Materials Science and Engineering C 45 (2014) 234–240

Contents lists available at ScienceDirect

Materials Science and Engineering C

journal homepage: www.elsevier.com/locate/msec

Effect of crown-to-implant ratio on peri-implant stress: A finite element analysis☆

Fellippo Ramos Verri *, Victor Eduardo de Souza Batista, Joel Ferreira Santiago Jr., Daniel Augusto de Faria Almeida, Eduardo Piza Pellizzer

Department of Dental Materials and Prosthodontics, UNESP, Univ Estadual Paulista, 1193 José Bonifácio Street, Araçatuba, São Paulo 16015050, Brazil

ARTICLE INFO

Article history:
Received 22 February 2014
Received in revised form 4 August 2014
Accepted 9 September 2014
Available online 16 September 2014

Keywords:
Dental implants
Finite element analysis
Dental prosthesis
Implant-supported
Biomechanics

ABSTRACT

The aim of this study was to evaluate stress distribution in the fixation screws and bone tissue around implants in single-implant supported prostheses with crowns of different heights (10, 12.5, 15 mm — crown-to-implant ratio 1:1, 1.25:1, 1.5:1, respectively). It was designed using three 3-D models. Each model was developed with a mandibular segment of bone block including an internal hexagon implant supporting a screw-retained, single metal-ceramic crown. The crown height was set at 10, 12.5, and 15 mm with crown-to-implant ratio of 1:1, 1.25:1, 1.5:1, respectively. The applied forces were 200 N (axial) and 100 N (oblique). The increase of crown height showed differences with the oblique load in some situations. By von Mises' criterion, a high stress area was concentrated at the implant/fixation screw and abutment/implant interfaces at crown-to-implant ratio of 1:1, 1.25:1, 1.5:1, respectively. Using the maximum principal criteria, the buccal regions showed higher traction stress intensity, whereas the distal regions showed the largest compressive stress in all models. The increase of C/I ratio must be carefully evaluated by the dentist since the increase of this C/I ratio is proportional to the increase of average stress for both screw fixation (C/I 1:1 to 1:1.25 ratio = 30.1% and C/I 1:1 to 1:1.5 ratio = 46.3%) and bone tissue (C/I 1:1 to 1:1.25 ratio = 30% and C/I 1:1 to 1:1.5 ratio = 51.5%).

1. Introduction

Dental implants have been highly successful in the rehabilitation of edentulous patients. However, they still suffer biological or mechanical failures [1]. Rehabilitation with implants in the posterior region of the mouth can be challenging due to resorption of the alveolar ridge, pneumatization of the sinus and/or the relative location of the inferior alveolar nerve [2]. Furthermore, in this region, occlusal forces may be three times higher than in the anterior region [2,3].

In this context, as preoccupation occurs in relation to unfavorable crown-to-root (C/R) ratio in single crown restorations, it can also occur in relation to the biomechanics of the single unit implant supported prostheses. The unfavorable crown-to-implant (C/I) ratio (>1:1) could show a biomechanical disadvantage over the years, because such implants may be less resistant to oblique occlusal forces, causing increase of the stress on bone tissue and prosthetic components [2, 4–6]. The increase of occlusal force may cause crestal bone loss, porcelain chipping, screw loosening of abutments or decementation or fracture of the components until loss osseointegration [5–8]. However, other studies did not show low survival rate of implants placed with the unfavorable C/I ratio [9,10]. Unfortunately, there is no protocol to determine the permissible range relations for this C/I ratio.

Factors such as the diameter of the implant, occlusal adjustment and type of prosthetic connection are reported as significant for the distribution of occlusal loads to bone tissue [11–13]. The literature has already evaluated the behavior of crown increase in implants [8,9,14], but biomechanical behavior in wide regular hexagon internal implants is still not fully described. Among biomechanical study methods, the 3-D finite element method has been efficient at evaluating the stress on dental and implant structures [5,6,13,15].

The aim of this study was to evaluate stress distribution in the fixation screw and bone tissue around internal hexagon implants in single-implant supported prostheses with crowns of different heights. Our study hypothesis is that increasing crown height increases stress on both.

2. Materials and methods

2.1. Experimental design

This study follows previous published methodologies [6,13,16]. Six models were developed with two variation factors: crown height (10, 12.5, 15 mm — C/I ratio 1:1, 1.25:1, 1.5:1, respectively) and two conditions of load (axial and oblique loadings) (Table 1).

☆ The authors declare no conflicts of interest.

* Corresponding author.
E-mail address: fellippo@gmail.com (F.R. Verri).

http://dx.doi.org/10.1016/j.msec.2014.09.005
0928-4931/

Table 1
Specifications of the models.

Model	Load	Description
1	Axial	Dental implant (3.75 × 10 mm), internal hexagon and crown height of 10 mm
2		Dental implant (3.75 × 10 mm), internal hexagon and crown height of 12.5 mm
3		Dental implant (3.75 × 10 mm), internal hexagon and crown height of 15 mm
4	Oblique	Dental implant (3.75 × 10 mm), internal hexagon and crown height of 10 mm
5		Dental implant (3.75 × 10 mm), internal hexagon and crown height of 12.5 mm
6		Dental implant (3.75 × 10 mm), internal hexagon and crown height of 15 mm

2.2. Three-dimensional modeling

Each model was composed of a mandibular bone section with an implant, crown and fixation screw. The bone section was composed of trabecular bone in the center, surrounded by 1 mm of cortical bone layer, obtained by decomposition of the computerized tomography (sagittal section) of the second molar region with InVesalius software (CTI, Campinas, SP, Brazil) and surface simplification with Rhinoceros 4.0 software (NURBS Modeling for Windows, Seattle, WA, USA).

The implant design was obtained by simplification of one original internal hexagon (IH) design (Conexão Sistemas de Protese Ltda., Aruja, SP, Brazil) measuring 3.75 × 10 mm connected to an UCLA abutment (Fig. 1). The implant and abutment designs were simplified by use of Solidworks 2010 (SolidWorks Corp, Waltham, MA, USA) and Rhinoceros 4.0 software. Three screw-retained single crowns were modeled with different heights (10, 12.5 and 15 mm — C/I ratio 1:1, 1.25:1, 1.5:1, respectively). Using a 3D scanner (MDX-20w, Roland DG, SP, Brazil), the surface crown design was digitized, modeled from one artificial second mandibular molar tooth (Odontofix Industria e Comercio de Material Odontologico Ltda., Ribeirao Preto, SP, Brazil). Feldspathic porcelain was used as veneering material on external crown surface. The crown framework was simulated as nickel–chromium alloy [16].

Table 2
Nodes and elements.

Model	Implant	Nodes	Elements
Crown height of 10 mm	3.75 × 10 mm	358,415	233,077
Crown height of 12.5 mm	3.75 × 10 mm	356,833	231,422
Crown height of 15 mm	3.75 × 10 mm	345,810	224,166

2.3. Three-dimensional FE configuration

The finite element software FEMAP 10.2 (Siemens PLM Software Inc., Santa Ana, CA, USA) was used to do the finite element models in pre- and post-processing stages. All meshes were simulated using tetrahedral parabolic solid elements. The number of nodes and elements for each model was determined in Table 2.

All mechanical properties of each simulated material were attributed to the meshes using literature values [17–20]. The modulus of elasticity and Poisson's ratio for trabecular bone [20], cortical bone [19], and titanium [19] were 1.37 GPa and 0.3, 13.7 GPa and 0.3, and 110 GPa and 0.35, respectively. The modulus of elasticity and Poisson's ratio for feldspathic porcelain [18] and NiCr alloy [17] were 82.8 GPa and 0.35 and 206 GPa and 0.33, respectively. All materials were considered isotropic, homogeneous and linearly elastic.

2.3.1. Interface conditions, boundary conditions, and loading

For this study, symmetric welds were simulated for all contacts, with the exception of the abutment/implant contact, which was simulated by symmetric contact. The boundary conditions were fixed in all axes (x, y, and z) at both bone block sections (anterior and posterior faces). All of the other model parts were under free restrictions. The applied force

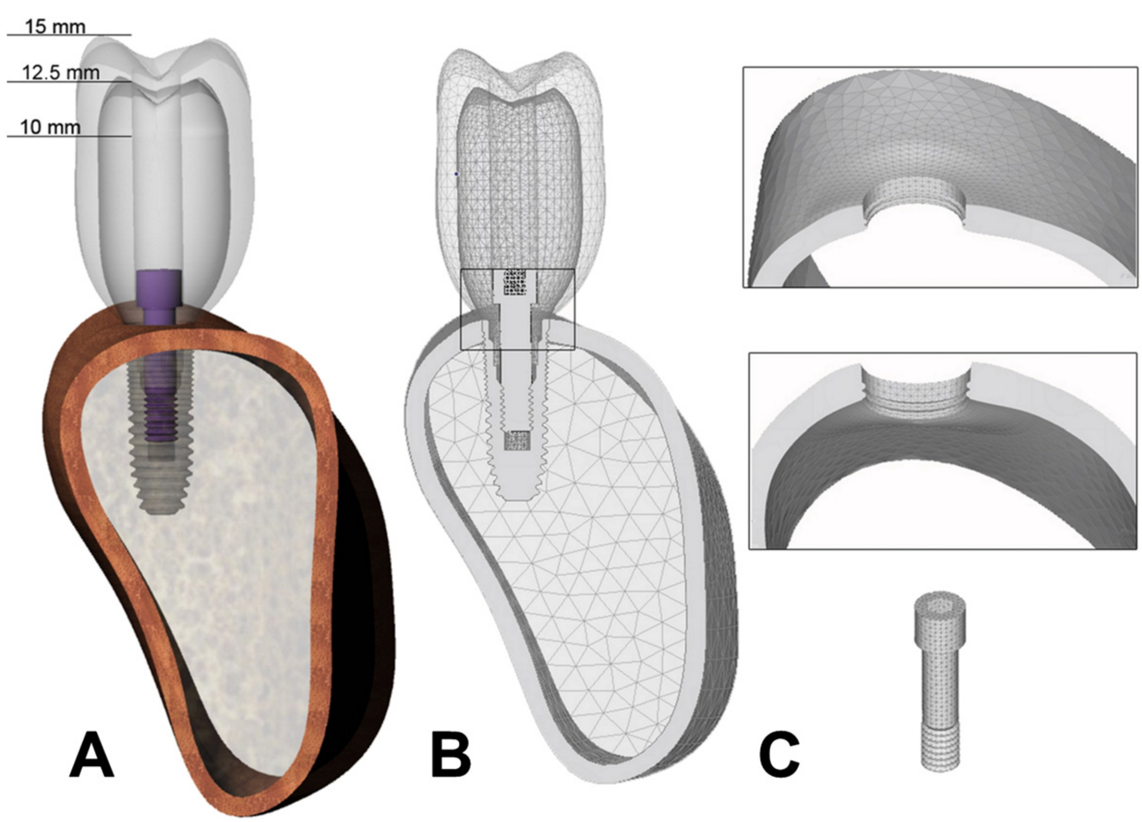

Fig. 1. A: Views of the solid model illustrating the different heights of the crown; B: Finite element model; and C: Zoom of the analyzed area.