Effect of different mucosa thickness and resiliency on stress distribution of implant-retained overdentures-2D FEA

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ABSTRACT

The study aimed to evaluate the effect of different mucosa thickness and resiliency on stress distribution of implant-retained overdentures using a two-dimensional finite element analysis. Models were used in order to simulate two situations. In group A, model represented an edentulous mandible supporting an overdenture retained by two-splinted-implants connected with bar-clip system while in group B, model simulated an edentulous mandible supporting an overdenture retained by two-splinted-implants connected with bar-clip system associated with two-distally placed o’ring system. In each group, mucosa assumed three characteristics of thickness (1, 3 and 5 mm) in the resiliencies: hard, resilient and soft, respectively. Evaluation was performed on Ansys software. Group A showed higher stress values regardless of the mucosa characteristics. Overall, stress decreased at the supporting tissues as mucosa thickness and resiliency increased. Regarding supporting tissues, cortical bone showed the highest stress values. The use of bar-clip attachment system with distally placed o’ring attachment design optimized the stress distribution.

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1. Introduction

Mandibular implant-retained overdentures using two to four implants [1-5] provide an effective treatment modality for edentulous patients and, particularly, for those who have persistent problems with the use of a conventional mandibular denture [5,6]. The high success rate of implants used to support mandibular overdentures is well documented with longitudinal studies [1,7-9]. Most patients who suffer from denture instability, especially with a mandibular denture, will benefit significantly from even a slight increase in retention [10].

The correct selection of an attachment system is also an important characteristic, since this is a critical link between prosthesis and implant [11]. Various attachment types can be employed, basically splinting (bar-clip constructions with various bar-shape designs) or not splinting the implants (various ball type attachments, magnet attachments and attachments with telescopic copings). According to Cune et al. the bar-clip attachments were the most used retention system [12].

Even though prosthetists seem to prefer splinting the implants by means of a bar-clip construction, ball and magnet attachments offer some potential advantages. Incorporating these attachments in a denture is less time consuming, which in addition to the lower costs of components makes their use cheaper when compared to bar-clip attachments. Furthermore, nonsplinted constructions facilitate easy cleaning. Magnet attachments are associated with a lower level of
implant moment loading [13] since the magnetic field does not resist to horizontal forces.

Another aspect that could influence the choice of the suprastructure type is the amount of maintenance required. The consensus of many studies is that maintenance requirements are highest during the first year of service, and they are usually related to adjustments of contour, loosening or breakage of clips or ball matrices, corrosion of magnets, retention loss of clips and ball matrices and loosening of fixation screws of the bar or ball [14–17].

As a patient functions with an implant-retained overdenture, loads are transmitted to the alveolar bone surrounding the implants [18]. For this reason, it is important not to cause excessive loads on the implants [19] because it has been reported that excessive loads may cause bone loss through the induction of bone microdamage [20]. Daas et al. observed that resilient attachments allowed the increase of the mastication load transmission through the denture bearing area, since during the mastication process, the load transferred was mainly supported by the mucosa, allowing a better load distribution between the dental implants [21].

Mericske-Stern verified that for unsplinted implants with ball attachment, chewing and grinding resulted in lower forces compared to maximum biting, particularly in the vertical direction [22]. The transverse force component in backward–forward direction, however, reached magnitudes that exceeded the vertical component by 100–300% during chewing function. This chewing pattern had not been observed in previous investigations with bars and telescopes [23].

Load transfer from implants to surrounding bone also depends on the type of loading, the bone-implant interface, the length and diameter of the implants, the shape and characteristics of the implant surface, the prosthesis type, and the quantity and quality of the surrounding bone [24]. In addition, by the difference between the displacement of the implant (20–30 μm) and the soft tissue (about 500 μm) there is stress concentration at the implant [10], and this stress increases as the resiliency of mucosa increases [10]. Payne and Solomons observed that the bar-clip attachment system can decrease the stress concentration at the implant since this type of attachment system allows vertical and rotational overdenture movement toward the oral mucosa around the long axis of the bar [25]. A certain amount of overdenture movement during mastication is necessary to protect the abutment and to allow for tissue resiliency [25]. However, Menicucci et al. found that rigid bar connecting two implants tends to counteract this movement, so that more stress reaches the peri-implant bone [26].

Thus, the aim of this study was to evaluate the effect of different mucosa thickness and resiliency on stress distribution of implant-retained overdentures with two different attachment systems (bar-clip system associated or not to two distally placed o’ring system) using a two-dimensional finite element analysis (FEA-2D).

2. Materials and methods

Finite element (FE) models were constructed reproducing a frontal section of an edentulous mandible in two situations: group A, model of edentulous mandible supporting an overdenture retained by two splinted implants connected with bar-clip system; group B, model of an edentulous mandible supporting an overdenture retained by two splinted implants connected with bar-clip system associated with two distally placed o’ring system. In each group, mucosa assumed three characteristics of thickness (1, 3 and 5 mm) in the resiliences hard, resilient and soft, respectively. The resiliencies of mucosa were determined by the elastic modulus variation. Mucosa, denture base, artificial teeth, implants and prosthetic components (attachment systems) were represented in all models.

The denture contour was obtained from a frontal photographic image of the demonstration model of a mandibular complete denture. The cortical bone and trabecular bone were reproduced as a 0.5-mm and 20-mm layer, respectively. Two hexagonal implants of 3.75 mm in diameter and 11.5 mm in length (Master Screw, Conexão Sistemas de Prótese Ltd., São Paulo, SP, Brazil) were positioned at the anterior regions of the models. The interimplant distance between 2 implants was 20 mm [27].

For bar fabrication it was used two UCLA type plastic cylinders (055021, Conexão Sistemas de Prótese Ltd., São Paulo, SP, Brazil) and plastic bar-clip attachment (204000, Conexão Sistemas de Prótese Ltd., São Paulo, SP, Brazil). The bar, with a round shape, was cast in CoCr alloy (CNG Soluções Protéticas, São Paulo, SP, Brazil) according to standard laboratory procedures. The plastic clip was connected to the bar and this set was screwed to the implants configuring group A. Group B was similar to group A with two o’ring attachments (049071, Conexão Sistemas de Prótese Ltd., São Paulo, SP, Brazil) located distally to the implants at the superstructure.

The sets were embedded in a cold acrylic resin (Jet, Artigos Odontológicos Clássico Ltd., São Paulo, SP, Brazil) using an embedding machine (Artotec PRE 30S, Artotec S.A. Ind. e Com., Cotia, SP, Brazil). The implant-attachment complex was longitudinal sectioned using a saw machine (Isomet 1000 Precision Saw, Buehler, Lake Bluff, IL, USA) and then digitalized on a scanner (HP scanjet 2400, Hewlett-Packard Company, Palo Alto, CA, USA). The scanned images were imported into image analysis software (AutoCAD 2005, Autodesk Inc., San Rafael, CA, EUA).

The outline of the models images was manually quoted and each point converted into x and y coordinates. The coordinates were finally imported into the finite element software (Ansys 11.0, Swanson Analysis System, Houston, PA, USA) as keypoints of definitive images.

Ten different types of materials were assigned for these two models: acrylic tooth, acrylic resin, mucosa, cortical bone, trabecular bone, titanium alloy, CoCr alloy, stainless steel, plastic clip and o’ring rubber. Each object was then subdivided in smaller elements. The elements shapes were 2D six-node triangular plane strain element (plane 2). The models of group A (Fig. 1) had a total number of 9778 elements and 20,494 nodes for 1-mm mucosa model, 9306 elements and 19,526 nodes for 3-mm mucosa model and 8758 elements and 18,398 nodes for 5-mm mucosa model. In group B (Fig. 2), models had a total number of 8872, 9084, 8778 elements and 18,686, 19,046, 18,408 nodes for 1-mm, 3-mm and 5-mm mucosa models, respectively.
Fig. 1 – Finite element mesh of group A models. (A) 1-mm mucosa model (20,494 nodes and 9778 elements). (B) 3-mm mucosa model (19,526 nodes and 9306 elements). (C) 5-mm mucosa model (18,398 nodes and 8758 elements).

Fig. 2 – Finite element mesh of group B models. (A) 1-mm mucosa model (18,686 nodes and 8872 elements). (B) 3-mm mucosa model (19,046 nodes and 9084 elements). (C) 5-mm mucosa model (18,408 nodes and 8778 elements).

Table 1 – Materials mechanical properties

<table>
<thead>
<tr>
<th>Materials</th>
<th>Young’s modulus (MPa)</th>
<th>Poisson’s ratio (ν)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylic tooth</td>
<td>3,000</td>
<td>0.35</td>
<td>Tanino et al. [28]</td>
</tr>
<tr>
<td>Acrylic resin</td>
<td>3,000</td>
<td>0.35</td>
<td>Tanino et al. [28]</td>
</tr>
<tr>
<td>Mucosa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hard</td>
<td>680</td>
<td>0.45</td>
<td>Ko et al. [29]</td>
</tr>
<tr>
<td>Resilient</td>
<td>340</td>
<td>0.45</td>
<td>Ko et al. [29]</td>
</tr>
<tr>
<td>Soft</td>
<td>1</td>
<td>0.37</td>
<td>Menicucci et al. [26]</td>
</tr>
<tr>
<td>Cortical bone</td>
<td>13,700</td>
<td>0.3</td>
<td>Barbier et al. [30]</td>
</tr>
<tr>
<td>Trabecular bone</td>
<td>1,370</td>
<td>0.3</td>
<td>Barbier et al. [30]</td>
</tr>
<tr>
<td>Implant (Ti-6Al-4V)</td>
<td>103,400</td>
<td>0.35</td>
<td>Sertgoz and Gunever [31]</td>
</tr>
<tr>
<td>Co-Cr alloy</td>
<td>218,000</td>
<td>0.33</td>
<td>Caglar et al. [32]</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>19,000</td>
<td>0.31</td>
<td>Manufacture*</td>
</tr>
<tr>
<td>Plastic clip</td>
<td>3,000</td>
<td>0.28</td>
<td>Manufacture*</td>
</tr>
<tr>
<td>O’ring rubber</td>
<td>5</td>
<td>0.45</td>
<td>Chun et al. [33]</td>
</tr>
</tbody>
</table>

* Personal communication.

All materials used in this study were considered to be isotropic, homogeneous and linearly elastic. Models were assumed to be in a plane strain condition ($\varepsilon_z = 0$ and $\sigma_z \neq 0$). The materials properties are shown in Table 1.

The implants and bone tissue were considered to be fully integrated in their interface. Between implants and prosthetic components, a screw joint was determined and the prostheses contact was defined as resting on the mucosa.

In order to simulate a clinical situation, the models were not supported at the bottom, but the left and the right side of the models were fastened to allow bending of the mandible [34]. An axial load of 100 N [34] was applied on the incisal surface of lower central incisive teeth.

Data for first principal stresses were produced numerically and color-coded and compared among the models. Additionally, first principal strains, and x- and y-axis displacement were evaluated.

3. Results

After the data were processed by the finite element program, the stress maps were obtained for groups A (Fig. 3) and B (Fig. 4). Maximum and minimum stresses and strains values and their location in the models are presented in Table 2.

Accurate assessment of stress and strain distribution was provided for implant, prosthesis and bar retainer structures. The data are summarized in Table 2.

It was observed that the highest stress regions were concentrated at left bar-implant contact area in the medial side for both groups (Figs. 5 and 6 and Table 2). Usually, the peak
strain values were located at the mucosa right edge for group A, and for group B were located at the o’ring rubber (Table 2).

In general, group A showed the highest stress values and lowest strain values regardless of the mucosa thickness and resiliency (Figs. 3, 4 and 7 and Table 2).

Analyzing the effect of mucosa thickness and resiliency in relation to each group, it was observed that there was a decrease of maximum stress values for 3-mm mucosa models when compared to the 1-mm mucosa models for both groups (Fig. 7 and Table 2). Nevertheless, when the thickness of mucosa was increased to 5 mm, there was an increase of maximum stress values when compared to the 3-mm mucosa models, but this increase was very slight for group B (Fig. 7 and Table 2). Regarding individual analysis of implants, a similar tendency in relation to the stress values was found (Table 2).

Analyzing bar retainer structure, while in group A there was an increase in maximum strain values when mucosa thickness and resiliency increased, in group B the maximum strain values decreased (Table 2).

In the supporting tissues (mucosa, upper cortical bone, lower cortical bone and trabecular bone) of group B, the stress values decreased as mucosa thickness and resiliency increased (Fig. 8). The same trend was observed for group A, although a slight increase in stress values was found for the 5-mm mucosa model when compared to the 3-mm mucosa model (Fig. 8). Furthermore, group A showed the highest stress values when compared to group B regardless of the mucosa thickness and resiliency, except for the 3-mm mucosa models, in which group B (70.159 MPa) the maximum stress values was slight greater than group A (68.340 MPa) (Fig. 8).

Regarding the supporting tissues, cortical bone showed the highest stress values for both groups independent of mucosa thickness and resiliency. Cortical bone stress concentrations were noted at the distal side of the implants for both groups (Figs. 9 and 10).

Table 3 illustrated the peak values of the x- and y-axis displacement of the implants, the prostheses and the mucosa (at the molar region) under load for groups A and B. The x-axis displacement values have a tendency to increase when the mucosa thickness and resiliency was increased for prostheses and mucosa structures in both groups. Independently of the group, it was observed that the y-axis displacement values increased as the thickness and resiliency of mucosa increased for all structures.
<table>
<thead>
<tr>
<th>Structure</th>
<th>Group</th>
<th>A-1 mm</th>
<th>A-3 mm</th>
<th>A-5 mm</th>
<th>B-1 mm</th>
<th>B-3 mm</th>
<th>B-5 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>MX stress</td>
<td>349.873 (contact area between implant medial platform and bar-retainer)</td>
<td>279.254 (contact area between implant medial platform and bar-retainer)</td>
<td>310.449 (contact area between implant medial platform and bar-retainer)</td>
<td>258.65 (contact area between implant medial platform and bar-retainer)</td>
<td>193.437 (o’ring capsule)</td>
<td>195.311 (contact area between screw-retainer and bar-retainer)</td>
</tr>
<tr>
<td></td>
<td>MN stress</td>
<td>0.002646 (bar superior area, above the implant)</td>
<td>0.74E−04 (bar superior area, above the implant)</td>
<td>0.29E−03 (bar superior area, above the implant)</td>
<td>0.15E−03 (bar superior area, above the implant)</td>
<td>0.969E−04 (bar superior area, above the implant)</td>
<td>0.140E−04 (bar superior area, above the implant)</td>
</tr>
<tr>
<td></td>
<td>MX strain</td>
<td>0.202E−07 (right edge of mucosa)</td>
<td>0.166E−07 (right edge of mucosa)</td>
<td>0.314E−07 (right edge of mucosa)</td>
<td>0.439E−07 (o’ring rubber)</td>
<td>0.438E−07 (o’ring rubber)</td>
<td>0.493E−07 (contact area between mucosa and prostheses)</td>
</tr>
<tr>
<td></td>
<td>MN strain</td>
<td>0.182E−13 (bar superior area, above the implant)</td>
<td>0.511E−15 (bar superior area, above the implant)</td>
<td>0.111E−14 (bar superior area, above the implant)</td>
<td>0.105E−14 (bar superior area, above the implant)</td>
<td>0.668E−15 (bar superior area, above the implant)</td>
<td>0.871E−15 (bar superior area, above the implant)</td>
</tr>
<tr>
<td>Implant</td>
<td>MX stress</td>
<td>202.966 (medial platform)</td>
<td>156.042 (medial platform)</td>
<td>192.177 (medial platform)</td>
<td>165.862 (medial platform)</td>
<td>128.631 (medial platform)</td>
<td>110.16 (medial platform)</td>
</tr>
<tr>
<td></td>
<td>MN stress</td>
<td>0.15286 (distal hexagon area)</td>
<td>0.06903 (distal hexagon area)</td>
<td>0.07703 (distal hexagon area)</td>
<td>0.036617 (distal hexagon area)</td>
<td>0.68744 (distal hexagon area)</td>
<td>0.113423 (distal hexagon area)</td>
</tr>
<tr>
<td></td>
<td>MX strain</td>
<td>0.265E−08 (medial platform)</td>
<td>0.204E−08 (medial platform)</td>
<td>0.251E−08 (medial platform)</td>
<td>0.217E−08 (medial platform)</td>
<td>0.168E−08 (medial platform)</td>
<td>0.141E−08 (medial platform)</td>
</tr>
<tr>
<td></td>
<td>MN strain</td>
<td>0.200E−12 (hexagon area)</td>
<td>0.901E−13 (distal hexagon area)</td>
<td>0.101E−12 (distal hexagon area)</td>
<td>0.478E−12 (distal hexagon area)</td>
<td>0.488E−12 (distal hexagon area)</td>
<td>0.148E−11 (distal hexagon area)</td>
</tr>
<tr>
<td>Prosthesis</td>
<td>MX stress</td>
<td>11.174 (contact area with clip)</td>
<td>13.184 (contact area with clip)</td>
<td>14.73 (contact area with o’ring capsule)</td>
<td>12.851 (contact area with o’ring capsule)</td>
<td>14.818 (contact area with o’ring capsule)</td>
<td>11.412 (contact area with clip)</td>
</tr>
<tr>
<td></td>
<td>MN stress</td>
<td>0.163263 (right lower canine incisal)</td>
<td>0.147363 (right lower canine incisal)</td>
<td>0.17649 (contact area with mucosa)</td>
<td>0.91219 (right lower canine incisal)</td>
<td>0.291756 (right lower canine incisal)</td>
<td>0.31018 (right lower canine incisal)</td>
</tr>
<tr>
<td></td>
<td>MX strain</td>
<td>0.503E−08 (contact area with clip)</td>
<td>0.593E−08 (contact area with clip)</td>
<td>0.663E−08 (contact area with o’ring capsule)</td>
<td>0.578E−08 (contact area with o’ring capsule)</td>
<td>0.667E−08 (contact area with o’ring capsule)</td>
<td>0.514E−08 (contact area with clip)</td>
</tr>
<tr>
<td></td>
<td>MN strain</td>
<td>0.735E−10 (right lower canine incisal)</td>
<td>0.663E−10 (right lower canine incisal)</td>
<td>0.794E−11 (contact area with mucosa)</td>
<td>0.410E−10 (right lower canine incisal)</td>
<td>0.131E−09 (right lower canine incisal)</td>
<td>0.140E−10 (right lower canine incisal)</td>
</tr>
</tbody>
</table>
In finite element analysis studies, the assumptions made regarding geometry, mechanical properties of the materials, and loads and constraints applied to the model have a key role in the accuracy of the experiment [35]. The present study used 2D models to evaluate the stress distribution in implant-retained overdentures regarding different attachment systems and different mucosa thickness and resiliency. Although the models used in this study do not allow evaluation of the stress distribution on buccal and lingual implant areas, the results give an overall insight on the influence of several variables on the stress distribution.

Comparing the attachment systems, it was observed that the highest stress values were concentrated at the bar-implant contact area, where group A showed the greater maximum.
stress values (Figs. 3–7). These findings are in agreement with the study of Celik and Uludag, who compared the effect of different attachment systems on stress distribution of implant-retained overdentures and found lower stress values for bar-clip system with distally placed ball attachment than bar-clip [18]. The use of distally attachments on bar-clip system creates a fulcrum line in this portion. The prosthesis rotates anteroposteriorly around the fulcrum line, and due to the elastic modulus of the resilient matrices that fit around the ball attachments, the stress magnitude on the implants is reduced [18]. This result is in concordance with Ben-Ur et al. study [36]. Furthermore, o’ring rubber can absorb stress leading to lower stress values as observed in group B [37]. Sadowsky and Caputo evaluated, photoelastically, the biologic behavior of 2 and 3 implants retaining different designs

Table 3 – Displacement values (unit: mm) in x- and y-axis for groups A and B in each mucosa thickness and resiliency

<table>
<thead>
<tr>
<th>Structure</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A-1 mm</td>
</tr>
<tr>
<td>Implant</td>
<td></td>
</tr>
<tr>
<td>x-Displacement</td>
<td>.370E–08</td>
</tr>
<tr>
<td>Prostheses</td>
<td></td>
</tr>
<tr>
<td>Mucosa</td>
<td></td>
</tr>
<tr>
<td>x-Displacement</td>
<td>−.400E–09</td>
</tr>
</tbody>
</table>
of cantilevered bar mandibular overdentures and compared load characteristics [38]. Plunger-retained prosthesis caused more uniform stress distribution to the ipsilateral terminal abutment when compared to the clip-retained prosthesis and provided retention security under tested loads. Nonetheless, Meijer et al. did not observe stress values decrease when cantilevered bar-clip attachment was used [34].

Concerning mucosa thickness and resiliency the present study showed a decrease of maximum stress values for the 3-mm mucosa models for both groups (Fig. 7). For the 5-mm mucosa models, which simulates a soft mucosa in a clinical condition, the maximum stress values were higher when compared to the 3-mm mucosa models (resilient), but they were lower than that observed for hard mucosa models (1 mm) (Fig. 7).

Tanino et al. examined the effect of different thickness and resiliency of stress-breaking attachments at the connections between maxillary overdentures and implants [28]. The stress is reduced with the 3-mm-thick material when compared to the 1-mm-thick material, and as the elastic modulus decreases so does the stress [28]. These findings are in agreement with the results of the current study since the 3-mm mucosa (resilient) models lower stress values were observed when compared to the 1-mm mucosa (hard) models. Hence, as elastic modulus decreased (high resiliency) so did the stress (Fig. 7). On the other hand, for the 5-mm mucosa (soft) models this trend was not found in view of the fact that there was an increase of maximum stress values when compared to the 3-mm mucosa (resilient) models (Fig. 7).

The type of mucosa found in the 5-mm mucosa models allows a higher prosthesis intrusion leading to elevated maximum stress values. These stress areas were concentrated mainly on implants and prosthetics components. In addition, the increase in stress values for the 5-mm mucosa models when compared to the 3-mm mucosa models was about 11% and 1% for groups A and B, respectively (Fig. 7). Thus, the application of distal extension (o’ring) in bar-clip system can optimize the stress distribution in soft mucosa due to the higher resiliency allowing superior prosthesis movement.

In relation to the supporting tissues, the stress values decreased as mucosa thickness and resiliency increased for group B (Fig. 8). In group A, a slight increase in stress values about 4.5% was found for the 5-mm mucosa model when compared to the 3-mm mucosa model (Fig. 8).

Fig. 9 – Distribution of first principal stress in supporting tissues for group A models (unit: MPa). (A) 1-mm (hard) mucosa model. (B) 3-mm (resilient) mucosa model. (C) 5-mm (soft) mucosa model. Colors indicate level of stress from dark blue (lowest) to red (highest). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)
Song et al. evaluated the energy relieving effect of different mucosa thickness beneath mandibular complete denture using a 3D FEA. The authors observed that as mucosa thickness increased so did the energy relieving, leading to lower bone tissue deformation [39]. Therefore, thicker mucosa is benefit to reduce bone loss [39]. In general, these results are in accordance with the present study since thicker and softer mucosas relieve the stress in supporting tissues mainly in cortical bone (Figs. 8–10).

In FE models, bone stress concentration around the implants neck in both anchorage systems (Figs. 9 and 10) probably results from the presence of the cortical layers, where the bone has a higher Young's modulus [34,40]. This finding is in accordance with Menicucci et al., Meijer et al., Chao et al. and Chun et al. studies [26,33,34,41].

The highest stress concentration in cortical bone was situated only at the distal side of the implants (Figs. 9 and 10). This location may be explained by the mandible bending as a result of the vertical load [34]. So, when the structure is loaded, the mandible deforms, but the abutments are kept in place by the bar [34]. This causes an extreme amount of stress at the distal sides of the connected implants [26,34]. This would appear to confirm the results obtained by Hobkirk and Schwab, who conducted an in vivo study on mandibular deformation in subjects with osseointegrated implants splinted by rigid superstructure [42], and by Meijer et al. and Menicucci et al. in their studies using FE models [26,34].

The finite element modeling technique used in the present study has some limitation when predicting the response of biologic systems to applied loads, as do all modeling systems, including photoelastic analysis and strain gauges measurement [18,43]. However, the findings of this study may provide a broader understanding about the potential stress concentration locations. Long-term clinical research is required to determine the influence of the observed stress levels on the tissue and prosthesis function [18].

5. Conclusion

Within the limitations of this study, the following conclusions were drawn:
• For implant-retained overdentures, the attachment systems produced different stress distribution characteristics and, in the supporting tissues, those characteristics were mainly concentrated in the cortical bone surrounding the implants.
• Group A (bar-clip system) showed higher stress concentration when compared to group B (bar-clip associated with distally placed o’ring system).
• In general, as thickness and resiliency of mucosa increased, the stress values in supporting tissues decreased for both groups.
• The use of bar-clip attachment system with distally placed o’ring attachment design optimized the stress distribution.

Conflict of interest statement
The authors claim to have no financial interest in any company or any of the products mentioned in this article.

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