Strain Gauge: study of strain distributions around three Morse taper prosthetic connections with offset positioning in machined and plastic copings under vertical load

**ABSTRACT**

The aim of this study was to evaluate through strain gauge the strain distribution occurred around 3 Morse taper implants with positioning offset, by varying the types of copings: plastic and machined. Microunit prosthetic abutments were connected onto the implant platforms. Ten frameworks composed of 3 copings were casted in cobalt-chromium alloy as single block (Co-Cr). Half of the copings were machined (n=5) and half were made of plastics (n=5). Four strain gauges were placed into the polyurethane block respective sites with the aid of a retaining screw with torque of 20 N.cm, achieve with a mechanical torquemeter. The vertical load of 30 Kg was applied through a spherical point of 2 mm diameter for 10 s, onto each one of the 3 screws of the framework through a device for load application. The records of the strain reading were submitted to ANOVA and Tukey tests (5%). There were type used (machined and plastic). The micro strain mean values were: point C at the machined coping 282.5 µm (±120.8), point B at the machined coping 229.5 µm (±76.1), point A at the machined coping 209.8 µm (±30.5), point C at the plastic coping 146.2 µm (±25.8) and point A at the plastic coping 130.36 µm (±21.83). It was concluded that the plastic coping exerted smaller micro strain on Morse taper implants than the machined copings.

**KEYWORDS**

Biomechanics; Dental implant; Dental prosthesis.
INTRODUCTION

The cautious control of biomechanical loading on dental implants is imperative to enable the long-term success of rehabilitation [1]. However, the precise mechanism of the load transferring is not fully understood, but it is certain that there is a remodeling response around the bone under particular tension [2,3]. Since both the definition and principles of osseointegration, various abutment/implant connection designs are available for clinical use in order to improve loading distribution [4].

The application of a functional loading induces tension and strain to bone/implant complex [5-7]. And the amount of this occlusal load transmitted to the implants and the tension induced depends on where the load is applied [8,9].

The major types of anchorage unit load are: non-axial and axial loads. The axial force is the most favorable, because it distributes the tension more evenly throughout the implant, while the non-axial load exerts higher gradients of tension on the implant as well as on the peri-implantar bone [10].

The mechanical and biological complications between abutment/implant such as the screw loosening, fracture of the crown as well as the inflammation of the peri-implantar tissues have been reported by several authors [11]. Esposito et al. 1998, [12]. Cardoso et al [13] and are of great relevance because they enable to assure the longevity of the restorations to the patients. One of the possible complications could be reduced according to Rangert and cols. [14] and Sahin et al. [15] by the insertion of the implant at an offset position, decreasing the bending moment.

Among the implant systems commercially available, morse taper implant system has an implant/abutment connection so-called “self-locking” with an angle < 5° [7]. Its locking system through friction between the components enables a closer contact between the implant body and the prosthetic abutment [15] and this design allows large resistance to friction and to lateral forces, integrity during larger period and function and great contact at the implant/abutment interface, favoring a safer connection [1,8,10,15-20].

The taper connection was proposed to be more biomechanically stable than external or internal hexagon connection [21-23]. The reduction of the micromovements allows resistance and higher stability [21]. The potential mechanical advantages of the internal taper design over the hexagon connection were previously reported on in vitro [21] and in vivo [24] studies.

One way to evaluate the strain distribution around the implants “in vitro” studies is the use of strain gauge, which is a technique for the recording of micro strain through the alteration of the electrical resistance. The function of this circuit is to convert a resistance change to an electrical voltage which can therefore be measured with great accuracy at the place where the strain gauge is placed [25,26].

The aim of this study was to verify the strain distributions occurring around each one of 3 morse taper implants at offset positioning, by varying the CoCr casting obtained through machined and plastic copings, during the application of axial loads.

MATERIAL AND METHODS

A polyurethane block (Polyurethane F16 Axson, Cercy – France) was constructed from a silicon mold (Silicone rubber for molding: Clássico artigos odontológicos, Catanduva- São Paulo, Brazil). The block was finished with the aid of 200 to 600 grit sandpapers to obtain surface as regular as possible. The final dimensions comprised 95 mm length x 45 mm width and 20 mm height.

To achieve the offset positioning of the morse taper implants, an aluminum matrix was constructed and machined comprising 3 parts [35]. These parts are overlapping each other and have perforations that enable the screwing of specific screws to achieve their union. Two of these parts have 3 central perforations at 3 mm among each other to guide the perforation of the block to insert the implants. In the block perforation, a set of standardized twist drills (AS TECHNOLOGY TITANIUM FIX – São José dos Campos, Brasil) was used. The protocol to execute these perforations followed the conventional patterns, except for the asepsis. The mean speed of the perforation was 1800 rotations per minute. The implants were placed with the aid of a surgical ratchet (AS TECHNOLOGY TITANIUM FIX – São José dos Campos, Brasil) with a torque of 40 N.cm onto each morse taper implant.

Over each morse taper implant, Microunit prosthetic abutments were connected (AS TECHNOLOGY TITANIUM FIX – São José dos Campos, Brasil) with torque of 20 N.cm with the aid of a mechanical torquemeter (AS TECHNOLOGY TITANIUM FIX – São José dos Campos, Brasil).

The uniaxial strain gauges KFG-02-120-C1-11N30C2 (Kyowa Eletronic Instruments Co., Ltd – Tokyo – Japan) were bonded to the polyurethane block with the aid of a cyanoacrylate-based adhesive (Super Bonder Loctite, São Paulo - Brazil). The 4 strain gauges...
were tangential to each one of the prosthetic abutments and to determine accurately the bonding sites, a straight line was drawn so that 2 strain gauges were placed onto the implant extremities and other 2 strain gauges were positioned diametrically at the central abutment parallel to those of the extremities. The plates of the terminals were bonded to the upper extremities of the greater sides of the polyurethane block, where the electrical connections were performed. To construct the samples to be placed onto the prosthetic abutments of the implants, 10 rectangular coping wax-up were obtained: 5 for the machined and 5 for the plastic copings. These coping wax-ups were embedded into silicon rings with graphite-free, phosphate bound investment (Bellavest SH Bego, Bremen – Germany). Casting was performed with Co-Cr alloy (Wirobond SG, Bremen, Germany) and the metal injection was carried out through a conventional centrifuge device. After the cooling of the samples, they were individually adapted to the prosthetic abutments at the block, where the abutment/coping stability was assessed without torque. The copings showing instability were excluded from the study (Figure 1).

The application of the static axial loads was executed through a load application device (DAC) onto each implant by using a spherical tip of 2 mm diameter with load of 30 kg for 10 s over each retaining screw of the framework. The electrical resistance changes were transformed into micro strain units (µε) electrical signal conditioner (Model 5100B Scanner – System 5000 – Instruments Division Measurements Group, Inc. Raleigh, North Carolina – USA,) which also recorded the information. Data was recorded through strain-smart software in a Pentium IV computer with 1.1Ghz, 256MB of RAM. All procedures were repeated twice and the strain distributions were determined by the charging recorded by 4 strain gauges.

**RESULTS**

Data recorded through strain gauge were submitted to statistical analysis through ANOVA and Tukey tests to compare the micro strain magnitude measured with the coping type and the points of load application. Homocedacity was obtained through logarithmic scale.

The descriptive statistics for the coping type is displayed in table 1.

<table>
<thead>
<tr>
<th>Table 1 – Micro strain (µε) data regarding to the coping type, obtained through four strain gauges</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coping</strong></td>
</tr>
<tr>
<td>Plastic</td>
</tr>
<tr>
<td>Machined</td>
</tr>
</tbody>
</table>

*application points versus number of samples

The micro strain means for the interaction factor between the coping type and the application point are seen in tables 2 and 3.

<table>
<thead>
<tr>
<th>Table 2 – Micro strain (µε) data regarding to the interaction between the plastic coping and the point of load application, obtained through four strain gauges</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Application point</strong></td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td>C</td>
</tr>
</tbody>
</table>

*number of samples

<table>
<thead>
<tr>
<th>Table 3 – Micro strain (µε) data regarding to the interaction between the machined coping and the point of load application, obtained through four strain gauges</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Application point</strong></td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td>C</td>
</tr>
</tbody>
</table>

* number of samples
Strain distributions data for the coping type and application point were submitted ANOVA of repeated measures of point of load application, as seen in table 4.

**Table 4 – Results of Repeated Measures ANOVA**

<table>
<thead>
<tr>
<th>Effect</th>
<th>GI</th>
<th>SQ</th>
<th>MQ</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coping</td>
<td>1</td>
<td>70198</td>
<td>70198.2</td>
<td>8.93</td>
<td>0.0174*</td>
</tr>
<tr>
<td>Residue I</td>
<td>8</td>
<td>62854</td>
<td>7856.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load application</td>
<td>2</td>
<td>12136</td>
<td>6068.2</td>
<td>2.48</td>
<td>0.1150</td>
</tr>
<tr>
<td>Interaction</td>
<td>2</td>
<td>3578</td>
<td>1789.2</td>
<td>0.73</td>
<td>0.4963</td>
</tr>
<tr>
<td>Residue II</td>
<td>16</td>
<td>39097</td>
<td>2443.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>29</td>
<td>187865</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p<0.05

Following, Tukey test for multiple comparison were applied and the results are shown in table 5.

**Table 5 – Tukey Test for Micro Strain Means in the 3 Experimental Conditions (Coping Types)**

<table>
<thead>
<tr>
<th>Coping</th>
<th>Point</th>
<th>Mean (log)</th>
<th>Homogenous groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machined</td>
<td>C</td>
<td>282.52 (2.42)</td>
<td>A</td>
</tr>
<tr>
<td>Machined</td>
<td>B</td>
<td>229.51 (2.33)</td>
<td>AB</td>
</tr>
<tr>
<td>Machined</td>
<td>A</td>
<td>209.76 (2.31)</td>
<td>AB</td>
</tr>
<tr>
<td>Plastic</td>
<td>C</td>
<td>154.97 (2.18)</td>
<td>AB</td>
</tr>
<tr>
<td>Plastic</td>
<td>B</td>
<td>146.23 (2.15)</td>
<td>AB</td>
</tr>
<tr>
<td>Plastic</td>
<td>A</td>
<td>130.36 (2.11)</td>
<td>B</td>
</tr>
</tbody>
</table>

*Means followed by the same letters are not statistically different.

**Discussion**

Several scientific studies have demonstrated the success of oral implantology as restorative and rehabilitative treatment. Thus, several studies have been conducted to understand and reduce the number of complications which may occur after the implant installation and masticatory load application. Several techniques have been used to assess the biomechanical loads over the implants, such as finite element analysis and strain gauge [8,25,27].

The bone amount is one of the factors influencing on the result of implant treatment. The bone surrounding the implants is not a homogenous substrate, so that its physical properties vary according to age, functional state, and systemic factors of the patients [15,28,29]. It is difficult to conduct in vivo studies, because the placement of the strain gauge inside the mouth and obtainment of reliable data would be impossible. Therefore, in vitro studies have employed homogenous and isotropic materials [26,27,30,31]. For this purpose, this study used a polyurethane-based block which has a modulus of elasticity similar to that of the human bone marrow (Polyurethane: 3.6 GPa/bone marrow: 4.0 to 4.5 GPa) [3,32].

Many strain gauges studies used special devices to apply the load on the implants [1,8], however, other coupled them to universal testing machine [26]. The load application device (DAC) employed in this study showed results compatible with those of the universal testing machine (EMIC). The load amount used in this present study (30 kg) was based on the study of Merick-Stern in 1995 [33] who researched the occlusal force in patients wearing implant-support fixed partial dentures and found a mean value of 30.6 kg for the posterior teeth.

An ideal model for micro strain assessment is not available yet. Some studies placed the strain gauge on the prosthetic units [31]; other [10] opted to bond them onto the implants. Notwithstanding, the placement of the strain gauge onto the surface of the polyurethane block close to the cervical area of the implant is justified because this is the area where the greatest strain distribution occurs after the load application [26,27].

Aiming to remove any type of dimensional alteration, this study eliminated the steps of transfer impression of the implants and dental cast obtainment. Both the machined and plastic copings were directly adapted onto the implants and incorporated to the standardized wax-ups. Several studies [32,34-36] reported that the metallic frameworks constructed onto dental casts produced highest deformations than those constructed without the impression procedures.

According to the results obtained, the loading performed onto the points of application A, B and C (Table 1) showed the highest micro strain occurring in the implants with machined copings at offset positioning. Point C for the machined copings (282.5 µε ±120.8) underwent the highest micro strain, while point A for plastic copings (130.36 µε ±21.83) undergone the lowest micro strain. According to table 4, ANOVA test showed that the statistical differences were related to the coping types (p = 0.0174).

These results suggested that the coping type, either machined or plastic, influences on micro strain when submitted to vertical load application at offset.
positioning, because in this present study, the machined copings exhibited the highest micro strain results. Nishioka et al. [34], compared different machined and plastic copings in external and internal hexagon implants and verified that there were no statistically significant differences regarding to the coping types for both prosthetic abutments. Other studies [35,36] exhibited statistical differences for other factors different from those of this present study. Nishioka et al. [36] assessed the strain distribution caused in internal and external hexagon implants verifying the highest micro strain values in the internal hexagon implants. In another study, Nishioka et al. [35] compared 3 types of prosthetic connectors: external hexagon, internal hexagon, and morse taper, both at linear and offset positioning and the data obtained showed that there were statistically significant differences regarding to the prosthetic connector. Thus, these aforementioned studies are not in agreement with the findings of this present research. Notwithstanding, Frost in 1994 [2] demonstrated that tensions between 100 µε and 2000 µε generated in the bone tissue did not produce pathological damage but a physiologic window of tension magnitude within the physiologic threshold. To generate a bone structure loss damaging to the oral rehabilitation with implant-supported fixed partial dentures, the deformation should surpass the physiologic threshold of 4000 µε [2,3].

Unlikely, Carr et al. [37] in a study with single crowns, demonstrated the accuracy of the frameworks obtained through machined copings which were higher than that of plastic cylinders. The results of smaller deformation obtained by the plastic copings of this present study can be attributed to the fact that we employed multiple prostheses, so that a possible pre-adaptation of the coping prior to casting due to the plastic deformation of the material itself could have favored the adaption at the moment of the plastic coping placement onto the prosthetic connector.

**Conclusion**

Based on the methodology employed and results obtained, it can be concluded that the used of either plastic or machined copings altered the final result of tension distribution after axial loading. The site of axial loading application did not influence on the micro strain magnitude. The axial loads applied onto different points of the implant produced a micro strain magnitude within the physiologic threshold.

**References**


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