Load Distribution in a Photoelastic Resin Model with Different Implant Designs

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ABSTRACT

The aim of this research was to identify the load distribution patterns of dental implants installed in a photoelastic resin model. Cylindrical and conical implants were used with external hex (EH), internal hex (IH) and morse taper (MT) connections. A photoelastic resin hemimandible was made with an implant installed in the sector corresponding to the second premolar; a prosthetic abutment was installed in the implants at 20N. A force of 150N was applied vertically on the abutment and the load distribution was obtained using a polariscope, observed as strips of different colors. A square mesh served to identify quantitatively the number of strips and their distribution, in order to then compare the effect of the different implant systems. The cylindrical EH implant presented high stress at the cervical level. The conical IH implant presented the greatest load distribution at the middle and apical levels; the conical MT implant presented the greatest stress level at the cervical and apical levels. The highest stress level was observed in the cylindrical implant. Finally, the cylindrical EH implant presented the greatest stress level when compared to the conical IH implant.

Key words: dental implant, photoelasticity, mechanical analysis.
INTRODUCTION

Rehabilitation with dental implants has demonstrated success, stability and viability in recent years (Olate et al. 2010, Ortega-Lopes 2011). Currently, other elements that optimize their functional and esthetic outcome are highly valued.

There are several types of implants, with both macroscopic and microscopic differences (Gracis et al. 2012, Rosa et al. 2012), generating variable responses when integrated into the adjacent bone tissue (Olate et al. 2011). In addition to this, the implant/abutment connection system also has differences, at times significant when evaluating the stability and functionality of the installed implant (Binon 2000, Finger 2003). When these differences between systems are analyzed, one partially studied situation is the impact that the load distribution has on different implant designs and connections (Jaimes et al. 2009).

There is clarity in the fact that implants distribute the load more than natural teeth (Bidez & Misch 1992); thus, an increase in the implant load or a deficiency in bone quality can generate cervical bone resorption (Balfour 1995, Alkan 2004) and finally the failure of implant. It may therefore be indicated that differences in designs and connections related to load distribution, present differences in clinical indications and installation protocols.

Studies with photoelastic resin have been used in the analysis of load distribution in different areas of mechanics and biomechanics (Orr 2003), demonstrating favorable results in proposed studies. The aim of this research was to determine the vertical load distribution of implants installed with a prosthetic abutment in a photoelastic resin system.
MATERIALS AND METHODS

Implant selection

An experimental study was designed to analyze the load distribution in dental implants in a mandible model made with photoelastic resin. Three implant systems were selected: the first was a prosthetic connection with external hex (EH) (4.0x13mm) and cylindrical design, the second (4.0x13mm) was a connection with internal hex (IH) and conical design, and the third was a morse taper (MT) connection system (4.0x13mm) and conical design. For the mechanical analysis, the system’s specific prosthetic abutment was installed in all the implants.

Preparation of the hemimandible with photoelastic resin

A polyurethane hemimandible with teeth was used for the study (Franceschi & Costa e Silva Ltda., Jaú, Brasil). The second premolar of the hemimandible was removed with an erosion drill down to cervical level; then a perforation was made with a helical drill 3.75mm wide and 13mm long where the dental implant was installed until the cervical level of the perforation; the implant installed was kept with its respective mounter (Figure 1A); the implants were not completely stable in order to be removed in the following steps. An acrylic box was built that allowed access to the polyurethane hemimandible with implants installed together with two capture pins installed in the basilar part of the mandible (Figure 1B); the box was filled with laboratory silicone (Silibor Clássico, Sao Paulo, Brazil) on two occasions (initially with filling in the upper half and later with filling in the lower half) in order to obtain a negative copy of the hemimandible (Figure 1C); silicone polymerization was maintained for 24h. The box was removed keeping the silicone intact. The two parts of the silicone were separated to remove the polyurethane hemimandible and retain the implant in the silicone thanks to the implant mounter; it was possible to extract the implant from the initial polyurethane without difficulties.
The two parts of the silicone were re-installed in the acrylic box and the negative internal model was filled with photoelastic resin at a ratio of 100 parts Araldite GY 279 and 48 parts Aradur HY 2963, (AraltecR Productos Químicos Ltda., Sao Paulo, Brazil) (Oliveira 2009); the mixture was incorporated using a 10cc syringe. After completing the model, the system was left to stand for 72h in an ambient temperature between 15ºC and 22ºC, with suitable ventilation to obtain total polymerization of the resin, as per the manufacturer’s instructions. Four days after this process the box was removed together with the silicone, and the hemimandible replica in photoelastic resin was obtained with implants integrated into the resin and the mounter free of contact with the resin, which enabled its removal and subsequent installation of the prosthetic abutment with a 20N torque (Figure 2A).

**Mechanical analysis**

Load distributions in hemimandibles constructed with photoelastic resin were analyzed qualitatively and quantitatively. The measurements were made in a circular polariscope (Eikonal Instrumentos Opticos Comércio e Servico Ltda., Sao Paulo, Brazil) connected to a digital SLR camera (Canon Rebel x 5 350D).

Force was applied with a universal testing machine (Instron, mod. 4411) using a round 2mm end that impacted the abutment installed in each implant vertically until arriving at a force of 150N at a speed of 1mm/min (Figure 2A). The width of the hemimandible was also defined in the different areas of analysis using a cross-section (Figure 2B).

Visualization of the photoelastic resin strips was obtained by immersing the experiment substrate in a 30x30x30 bucket made of tempered glass containing transparent mineral oil (Campestre Ind. E Com. De Óleos Cegetais, Sao Bernardo do Campo, Sao Paulo, Brazil).

The qualitative analysis consisted in determining the starting point of the load distribution and the way in which the color strips were distributed. The quantitative analysis was done
by preparing a glass slide with grids 5mm long and 5mm wide, with the lateral 10mm being closest to the implant having 1mm² grids (Figures 3, 4 and 5).

The maximum shear stress was determined along the entire model using the strain optic law, where the respective order the strips at the point of interest (data obtained during study implementation), the optical constant of the material used (fo=11271 N/m according to Oliveira (2009)) and the width of the resin model (measurement of the substrate using a model sectioned prior to the investigation, Figure 2B) must be ascertained.

RESULTS

This research was developed without difficulties and according to the originally established protocol. The results showed some differences among the implants:

a. EH implant: the maximum stress analysis showed a greater load at the cervical level (t 5897), followed by the middle region (t 4587) and finally the apical region (t 3276). For the specific points close to the implant, there was a uniform distribution between the middle and apical areas, although there was always a greater load concentration in the cervical sector (Table 1, Figure 3).

b. IH implant: the stress analysis showed isochromatic strips that initially presented at the middle and apical levels at the same time. At maximum stress level, similar results were observed in the cervical, middle and apical areas. When the stress was observed at specific points of the implant, greater loads were observed at the cervical level (t 2621) (Table 2, Figure 4).

c. MT implant: the initial analysis showed the first isochromatic strips in the cervical and apical regions. The maximum stress analysis showed the greatest impact at the apical level (t 4587), followed by the cervical and middle levels with the same impact. In the analysis of
close points, the cervical and middles areas showed the greatest stress level (t 2621) (Table 3, Figure 5)

Comparison of the maximum stresses observed showed that the EH system exhibited the greatest amount of stress at cervical level, whereas the IH and MT systems behaved similarly in the maximum stress analyses (Figure 6).

DISCUSSION

The photoelastic resin-based model has been shown to be an adequate way to analyze stress and load distribution (Kim et al. 1993). In the analysis of dental implants, Meirelles (2003) installed IH and EH implants in photoelastic resin, perforating the resin with the implant system’s cutter. Already in the initial analysis it was proven that residual stresses resulting from this perforation were observed, which could alter the load pattern analysis. Subsequent studies (Bernardes 2005, Jaimes 2008) used the same model as this investigation to avoid residual stresses, thus making the results with the proposed load more precise.

The different prosthetic abutment connections serve different functions and one of these is to contribute to the load distribution (Bernardes 2005); our results showed that cylindrical EH implants have a higher stress level than conical IH implants. These results are consistent with those recently published by Pellizer et al. (2011) and Coelho Goiato et al. (2012), who indicated that the MT connection has a better and more balanced load distribution than EH implants. This was also observed in multiple implant rehabilitation models, where those with an internal connection had less stress than those with an external connection (Asvanund & Morgano 2011).

Thus, prosthetic connection analyses tend toward IH being more favorable than EH. Nevertheless, the body design of the implants is relevant to the load distribution; previous results presented by our group (Jaimes et al. 2008), comparing conical and cylindrical implants with no prosthetic connection demonstrated that conical implants distribute loads
principally at the apical and middle levels, whereas the cylindrical type does so throughout the implant with the greatest impact at cervical level. Da Costa et al. (2007) reported similar results, with the conical IH implant having higher stress at the apical level than other designs and connections. Those results are consistent with the results of the present investigation. We can conclude that in this study model, the load distribution of cylindrical EH implants is greater at the cervical level than in conical IH or MT implants.

REFERENCES


TABLES

Table N 1: Loads observed in mechanical test of external hex implants

<table>
<thead>
<tr>
<th>Implant area</th>
<th>Number of strips at maximum stress</th>
<th>t (maximum stress)</th>
<th>Number of strips at specific points</th>
<th>Number of specific points analyzed</th>
<th>t (specific points)</th>
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<tr>
<td>Middle</td>
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<td>3</td>
<td>80</td>
<td>1965</td>
</tr>
<tr>
<td>Apical</td>
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<td>3276</td>
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<td>1965</td>
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</table>

Table N 2: Loads observed in mechanical test of internal hex implants

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<th>Implant area</th>
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<th>Number of strips at specific points</th>
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<tbody>
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<tr>
<td>Middle</td>
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<td>3</td>
<td>80</td>
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<tr>
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Table N 3: Loads observed in mechanical test of morse taper implants

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FIGURES

Figure 1: A. Polyurethane hemimandible with implants installed with the implant mounter. B. Polyurethane hemimandible with pins in the area of the installed mandibular base inside the acrylic box. C. Incorporation of silicone to make part of the negative model that will then be filled with photoelastic resin.
Figura 2: A. Hemimandible made in photoelastic resin with the abutments of each implant installed (external connection, internal connection, morse connection) B. Cross-section of a previous model that measures the width of the hemimandible at different levels of the model.

Figure 3: Load distribution of the EH implant, showing distribution at the three levels. A. Maximum stress level. B. Close stress level.
Figure 4: Load distribution of the IH implant, presenting a more homogenous load distribution at the different levels. A. Maximum stress level. B. Close stress level.

Figure 5: Load distribution of the morse taper implant presenting greater stress level at the cervical and middle levels. A. Maximum stress level. B. Close stress level.
Figure 6: Comparison of the different systems evaluated, with the EH implant exhibiting the highest values of load distribution.