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Evaluation of marginal bone loss in implant supported over-dentures: An original research

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Abstract---Aim: The purpose of the present research was to assess the marginal bone loss due to stresses encountered in implant supported over-dentures. Methodology: Tridimensional models were built from the images of a computerized tomography of a mandible and 3D laser digitalization of implants, abutments, mucosa, and complete denture. The geometric models of implants and abutments were mounted at the canine region to build reference model 1 - absence of bone resorption. To build the test models the mandible

geometric solid was modified to simulate 2-mm vertical bone loss surrounding the implants (model 2) and resorption of the distal ridge (model 3). Finite elements models were generated, and a 100 N static load was applied at the first molar region of each model to compare the von Mises stress distributions in selected points. Results: Von Mises stresses increased on the bone surrounding implants and on the prosthetic components in the model with 2-mm vertical bone loss. The combination of 2-mm vertical bone loss and resorption of the distal ridge did not increase the stresses compared with the model with only bone loss surrounding implants. The highest stress concentration at marginal bone and implants occurred on the same side of the vertical load application for all models. Conclusion: The results suggest that the bone loss surrounding implants increases stress concentration in dental implants, abutments, and marginal bone independently from the bone resorption of the distal ridge.

Keywords---dental implants, overdenture, biomechanics, finite element analysis.

Introduction

Since their introduction in the 1960s and 1970s, osseointegrated dental implants have been used worldwide to rehabilitate patients with partial or complete edentulism.¹ The evaluation of bone stability is essential to ensure optimal long-term results of osseointegrated implants, because excessive bone loss can result in periimplantitis,² which can lead to eventual implant loss. Additionally, the loss of marginal bone height can change the surrounding soft tissue architecture, resulting in the loss of interdental papilla and causing esthetic and phonetic changes and food impaction.³ Decreases in inflammatory reactions, load concentrations, and bacterial leakage at the implant abutment interface are closely associated with marginal bone loss.^{4,5} Several factors can influence marginal bone loss around dental implants, including patient characteristics (smoking and hygiene deficiency or parafunctional habits),⁶ prosthesis characteristics (retention method and number of elements), and dental implant characteristics (diameter, surface treatment, and connection type).^{7,8} Various dental implants with different internal and external connection types are available. These connections and how they relate to the implant abutment may influence marginal bone loss. The abutment and the implant can be of equal diameters, or an abutment with a narrower diameter (the platform switching concept) can be used.⁷ The connection between the abutment and implant is related to the formation of microgaps, bacterial leakage, micromovements of the abutments, and alteration of biologic width formation, all of which may cause higher or lower marginal bone loss. Studies have compared the marginal bone loss of several types of implants by considering implant macrodesign, surface treatment, and installation depth. However, few studies have evaluated the marginal bone loss around implants by considering the connection type. The management of complete edentulism and its sequelae with implant-supported prostheses has been reported to be both efficacious and effective. Both fixed and overdenture clinical protocols have now expanded to include diverse loading ones

in spite of the fact that there is a lack of uniformity in the determinants of successful outcome criteria. Nevertheless, mandibular two-implant overdentures opposing conventional complete maxillary dentures have been proposed as the standard of care⁴ since this treatment option appears to provide higher levels of patient treatment satisfaction. It is also conceded that the response continuum may be influenced by a number of factors such as specific site response, surgical skill, the implant's micro- and macroscopic surface design, timing, and control of the occlusal loading. Early recommendations included a projected 1.0 mm of marginal bone loss during the first year of function and 0.2 mm annually thereafter. A subsequent publication extended the "permissible" marginal bone loss during the first year to 1.5 mm and added the descriptor "average," which reflected the consideration that implant success should be determined on an entire-mouth basis and not by each implant as an independent unit.⁹ The mandibular bone loss inevitably occurs after the extraction of teeth, and the resorption of the posterior ridge is not prevented with the installation of implants in the anterior region. A marginal periimplantar bone loss of approximately 1 mm in the first year and of additional 0.1mm annually has been reported as normal in the literature. This rate of bone loss can vary due to unfavorable conditions of masticatory loading and plaque accumulation on the implant sites, which could compromise the prognosis of the oral rehabilitation treatment over the years since it is related to the preservation of the supporting tissues. This study has a comparative, descriptive design to evaluate stress distribution pattern in overdentures simulating the following conditions: 1) no loss of marginal bone around dental implants, 2) marginal bone loss of 2mm around the implants, and 3) resorption of the posterior ridge of the mandible associated with marginal bone loss 2 mm around the implants.

Aim of the present study

The purpose of the present research was to assess the marginal bone loss due to stresses encountered in implant supported over-dentures.

Methodology

Seventy 1 mm-thick slices of the mandible were obtained by means of a helical computed tomography using a spiral CT GE HiSpeed CTI System Series 6.4. The assembly of the computational geometric model was performed only for half of the sections generated by the CT scan, and by symmetry it was generated the entire mandibular 3D geometric model without bone loss (model 1 – reference model). For the construction of the test models, the outline of the geometric model of the mandible was altered to simulate the 2mm periimplantar bone loss (model 2) and the bone resorption of the posterior ridge of the mandible associated with 2mm periimplant bone loss (model 3). The 3D models of the complete denture, resilient mucosa simulation, implant and components were created using a laser scanning system. A computer file was generated with extension. "Txt" from coordinates x, y, z from each point of the scanned external surfaces. This file was opened in Geomagic® software v. 7.0. In the software the images were cleaned beforehand, and then 3D images of the prototypes of the research began to be visualized. The geometric models of implants and prosthetic components were mounted in the canine region of the mandibular model with the mucosa simulation. In relation to

contact between the components of the model, it was adopted a situation of perfect contact between implants and bone tissue. To impose restrictions on movement of the rigid body model, restrictions have been adopted for all degrees of freedom for each node found in the articular surface of the condyles and the regions of insertion of the masticatory muscles. A load of 100 N was applied to the model indirectly over a simulation of a masticatory bolus, which was shaped as a semi-sphere in contact with the right first molar. The distributions of von Mises stresses induced by the applied loads on the three models were qualitatively analyzed in selected areas: 1) peri-implant cortical bone and 2) implants and prosthetic components.

Results

For all models the highest stress concentration at marginal bone and implants occurred on the same side of the vertical load application (right side). (Table 1) The Von Mises stresses increased on the peri-implant marginal bone and in the prosthetic components in the model with 2-mm vertical bone loss. As the layer of cortical bone was thinner in the models with peri-implant bone loss (models 2 and 3), the stresses were located closer to the platform of the implant in comparison with model 1. Thus, the right and left implants in the models 2 and 3 showed larger area of high stress and also maximum values than model 1. There was a similar stress distribution pattern in the peri-implant region of the models 2 and 3. Only the left peri-implant region of the model without bone loss (model 1) did not show stress values considered critical. (Table 1)

Discussion

Most studies showed marginal bone loss values for internal connection implants that were lower than those for external connection implants.¹⁰ However, fewer studies^{7,8} had a similar macrodesign and surface treatment of the dental implant, differentiating between the groups only by connections. Nevertheless, other factors, related mainly related to participants, may have influenced the results of Koo et al.⁷ Additionally, although Canullo et al.⁸ had placed implants with both types of connections in the same participants, they did not standardize the distance between the implants and did not report whether the procedure was performed by a single surgeon. After completion of treatment with overdentures, changes in the support structures of implants and prostheses may occur over time, mainly periimplantar marginal bone loss and ridge resorption.¹¹ In the tested models of implant-supported overdentures, the periimplantar marginal bone loss increased stress concentration in dental implants, abutments, and marginal bone independently from the bone resorption of the distal ridge. The combination of 2-mm vertical bone loss and resorption of the distal ridge (model 3) did not substantially modify the stress distribution pattern and magnitude compared with the model with only periimplantar marginal bone loss (model 2). This finding indicates that an overdenture supported by two implants may not have a negative biomechanical prognosis for patients with distal ridge resorption if adequate support is given by the denture bearing area. Previous studies¹² related the progressive marginal bone loss with increasing values of tension in the cervical area of the implant and the support bone tissue. In the present research, the thickness of cortical bone tissue was reduced in the region of periimplantar bone

loss, since the layer of cortical bone tissue narrows as bone remodeling occurs due to the occlusal stimuli that promote progressive marginal bone loss. Thus, this may have been one of the causes on the wider distribution of tension in the cortical layer, since the area for dissipation of the applied force decreased. This explanation is consistent with the finite elements study by Sevimay et al., in which the authors found that implants placed in the region of small thickness of cortical bone and poor quality of cancellous bone showed higher micromovement under occlusal loads and higher concentration of stresses in the adjacent bone tissue.¹³ Another possible explanation for the tensions to be higher in the region of periimplant bone loss would be the dislocation to the apex of the fulcrum of rotation in the cervical implant region due to lower insertion of the latter in the bone tissue. Only Von Mises stresses of low magnitude were observed in the cancellous bone tissue, whereas different patterns of stress concentration occurred in cortical bone tissue. This happens because the elasticity modulus of the two types of bone is very different, and the stress distribution is also modified in the cancellous bone with variable bone density.¹⁴ The high values of stress concentration in the cortical bone may indicate increased participation in the absorption of functional loads transmitted by the implant-supported prosthesis. For the current study, it was simulated an application of a vertical load of 100 N, which is considered a physiological value in edentulous patients and sufficient to obtain significant results in previous studies with finite element.¹⁵ It was observed that the largest gradient forces in the bone periimplantar marginal regions occurred on the right side, close to the place of application of vertical loading, corresponding to the right first molar.

Conclusion

This study showed that the Von Mises stresses increased on the periimplant marginal bone and prosthetic components in the model with 2-mm vertical bone loss (model 2). However, the combination of 2-mm vertical bone loss and resorption of the distal ridge (model 3) did not increase the stresses compared with the model with only periimplant marginal bone loss (model 2).

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Tables

Table 1- Mechanical elastic properties of bone tissue and materials used in the anisotropic models

Variables	Young's modulus (MPa)	Poisson's ratio
<i>Cortical bone</i>	13,700	0.3
<i>Cancellous bone</i>	1,370	0.3
<i>Mucosa</i>	1	0.37
<i>Mandibular nerve</i>	0.1	0.3
<i>Overdenture (acrylic resin)</i>	4,500	0.35
<i>Implant (titanium)</i>	135,000	0.3
<i>Screw (titanium)</i>	114,000	0.3
<i>Attachment (titanium)</i>	114,000	0.3
<i>PTPE attachment component</i>	19,000	0.3

Table 2- Stress distribution pattern in overdentures

Model number	Pattern of bone loss
1	No bone loss
2	2-mm peri-implant marginal bone loss
3	2-mm peri-implant marginal bone loss + distal ridge resorption.