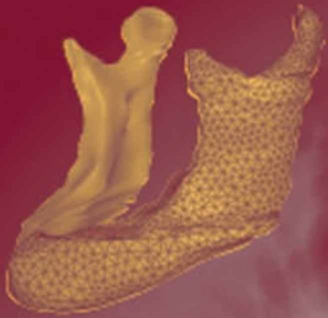

BIODENTAL ENGINEERING V

J. Belinha
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J.C. Reis Campos
Mário A.P. Vaz
João Manuel R. S. Tavares
EDITORS

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BIODENTAL ENGINEERING V

PROCEEDINGS OF THE 5TH INTERNATIONAL CONFERENCE ON BIODENTAL ENGINEERING, PORTO, PORTUGAL, 22–23 JUNE 2018

Biodental Engineering V

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Table of contents

Biodental Engineering V – Belinha et al. (Eds)
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Preface

Dentistry is a branch of medicine with peculiarities and diverse areas of action, being commonly considered as an interdisciplinary area. The development, validation and clinical use of better and more advanced techniques and technologies has led to greater demand and more interest.

Biodental Engineering V contains the full papers presented at the 5th International Conference on Biodental Engineering (BIODENTAL 2018, Porto, Portugal, 22–23 June 2018). The conference had two workshops, one of them dealing with computational imaging combined with finite element method, the other dealing with bone tissue remodelling models. Additionally, the conference had three special sessions and sixty contributed presentations.

The topics discussed in **Biodental Engineering V** include:

- Aesthetics
- Bioengineering
- Biomaterials
- Biomechanical disorders
- Biomedical devices
- Computational bio-imaging and visualization
- Computational methods
- Dental medicine
- Experimental mechanics
- Signal processing and analysis
- Implantology
- Minimally invasive devices and techniques
- Orthodontics
- Prosthesis and orthosis
- Simulation
- Software development
- Telemedicine
- Tissue engineering
- Virtual reality

The purpose of the Series of BIODENTAL Conferences on Biodental Engineering, initiated in 2009, is to perpetuate knowledge on bioengineering applied to dentistry, by promoting a comprehensive forum for discussion on recent advances in related fields in order to identify potential collaboration between researchers and end-users from different sciences.

The conference co-chairs would like to take this opportunity to express their gratitude to the conference sponsors, all members of the conference scientific committee, invited lecturers, session-chairs and to all authors for submitting and sharing their knowledge.

J. Belinha
R.M. Natal Jorge
J.C. Reis Campos
Mário A.P. Vaz
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Numerical analysis of titanium hybrid-plates in atrophic maxilla

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ABSTRACT: The use of osseointegrated implants in severely atrophied maxilla has important limitations. Two different titanium hybrid-plates are evaluated with finite elements as another viable alternative for atrophic maxilla rehabilitation. The three-dimensional model analyzed is based on a real clinical case. An axial force of 100 N was applied in each plate. The model was subjected to a rigid fixation restriction in the upper and lateral maxilla to prevent displacement in the x, y and z axes. A non-penetration condition between plates and maxilla was added to prevent interferences during the execution process. Von Mises stresses on plates and principal stress on maxilla were obtained with a maximum value of 180 MPa in plates and 80 MPa in maxilla. According to these results, it is possible to conclude that this technique can be considered a viable alternative for atrophic maxilla rehabilitation although it is necessary more studies to corroborate the clinical results.

1 INTRODUCTION

The reconstruction of an atrophic maxilla has been always a challenge because of anatomical and clinical factors (Ali et al. 2014, van der Mark et al. 2011). The most common techniques in atrophic maxilla rehabilitation are bone grafting (Chiapasco et al. 2014), pterygoid (Cucchi et al. 2017) or zygomatic implants (Aparicio et al. 2014), bone regeneration (Gultekin et al. 2017, Kaneko et al. 2016) and, finally, short implants (Alqutaibi et al. 2016).

Hard tissue augmentation provides an adequate bone volume for ideal implant placement and to support soft tissue for optimal esthetics and function. Zygomatic implants present a viable alternative because of their design and length. Pterygoid implants have the advantage of allowing anchorage in the pterygomaxillary region, eliminating the need for sinus lifts or bone grafts. And, finally, short implants are widely used because of their efficiency on implant treatment in atrophic jaw and maxilla (Anitua et al. 2008, Anitua et al. 2014).

The protocol employed in this study is called Cortically Fixed @ Once (CF@O). It is an alternative to conventional implant placement for atrophied maxilla and mandible. This technique has its origins in basal implantology, which was developed by Dr. Scortecci in the early 1980's when he proposed the Diskimplant® (Scortecci & Bourbon 1990).

The aim of this study is to evaluate the biomechanical behavior of CF@O plates on a completely edentulous and atrophic maxilla.

2 MATERIAL AND METHODS

The three-dimensional model analyzed in this study correspond to the real clinical case shown in Figure 1.

Figure 1 represents the final solution to a real case which was employed in a 58-year-old female

Figure 1. Model employed to reproduce the 3D finite element model.

who wanted fixed teeth in the maxilla in a compromised bone.

2.1 *Plates*

The plates used in the CF@O protocol are very thin, lightweight and highly flexible and therefore may be adapted to any bone anatomy.

In this study two plates have been employed, which are detailed in Figure 2, where HENGG means Highly Efficient No Graft Gear:

The HENGG-1 plate is appropriated for atrophied maxilla. The HENGG-2 plate is recommended for premaxilla, and the retromolar region.

2.2 *Finite element model*

Geometry of the maxilla was obtained using CT and transformed to STL format. Maxilla file was imported to SolidWorks 2016 (Dassault Systèmes, SolidWorks Corp., Concord, MA, USA), where the assembly with the four plates was done. All three-dimensional plates were adjusted to the anatomic characteristics of the maxilla. The final reconstruction of the three-dimensional model is detailed in Figure 3.

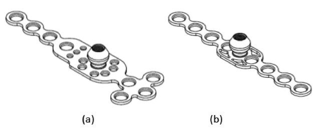

Figure 2. Plates employed in this study: (a) HENGG-1 and (b) HENGG-2.

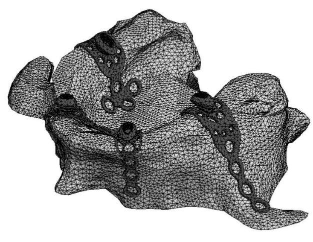

Figure 3. Three-dimensional assembly.

Table 1. Material properties.

	Modulus of elasticity	Poisson's ratio
Plates		
(Titanium Grade II) (Boyer et al. 1994)	105 GPa	0.37
Cortical bone (Bhering et al. 2016)	13.7 GPa	0.3
Trabecular bone (Bhering et al. 2016)	1.37 GPa	0.3

All materials were considered isotropic, linear, elastic and homogeneous with the properties detailed in Table 1.

2.3 *Mesh, boundary conditions and loading configuration*

The 3D model was meshed in SolidWorks 2016 (Dassault Systèmes, SolidWorks Corp., Concord, MA, USA) with a fine mesh and all regions of stress concentration that were of interest were manually refined. The convergence criterion was a change of less than 5% in von Mises stress in the model (Peixoto et al. 2017).

A rigid fixation restriction in the upper and lateral maxilla to prevent displacement in the x, y and z axes was applied. A non-penetration condition was also added to prevent interferences between plates and maxilla during the execution. Finally, an axial load of 100 N (Shimura et al. 2016) was directly applied to the area where the prosthesis is fixed to the plate.

3 RESULTS

Figure 4 shows the von Mises stress on plates. The difference between the maximum von Mises stress in HENGG-1 right and left plates is 3%, while the difference between HENGG-2 right and left is 2%.

In view of Figures 5 and 6, which are the plates placed on the molar region, it can be seen that the plate located in the left of the maxilla has bigger stresses on the area situated in the palate than the plate located in the right of the maxilla.

Figures 7 and 8, which represent the plates placed on the premaxilla, detail that both plates have the highest stresses on the area situated in the palate.

All plates showed a similar distribution patterns of maximum principal stress over the atrophic maxilla.

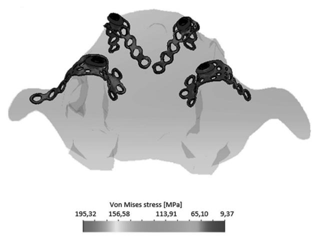

Figure 4. Stress distribution on plates [MPa].

Figure 5. Stress distribution on plate HENGG-1 left.

Figure 6. Stress distribution on plate HENGG-1 right.

Figure 7. Stress distribution on plate HENGG-2 left.

Figure 8. Stress distribution on plate HENGG-2 right.

The difference of principal stress value between the four regions in contact with plates is a 5%, with a mean maximum value of 80 MPa in plates' region.

4 DISCUSSION

The biomechanical behavior of CF@O plates on a completely edentulous and atrophic maxilla has been evaluated employing finite element methods.

The accuracy of results in numerical studies depends on the precision of the model analyzed, the material properties and the constraining conditions (Van Staden et al. 2006). CT was used to obtain the geometry of the atrophic maxilla while plates were provided by the manufacturer.

This study has some limitations and assumptions. All materials were considered homogeneous, isotropic, and linearly elastic. Although these assumptions do not occur in clinical practice, they are common in finite element studies due to the challenges in establishing the properties of living tissues. These assumptions are consistent with other numerical studies (Prados-Privado et al. 2017, Almeida et al. 2015). Another limitation was the use of static loads although cyclic loads occur during chewing movements. This limitation is also validated in the several finite element analyses to study biomechanical behavior (Gümrükçü et al. 2017). However, this study analyzed biomechanical behavior of a new alternative to conventional treatments for atrophic maxilla.

There are several studies available in the literature that employed different techniques to treat edentulous and atrophic maxilla, such as basal disk implants (Odin et al. 2012) or bone augmentation (Baldan et al. 2017).

Küçükkurt et al. compare the biomechanical behavior of different sinus floor elevation for dental implants placement (Küçükkurt et al. 2017). Under the condition of vertical loadings, von Mises stresses in mesial implants were lower than our results in plates in the case of lateral sinus lifting. However, plates analyzed in this study obtain lower von Mises stresses than prosthetic distal cantilever application and short implant placement. Regarding to distal implants, our plates obtained lower stresses than prosthetic distal cantilever.

Ultimate stress limits in cortical bone have been described as 170 MPa in compression and 100 MPa in tension (Pérez et al. 2012). Based on these limits, the values observed in this model were lower than those considered physiologic to bone tissue.

A good biomechanical behavior of plates is understood when a homogeneous stress is transferred to the bone. In this case, the maximum difference between all four plates' region is 5%, meaning that the principal stress transferred from plates to maxilla can be considered homogeneous.

Küçükkurt et al. obtained similar maximum principal stress in maxilla than our results in the case of short implant placement and higher principal stress than our results in prosthetic distal cantilever application (Küçükkurt et al. 2017).

Further studies simulating these titanium hybrid-plates alternatives for atrophic maxilla and jaw that include dynamic forces that occur during chewing and consider the anisotropic and regenerative properties of bone are needed. Furthermore, some *in vivo* clinical trials are necessary to validate the model and to confirm the efficiency of this protocol. A numerical study of the combination of prosthesis-plates-implant under different functional conditions (bruxism and other parafunctions) just like the antagonist arcade. Finally, a simulation of blood flow and bone regeneration around the plates is also necessary.

5 CONCLUSION

Based on the results provided by this numerical analysis, it is possible to conclude that in terms of clinical application, these titanium hybrid-plates have a better behavior than conventional treatments as prosthetic distal cantilever application and short implant placement. Titanium hybrid-plates distributed load to the maxilla with similar values as the case of short implants but with higher values than prosthetic distal cantilever application. In any case, resistance limits of bone and titanium were not exceeded. Finally, this technique can be considered a viable alternative for atrophic maxilla rehabilitation although it is necessary more studies to corroborate the clinical results.

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3D analysis of rest seats in clinical environment

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The biomechanical simulation of a zygomatic bar implant using meshless methods

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