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Assessment of stress distribution around implant fixture with three different crown materials

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Abstract

Objectives: Selection of crown material should be based on patient bone status. Therefore three different crown materials (in-ceram – porcelain fused to metal crowns – Acrylic) were investigated in this study.
Methods: A 3D finite element model was constructed under Finite element package environment for the upper first premolar. Different loading conditions (vertical and oblique) form **18** case studies were analyzed for comparison.
Results: According to FEA results, changing crown material altered stresses and deformation values on cortical and spongy bones. Whereas linear static analysis results showed similar distributions, and safe values of stresses and deformations, that generated on all parts of the studied system.
Conclusions: Using softer (lower rigidity) crown material reduces the stresses generated on the jaw bone (cortical and spongy), that it absorbs more energy from the applied load, and transfers less energy to the following parts of the system (implant–abutment complex and bones).

Keywords: Finite element method; Stress distribution; Dental implant; Crown material

1. Introduction

In the past two decades, huge number of research work adopted the finite element analysis (FEA) as a method in the design, modifications or checking the feasibility of new systems and materials before conducting IN-VIVO trials [1,2]. In dentistry, the FEA has become an increasingly useful tool for the prediction of the effects of stress on the implant and its surrounding bone [3–5]. Vertical and transverse loads from mastication induce axial forces and bending moments that result in stress gradients in the implant, as well as in the bone. Due to having multi-components in a dental implant – abutment – bone system, that are extremely

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complex geometrically, the FEA has been viewed from biomechanics point of view as the most suitable tool to study the stresses affecting dental implants [6].

Unfortunately, osseointegrated implants react differently to physiological loads compared to natural teeth. This is due to the difference in their manner of anchorage to bone the biological differences between teeth and dental implants are clear. The natural tooth is suspended by the PDL whereas the dental implant is in direct contact with the bone [3]. Under loading, the resilient PDL provides a shock-absorbing feature for the teeth. On the other hand, for implants, a high stress concentration occurs at the crestal bone when loaded, due to the lack of a PDL [7]. The mean value for axial mobility of the teeth is 25–100 μm, whereas the axial displacement of osseointegrated implants is 3–5 μm [7–9]. During lateral loading, the tooth moves at the apical third of the root [10], and the force is instantly dissipated from the crest of the bone along the roots [11]. Conversely, the implant moves at 10–50 μm laterally; and the concentration of forces is at the crestal bone [11]. Clinical signs of occlusal overloading of teeth include widening of the PDL, fremitus, and mobility of the tooth [12]. On the other hand, signs of inflammation [13] and crater-like bone defects have been associated with the overloading of implants. Occlusal overloading of implants may also lead to mechanical complications of the supported prostheses, such as screw loosening or fracture, abutment or prosthesis fracture, or even implant fracture [12]. The greatest natural forces exerted against teeth or implants during mastication can range from 42 to 1245 N. The average magnitude of force is greater in the molar region (200 lb), less in the canine area (~100 lb), and least in the anterior incisor region (~25–35 lb) [14]. These average bite-forces increase with parafunction to magnitudes that may approach 1000 lb [15]. It has been suggested that the general features of mastication in patients with normal and implant – restored dentition are approximately the same [16]. Richter [17] performed an in–vivo study to quantify the load level that is applied to implants in comparison to that of teeth under different physiologic oral functions. Results showed equivalent load levels of implants and natural teeth. Single molars and premolars carried maximum vertical forces of 120–150 N [17].

Therefore, it is important to control any factor that may affect loads transferred to dental implants [17]. The correlation between occlusal overloading and peri-implantitis, which consequently results in implant failure, has been controversial [3,18]. Supra-occlusal axial and lateral loading has been shown to create some crater-like bone defects lateral to the implants and loss of osseointegration [19–21]. However, it should be noted that the loss of osseointegration observed in those studies could have been attributed to the use of short and narrow implants, impractically high-occlusion, or excessive lateral overload [22–24]. Furthermore, it could be that the implants evaluated were smooth surface implants instead of rough surface implants that have a more favorable success and survival rates [25,26]. On the other hand, some studies have indicated that axial and lateral occlusal overload leads to no differences from nonloaded sites according to clinical, radiographic, and histologic observations [27,28]. No crestal bone loss was observed. Occlusal forces are hardly in the vertical direction; mastication involves side-to-side action as well [29]. Evidence does not support that nonaxial loading has a detrimental effect on osseointegrated implants [30,31]. However, occlusal overload may consequently lead to mechanical complications such as loss of veneering acrylic and porcelain fractures. This may consequently result in failure of the implant and its supported prosthesis [32]. Therefore, ongoing maintenance and periodic evaluation of an ISFDP are important in order to monitor any changes and manage potential mechanical complications [33,34].

Adequate bone quality and good stress distribution on the bone are the main factors ensure implant success. Placing of implants in bone with greater cortical bone thickness and higher density of the core will result in less micro-movement and reduce the stress concentration that means increase the implant stabilization and tissue integration [35]. Therefore, in FEA the maximum von Mises stress in bone will decrease as cortical bone thickness increases. On the other hand, the maximum von Mises stress will increase as cortical bone modulus of elasticity increases [35].

Restorative materials significantly affect implant–bone interface zone's stress distribution and load transfer. Crown materials with high modulus of elasticity (as Zirconia and ceramic crowns) transfer high values of the applied load to underlying bone, while Acrylic resin (has low modulus of elasticity) reduce the transmitted forces to bone by about 94% when compared with Zirconia [36]. Therefore, crowns made from composite and above all acrylic resin are more able to absorb shock from occlusal forces than crowns made of zirconia, ceramic material, or gold alloy [37]. Lower modulus of elasticity crown material, absorbs more energy from the applied load, and transfers less energy to the underlying system. In other words, occlusal material with a low modulus of