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Research Article

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The Effect of Occlusal Contacts in the Stress Concentration of Implant-Supported Zirconia Restorations

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Abstract

The present article evaluated the effect of occlusal contacts in the stress concentration of implant-supported zirconia restorations, with Morse-taper connection implants. One implant model was analyzed according to the loading region (center of the crown or working cusp). Both systems received cement-retained zirconia crown. The peri-implant tissue was created as an isotropic resin, that has been fixed. The load of 500 N was applied in two different regions (center of the crown or working cusp). The results were analyzed in terms of von-Mises stress. The materials were assumed as isotropic, homogeneous, linear and elastic. The results showed that there is difference regarding the loading method for the calculated stress. The working cusps loadings increased the stress in the crown and the prosthetic connections. In conclusion, the occlusal contact region can modify the implant biomechanical behavior. In addition, the dentists should proper plan the prosthetic crown to reduce the stress in the zirconia crowns.

Keywords: Biomechanics, Bone, Dental implants, Prosthetic dentistry, Stress

Introduction

Dental implants present high success rate, but failures can occur during the osseointegration process, especially in posterior implant restorations with overload conditions [1-3]. In addition to the occlusal loading intensity, the loading direction can modify the stress magnitude [4,5]. As the digital workflow for dental restorations has increasingly in the last years, the manufacturing of implant-supported restorations should be very well planned [3,6]. In addition, it has been reported that oblique loading facilitate the failure when using monolithic crowns [1,7]. Although, the effect of different dental materials on the peri-implant tissue microstrain is controversial in the literature [7-9].

Other parameters daily found in the dental practice are the prosthetic connection and the peri-implant tissue level [7]. A previous and in vitro study analyzing the peri-implant microstrain, showed that there is no difference between dental implants with external hexagon or Morse-taper prosthetic connection at different the bone level [8].

In addition, the usage of conical prosthetic connections can reduce the bone crest resorption; and consequently promoting a better prognosis compared to the external hexagon connection in some cases [8-12]. Many studies shown differences between implant systems mechanical effect caused by the prosthetic connection, however more studies are need focusing in the dental crown [13-15]. To study the dental implants biomechanical behavior, the finite element analysis can be widely applied in dentistry [1,2,13]. This methodology is a numerical calculation using the simulation chewing loads, representative models, mechanical properties and the oral condition [16]. With this tool, is possible to offer predictability of situations for further in vivo or in vitro studies. Therefore, the aim of this study was to investigate the biomechanical effect of loading direction on a posterior unitary zirconia implant-supported restoration using the finite element analysis.

Methods

For the present simulation, a previous validated model was used (Figure 1) [8]. The model was composed by a regular morse-taper internal connection implant (DriveCM Acqua, Neodent, Curitiba, Paraná, Brazil) that was created with standard dimensions (4.3 x 10 mm), using CAD (Computer Aided Design) software (Rhinoceros 4.0, SR8, McNeel North America, Seattle, WA, USA).

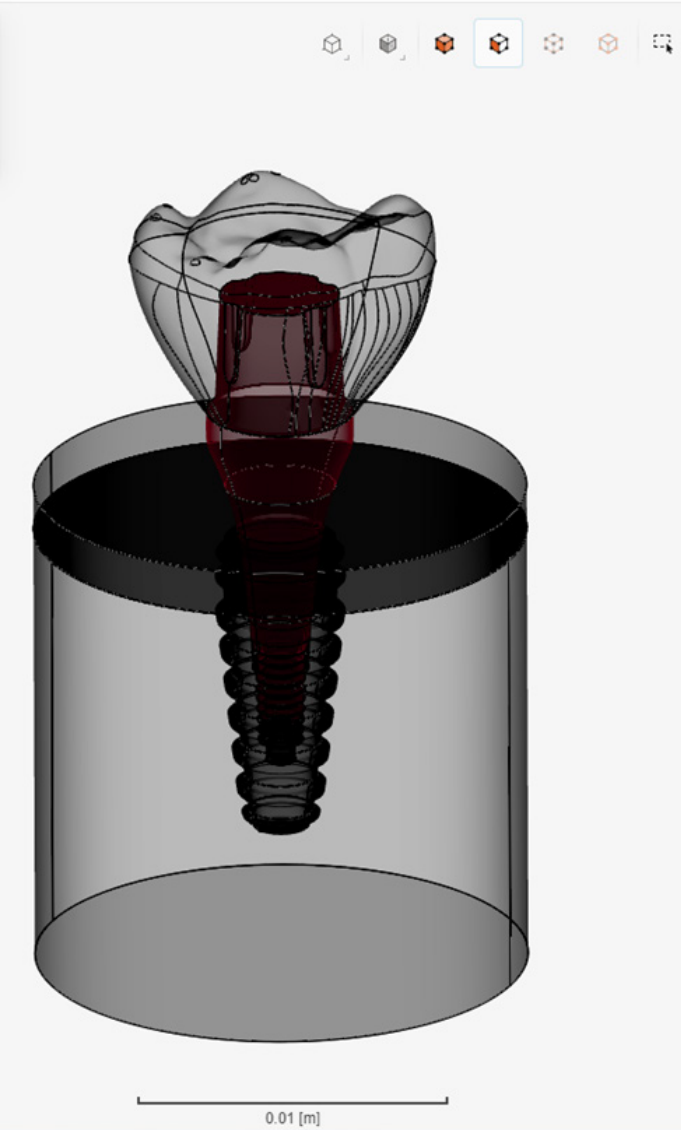

Figure 1: 3D Model considered in the present study.

In addition, the model presented an anatomic prosthetic solid abutment. The implant was placed axially centralized to the three-dimensional simplified bone model (40 x 40 x 20 mm) without exposed threads. An anatomic cemented crown representing a first upper molar previously described was and placed on the abutment. After modeling, the 3D model was imported to open-source analysis software (SimScale GmbH, Munich, Germany). Each material was then assigned as homogeneous, linear and isotropic to perform the static analysis. The information of Young's modulus and Poisson's ratio were selected from the software database. The mechanical properties of PVC were used to simulate bone structure and Zirconia was used to simulate the crown material. For the abutment and implant, the titanium alloy was considered. To simulate absence of defects all contacts were considered perfects. The 3D geometry was automatically subdivided in elements that formed the mesh. The number of finite elements was 432.5K with 89.3K nodes.

Two different loading protocols were performed: In the axial loading, the center of the crown was defined as the contact area with 500N in Z-axis (Figures 2 and 3). The second loading was applied in the buccal cusps with similar intensity simulating the oblique loading condition. The base of the cylinder was selected for the fixation support. The results were required according Von-Mises criteria.

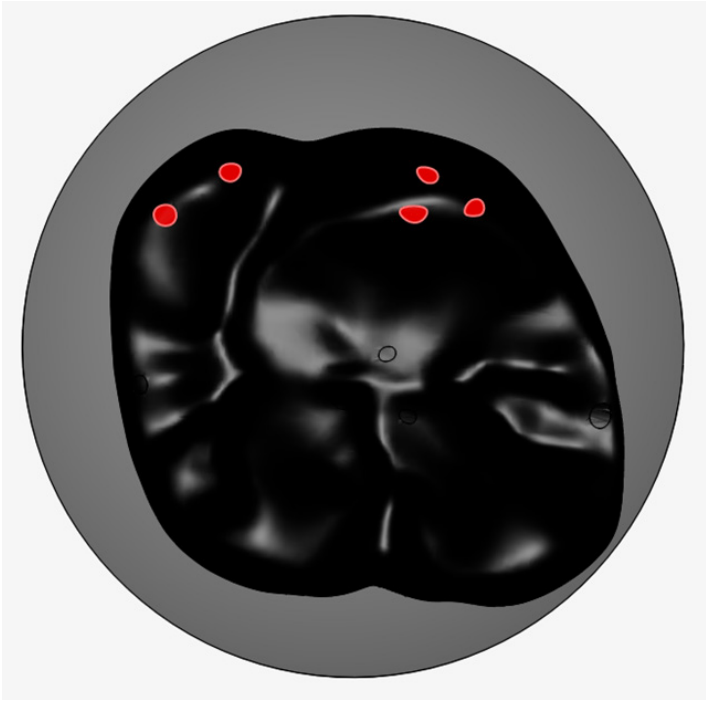

Figure 2: Working cusps loading

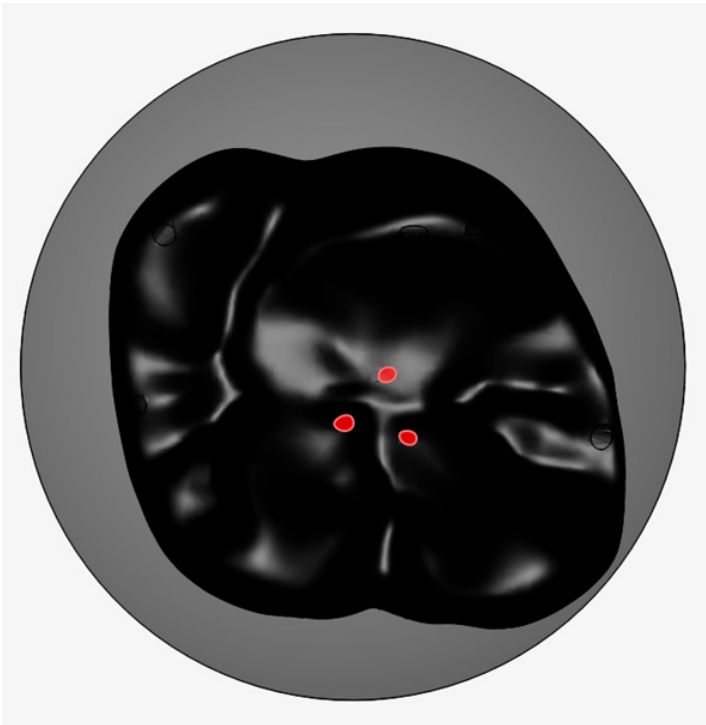

Figure 3: Central are loading

Results

After the finite element analysis calculation it was possible to observe a similar stress trend for both models (Figures 4-7). The qualitative comparison showed a higher stress concentration in the models with cusp loading in comparison with axial loading. In addition, both models showed the worst condition of stress magnitude at the bone level.

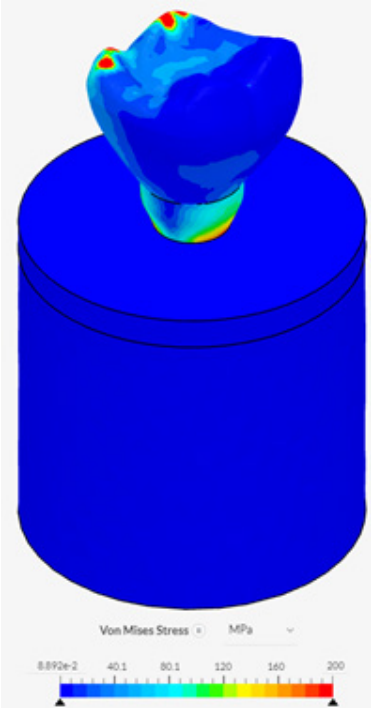

Figure 4: Von Mises stress in the working cusps model

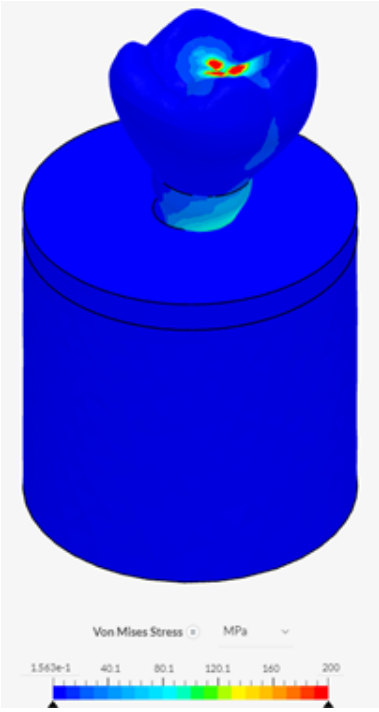

Figure 5: Von Mises stress in the central area model

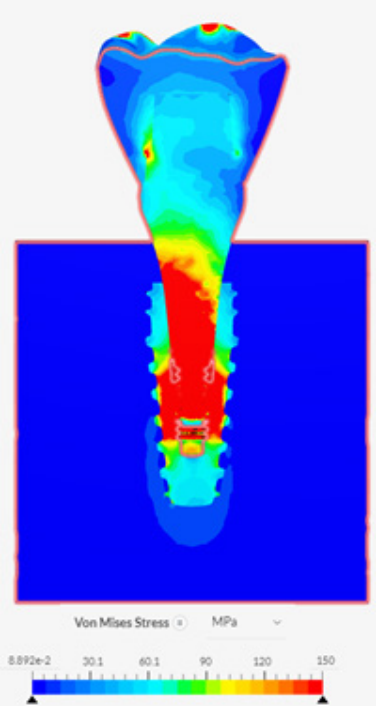

Figure 6: Section plane of Von Mises stress in the working cusps model

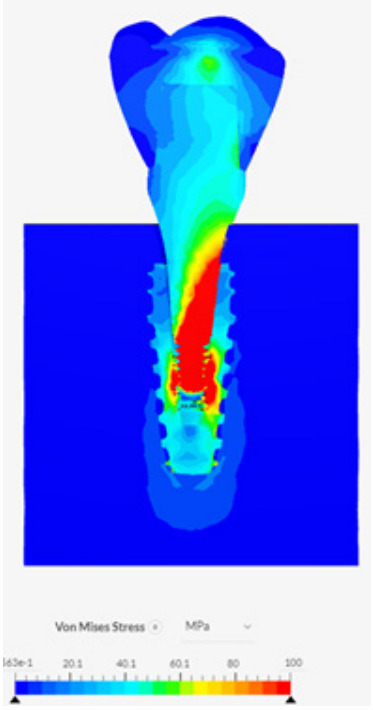

Figure 7: Section plane of Von Mises stress in the central area model

Discussion

The aim of this study was to investigate the biomechanical effect of loading condition on a posterior unitary implant-supported zirconia restoration, using the 3D finite element analysis. Results showed that loading protocols are able to generate different stresses in the implant and in the peri-implant, corroborating with previous studies [1-5]. In addition, the prosthetic connection showed the highest stress concentration regions, similar to reports by previous in vitro and in silico reports [7-9].

According to the clinical measurements, the annual amount of bone loss less than 0.2 mm following the first year of implant service is recommended as one of the criteria for implant success [1]. Therefore, the present study simulated an ideal condition without bone loss. According to the literature, the reduction in the bone height reduces the implant longevity [7]. In addition, the results suggesting that, if non-axial loads are present the a more problematic factor to the implant treatment would be present [7,13].

Finally, it is important to emphasizes that the finite element analysis is an ideal simultion that uses perfectly contacts different from the clinical condition [15]. In addition, the processing method used in the crowns manufacture could affect the restoration longevity [18,19].

A previous investigation evaluate the stress caused by the fixed prosthesis under oblique forces around dental implants and bone by using different infrastructure materials and different inclusions, by 3-dimensional finite element analysis method [18]. When the stress results in the mandible during oblique loading were evaluated, it was found that the stresses on the cortical bone were higher than the stresses on the trabecular bone [18]. It was observed that the highest stress values occurred in the implants similar to the present study.

It was also reported that monolithic zirconia has excellent mechanical and biologic properties but the evidence of the clinical properties of implant-supported monolithic zirconia prostheses is limited [15,20]. In addition, the peri-implant marginal bone level is comparable for metal-ceramic and monolithic zirconia single crowns, but monolithic zirconia present reduced plaque [20-22].

Not only the stress behavior, the zirconia posterior crowns have adequate fatigue and fracture resistance required for posterior crowns and when heavy fatigue forces are expected, zirconia material is preferable over lithium disilicate [17].

Translucent Zirconia (TZ) is one of the all-ceramic crowns materials indicate to posterior single implant replacements that present a promising treatment option in the medium-term period [20]. Overall, a high implant survival rate, good biological integration, and excellent esthetic performance can be expected when using this material. Moreover, a previous investigation reported the complication-free rates were 94.8% for abutments and 86.2% for crowns respectively [20]. Justifying the use of a well-planned loading orientation as demonstrated by the present results [21].

Previous investigation showed that the occlusion with monolithic zirconia crown materials is promising for implant-supported prostheses in the canine and premolar areas [22]. However, the crown material does not influence stress distribution in the surrounding bone and implant structure [23]. Despite that, in patients with a high biting force physiological values, the zirconia can be indicated [24].

The literature demonstrates that prosthetic hybrid abutments are excellent alternatives for implant-supported restorations, associating esthetic results, soft tissue response and bone stability [25]. Properties that could be associated with the zirconia material also.

Conclusion

In conclusion, the occlusal contact region can modify the implant biomechanical behavior. Dentists should proper plan the prosthetic crown to reduce the stress in the zirconia crowns.

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