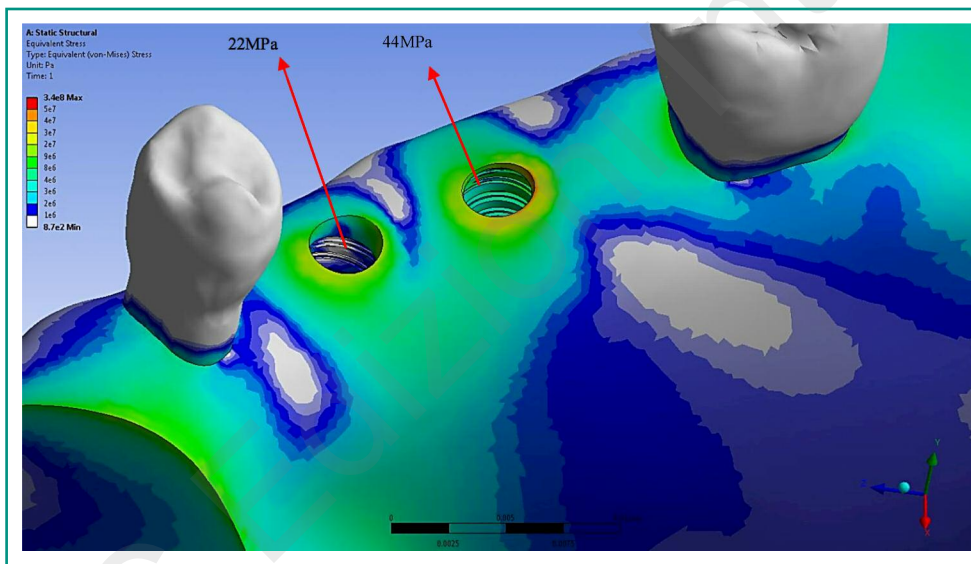


Figure 4
Trend of stress on the bone crest, in the configuration of Case B; it is possible to observe, in the areas of color between yellow and red, the peaks of maximum stress.

The case A shows a maximum stress slightly higher than that shown by the case B. In this outcome, it is important to evaluate the role of the geometry of the implants used, as well as the prosthesis chosen and integrated in the oral cavity (11, 12).

Moreover, the stress distribution on the mandibular ridge appears more uniform in case A, compared to the case B. It's important to underline that the bone modification is a physiological process that combines the osteogenesis and the bone remodelling (13-15). In such cases where a guided bone regeneration is need-

ed, the bone regeneration can be improved by using platelets concentrates (16, 17), new generation of biomaterials, new surgical techniques (18-25) or innovative devices.

Conclusions

The stress values, according to von Mises, described in Figures 3 and 4, are also dependent on the shape of

the implant thread, and the morphology of the emerging part. The ideal thread to manage bio-dynamic stress should increase the functional surface of the implant body.

To increase the functional surface of the implant, the depth of the thread can be variable along the implant axis, to provide greater functional surface in those regions of major stress.

However, the results are dependent on constraints and the applied forces, therefore are useful additional studies on such matters.

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