Materials Science and Engineering C 71 (2017) 35–42

Contents lists available at ScienceDirect

Materials Science and Engineering C

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

Effect of different types of prosthetic platforms on stress-distribution in dental implant-supported prostheses

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ARTICLE INFO

Article history:
Received 31 March 2016
Received in revised form 17 September 2016
Accepted 27 September 2016
Available online 28 September 2016

Keywords:
Dental implant
Bone tissue
Mechanical stress
Finite element analysis

ABSTRACT

A biomechanical analysis of different types of implant connections is relevant to clinical practice because it may impact the longevity of the rehabilitation treatment. Therefore, the objective of this study is to evaluate the Morse taper connections and the stress distribution of structures associated with the platform switching (PSW) concept. It will do this by obtaining data on the biomechanical behavior of the main structure in relation to the dental implant using the 3-dimensional finite element methodology. Four models were simulated (with each containing a single prosthesis over the implant) in the molar region, with the following specifications: M1 and M2 is an external hexagonal implant on a regular platform; M3 is an external hexagonal implant using PSW concept; and M4 is a Morse taper implant. The modeling process involved the use of images from InVesalius CT (computed tomography) processing software, which were refined using Rhinoceros 4.0 and SolidWorks 2011 CAD software. The models were then exported into the finite element program (FEMAP 11.0) to configure the meshes. The models were processed using NeiNastram software. The main results are that M1 (regular diameter 4 mm) had the highest stress concentration area and highest microstrain concentration for bone tissue, dental implants, and the retaining screw ($P < 0.05$). Using the PSW concept increases the area of the stress concentrations in the retaining screw ($P < 0.05$) more than in the regular platform implant. It was concluded that the increase in diameter is beneficial for stress distribution and that the PSW concept had higher stress concentrations in the retaining screw and the crown compared to the regular platform implant.

1. Introduction

Different types of implant connections can be used for oral rehabilitation [1–3]. The identification of the best connection profile is particularly relevant to implantology. Current research seeks to determine connections that can distribute stresses more efficiently in the bone tissue and structures linked to the implant-supported prosthesis. [4,5]; peri-implant bone preservation is also a point of extensive discussion [2,3].

Clinically controlled trials and systematic reviews have indicated that the use of implants with the PSW (PSW) concept can reduce peri-implant bone loss [6–8]. This situation would ensure the maintenance of the gingival soft tissue and bone tissue, both of which are very important aesthetic factors [9,10].

The platform switching concept is obtained when using a prosthetic component (abutment) that is narrower than the diameter of the implant [11]. The literature on the topic indicates that this concept can provide better preservation of the bone tissue than the regular platform can [6,12,13]. Furthermore, studies have suggested that this type of implant may reduce the magnitude of stress in the cortical bone [14–16].

Recent analyses of the cortical and trabecular bone tissue, which are the main focus of studies in this area, indicate that the PSW concept decreases the concentration of deformation in bone tissue around dental implants [16,17]. However, a definitive consensus on this issue has not been reached, as some reports indicate that the lowest concentration of stresses on the cortical bone may not be observed [18,19]. Furthermore, there is still not enough data in the literature to evaluate the screw and implant abutments using the PSW [16,20]. This issue is very important because complications in implant-supported prostheses, which are common in rehabilitation treatments—for example, screw loosening—are an unpleasant factor associated with implant rehabilitation [21].

Although studies indicate that using the PSW concept reduces the concentration of stress in the peri-implant implant region [14,15], this

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http://dx.doi.org/10.1016/j.msec.2016.09.062
0928-4931/

technique has some disadvantages because the prosthetic abutment reduction can result in a shift in stress in the screws and the prosthetic abutments [14] and can even lead to a fracture because of the reduction of the abutment wall. This situation would be detrimental biomechanically because it can deform the prosthetic screw beyond the material's tolerable limit of elasticity [14]. Furthermore, some biomechanical studies have indicated the possibility of greater stress concentration in the settlement region of the implant-supported prosthesis, in the abutment-implant interface, and in the platform region [22,23].

The diameter of the implant is another important factor to consider [24]. An increase in the diameter has been associated with a reduced magnitude of the stresses around the dental implants, mainly in the cortical bone [16,19,24]. However, there is no consensus as to the existence of an advantage from the use of the PSW concept in stress distribution for wide-diameter implants, especially in relation to the stress concentration in implant prostheses and the retaining screw [19,25].

Different types of implant connections can generate diverse biomechanical behavior. An external hexagonal implant has the advantage of reversibility [16,26] and an ease of implementation with regard to the implant-supported prosthesis. Implants with external hexagonal geometry have been associated with concentrated stresses in the first threads (uppers threads) of the implant and in the implant-abutment interface [24]. On the other hand, dental implants with Morse taper connections have shown a higher stress concentration near the long axis of the implant [16,26] and a better locking of the abutment with the inner surface of the implant [26], thus reducing micromovements. Therefore, there is a need to study the effect of a narrow-diameter abutment of the implant-supported prosthesis (both the PSW concept and the Morse taper) in the retaining screw. Thus, the aim of this study is to evaluate the stress distribution associated with the use of the PSW, the external hexagon, and the Morse taper connections (Fig. 1) by analyzing the effect that reducing the abutment platform has on the screw, the abutment, and the bone tissue. It is also an aim of this study to evaluate the variation in the implant's diameter (4 vs. 5 mm) and the loading type.

The study's first null hypothesis is that the PSW concept would lead to similar values and areas of stress concentration for the fixation screws and the implant-supported prostheses compared to the implants using the regular platform. The second null hypothesis is that regular-diameter implants (4 mm) would present a similar stress distribution as the large-diameter implants (5 mm). Finally, the third null hypothesis is that the Morse taper implants would show the same stress distribution as the external hexagonal implants on bone tissue and the crown.

2. Material and methods

2.1. Experimental design

This research was designed to consider four study factors: (1) the effect of the diameter of the implants on the external hexagonal implant (4 vs. 5 mm); (2) the effect of the different connection types: external hexagon (PSW concept or regular platform) and Morse taper; (3) the effect of the loading type: axial and oblique loading; and (4) the effect of stress distribution on the retaining screw using the PSW concept compared to an external hexagon with a regular-diameter abutment. The models are shown in Table 1.

2.2. Description of the models

Four models were designed for this research. The models were simulated to present a bone block with a section of trabecular and cortical bone tissue in the second molar region and a single, fixed prosthesis over the implant (Connection Implant Systems, Arujá, São Paulo, Brazil). The models were designed according to the diameters of the implants (external hexagons of 4 or 5 mm in diameter and 10 mm in length) to support a screwed crown. Also, a comparative model was designed using a Morse taper implant with the dimensions of 5 × 10 mm (Connection Implant Systems, Arujá, São Paulo, Brazil). The mechanical properties of the bone tissue and the metal-ceramic crown dimensions were constant, varying only in the abutment configuration (PSW × conventional use), in accordance with Table 1 and Figs. 2 and 3.

2.3. Metal-ceramic crown

The external surface of the metal-ceramic crown was obtained through surface scanning of a dental mannequin's second molar, as previously described [24,27]. The model was finalized and simplified using Rhinoceros 4.0 software to fit into the proposed abutments [27].

2.4. Bone tissue geometry

The cancellous and cortical bone tissues were obtained from the decomposition of a computed tomography (CT) scan of the second molar region with the aid of InVesalius 3.0 software. The external surface of the bone tissue was simplified using 3D software (Rhinoceros 4.0) and simulated bone type III, a cortical bone with a thickness of 1 mm around the trabecular bone, which is commonly found in this region [28].

2.5. Dental implants and prosthetic components

The simulated implants were external hexagons and Morse tapers (Connection Implant Systems, Arujá, São Paulo, Brazil). The implant designs were simplified with the assistance of Solidworks 2011 software, so that the dimensions of the implants' internal and external shapes and their components could be reproduced with sufficient reliability to develop a finite element method.

The abutments were simulated using universal castable long abutment (UCLA) components (Connection Implant Systems, Arujá, São Paulo, Brazil). The component for the PSW model was simulated using a UCLA 4 mm in diameter in an external hexagonal implant of 5 × 10 mm. This abutment was similar to the implant model of 4 × 10 mm. A UCLA 5.0 mm in diameter was inserted over an external hexagonal implant of 5 × 10 mm (regular use). An implant-supported prosthesis using a Morse-taper dental implant was modeled with an abutment component for the Morse taper dental implant (Connection Implant Systems, Arujá, São Paulo, Brazil).

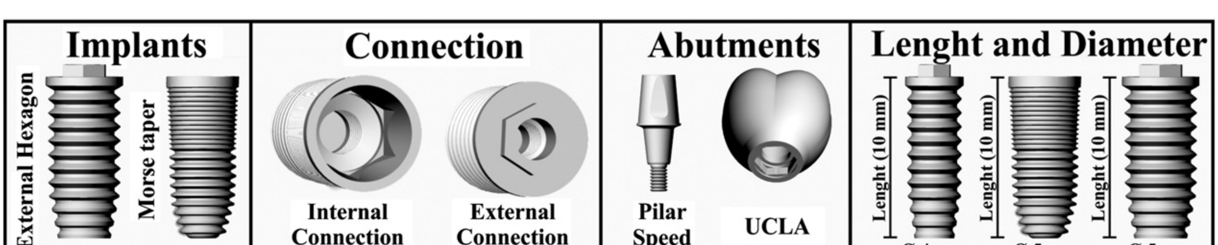

Fig. 1. Schematic drawing of the implants, connections, and abutments.