Influence of Different Tightening Forces Before Laser Welding to the Implant/Framework Fit

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Abstract
Purpose: The aim of the present study was to evaluate the influence of abutment screw tightening force before laser welding procedures on the vertical fit of metal frameworks over four implants.

Materials and Methods: To construct the frameworks, prefabricated titanium abutments and cylindrical titanium bars were joined by laser welding to compose three groups: group of manual torque (GMT), GT10 and GT20. Before welding, manual torque simulating routine laboratory procedure was applied to GTM. In GT10 and GT20, the abutment screws received 10 and 20 Ncm torque, respectively. After welding, the implant/framework interfaces were assessed by optical comparator microscope using two methods. First, the single screw test (SST) was used, in which the interfaces of the screwed and non-screwed abutments were assessed, considering only the abutments at the framework extremities. Second, the interfaces of all the abutments were evaluated when they were screwed.

Results: In the SST, intergroup analysis (Kruskal Wallis) showed no significant difference among the three conditions of tightening force; that is, the different tightening force before welding did not guarantee smaller distortions. Intragroup analysis (Wilcoxon) showed that for all groups, the interfaces of the non-screwed abutments were statistically greater than the interfaces of the screwed abutments, evidencing distortions in all the frameworks. ANOVA was applied for the comparison of interfaces when all the abutments were screwed and showed no significant difference among the groups.

Conclusions: Under the conditions of this study, pre-welding tightness on abutment screws did not influence the vertical fit of implant-supported metal frameworks.

Dental treatments using osseointegrated titanium implants have been recognized and established by research that began over 40 years ago. Since then, new techniques and technologies have been added to the initial protocol to optimize known procedures. One of the main objectives of current research is to develop means of fabricating implanted dental prostheses with increasingly better fits among the components, as this is one of the main determinants of treatment longevity.

The load falling on the non-passive dental prosthetic system could result in mechanical complications, such as loosening or fracture of screws, fractures of components and of the implant itself, and biological complications, such as mucositis, peri-implantitis, and loss of osseointegration.

Different clinical and laboratory methods have been suggested for optimizing the fit of implant-supported prosthetic frameworks, among them laser welding of cast parts, electrical discharge machining, and splinted transfers impression.

In dentistry, the use of laser welding has expanded with the advent of implant-supported prostheses, due to the concern about the need for passive fit inherent to these treatments. Moreover, the speed of the procedures favors their use in immediate loading techniques. The advantages of using laser welding have been demonstrated in various studies, although there are still difficulties and limitations. There is no clear information in the literature regarding the parameters for optimizing joints between titanium parts. One perceives that the techniques for dental prostheses have no reference protocol to be followed, and the results of one’s work depend on one’s technical skill and experience obtained through trial and error.
The tightness applied to abutments or prosthesis fixation screws alters the level of fit among the components; however, it is not a routine procedure for laboratories to control the screw tightening force on metal frameworks by a torque controller device before performing welds. Generally, screws receive manual tightness before welding.

In this context, there is a hypothesis that the framework of implanted prostheses would present better fit after laser welding if the tightening force applied to the screws was controlled before the welding procedure. This being so, the aim of this study was to assess the influence of the tightening force applied to abutment screws before laser welding, and if possible, identify the tightness that would provide the best metal framework fit.

Materials and methods

A master cast was made of aluminum, in which four implants, 3.75 mm in diameter and 10 mm in height (Master Screw, Conexão Sistemas de Próteses, São Paulo, Brazil) were placed parallel to each other but at variable distances, as occurs in the majority of clinical situations (Fig 1).

Five working casts with implant analogs (013020, Conexão Sistemas de Próteses) were fabricated from five separated impressions of the master cast with the splinted impression technique and open custom tray. The transfers were positioned over the implants and joined using metallic pins and acrylic resin (Duralay, Reliance Dental Co., Worth, IL) (Fig 2). This technique ensures the maintenance of the transfers’ positions and prevents their rotation within the impression. Regular viscosity polyether (Impregum-F®, 3M ESPE, Seefeld, Germany) was used as the impression material.

As a control, all abutment screws were manually tightened to the implants and assessed by scanning electronic microscopy (LEO-435 VP, Carl Zeiss, Oberkochen, Germany) at 500 × magnification to ensure that all abutments presented the same standard fit to the implants.

Twenty abutments and cylindrical titanium bars (055024/Laser Abutment, 400204/Laser Bars; Conexão Sistemas de Próteses) were used to construct five metal frameworks for each group (Fig 3).

Before laser welding, the abutment screws received the following tightening forces: Group GTM—manual torque, Group GT10—10 Ncm torque, Group GT20—20 Ncm torque. The screws were tightened in GT10 and GT20 with a torque controller device (Conexão Sistemas de Próteses).

To study the passivity of the frameworks, the Sheffield test or single screw test (SST) was used on the master cast, in which only one screw was tightened; first the one on the left extremity (#1) and then on the right extremity (#4). The vertical fit interfaces between implants/framework were measured on both sides and were termed screwed and non-screwed side. The readings were done in the proximal surfaces, mesial and distal, on the screwed and non-screwed abutments (Fig 4). The interfaces were also evaluated when all the abutments were screwed with a tightening force of 20 Ncm over the implants of the master cast. The readings were performed with an optical comparator microscope at 40 × magnification (Mitutoyo TM-500, Tokyo, Japan). All readings, including that done in the SST, were repeated three times by the same operator to obtain the mean value.

The interface values were statistically analyzed and discussed considering three tightening conditions: interface values of screwed abutments, interface values of non-screwed abutments (both were obtained by SST), and interface values when...
Discussion

The tested hypothesis was not confirmed. The fit interface between implants/frameworks was not influenced by the tightening force applied to the abutment screws before welding. Some important points regarding the methodology used and the results obtained should be discussed.

Inherent to laser welding procedures, there are some variables capable of influencing the final results of the joints. The present study focused the tightening force on the abutment screw to the analogs in the working cast before laser welding was performed. SST was used to assess the passive fit of dental prosthetic frameworks after welding. The distortions caused by welding were characterized by the creation of a gap (interface) between the abutment and implant on the vertical axis when a single abutment was screwed. Therefore, the larger the vertical interfaces created by tightening a single screw, the larger the distortions were considered to be.

There are other methods for assessing the fit of implant-supported dental prosthetic frameworks but the SST is a simple, economic, and feasible method to use clinically and in dental laboratories. This justifies its use in this study.

By the intragroup statistical analyses, the interface values of the SST were compared between the screwed and non-screwed abutments for the three groups separately. In all analyses, the results were statistically different, and the interface value means for the non-screwed abutments were significantly higher. This result indicates that no specimen obtained passive fit, and this is in agreement with the affirmations of Wee et al. in a literature review.

The intergroup analyses showed no significant difference among the three groups for two tightening conditions in the SST. The pre-welding torque of 10 Ncm in group GT10 and 20 Ncm in group GT20 did not guarantee parts with smaller

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**Table 1** Mean (mesial and distal) interface values (in μm) in accordance with the different tightening conditions in the single screw test

<table>
<thead>
<tr>
<th>Framework</th>
<th>GTM Screwed abutments</th>
<th>GTM Non-screwed abutments</th>
<th>GT10 Screwed abutments</th>
<th>GT10 Non-screwed abutments</th>
<th>GT20 Screwed abutments</th>
<th>GT20 Non-screwed abutments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>14.5</td>
<td>23</td>
<td>6.5</td>
<td>106.83</td>
<td>8.66</td>
<td>211.66</td>
</tr>
<tr>
<td>B</td>
<td>9.5</td>
<td>29.5</td>
<td>24.16</td>
<td>38.16</td>
<td>6.66</td>
<td>215.33</td>
</tr>
<tr>
<td>C</td>
<td>29</td>
<td>128.8</td>
<td>17.16</td>
<td>136.33</td>
<td>17.17</td>
<td>242.66</td>
</tr>
<tr>
<td>D</td>
<td>11.65</td>
<td>42.15</td>
<td>11.33</td>
<td>19.74</td>
<td>6.83</td>
<td>37.83</td>
</tr>
<tr>
<td>E</td>
<td>11</td>
<td>33</td>
<td>13.17</td>
<td>269.33</td>
<td>15.5</td>
<td>199.33</td>
</tr>
<tr>
<td>D</td>
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<td>49.8</td>
<td>9.66</td>
<td>142.16</td>
<td>8.16</td>
<td>98</td>
</tr>
<tr>
<td>A</td>
<td>0</td>
<td>100</td>
<td>0</td>
<td>135.33</td>
<td>2.83</td>
<td>71.67</td>
</tr>
<tr>
<td>B</td>
<td>9</td>
<td>33.6</td>
<td>10.16</td>
<td>47.16</td>
<td>5.83</td>
<td>22.83</td>
</tr>
<tr>
<td>C</td>
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<td>23.8</td>
<td>7.16</td>
<td>22.5</td>
<td>7.83</td>
<td>88.66</td>
</tr>
<tr>
<td>D</td>
<td>10.15</td>
<td>23.3</td>
<td>0</td>
<td>8.33</td>
<td>6</td>
<td>29.83</td>
</tr>
</tbody>
</table>
distortions. The interface values for the non-screwed abutments were statistically similar. Linear distortions occurred, characterized by interface measurements (gaps) on the vertical axis for all the groups, irrespective of the amount of pre-welding screw tightening force. Probably, the shrinkage force generated by weld cooling was higher than the abutment screw capacity to prevent displacements.

In addition to the SST, the welded frameworks were analyzed after the application of 20 Ncm torque on all the screws. There was also no significant difference for the three groups. Group GTM had the highest mean interface value when all the abutment screws were tightened (9.13 ± 7.34 μm), nevertheless, it is in agreement with values found in the literature.26 The 20-Ncm torque on all abutment screws over the implants in the master cast made the implant/framework interface values acceptable. In spite of distortions having occurred after welding, as was shown by the SST, the force generated by the torque significantly improved the implant/framework fit. These results showed that clinically, the fit of implant-supported frameworks should be assessed without tightening all the screws, and that radiographs taken of completely screwed frameworks do not evidence non-passive frameworks.

It is important to consider that manual tightening for group GTM was performed by a technician experienced in laser-welding procedures. Although the results have not demonstrated differences in the vertical adjustments of frameworks for the three groups (GTM, GT10, GT20), it is not known whether this experience could influence the results. Therefore, the use of a torque controller device is recommended to guarantee standardized framework tightening before welding, particularly by inexperienced technicians.

The torque applied to abutment screws was only one among various technical procedures that could influence the final result of laser-welded prosthetic work. There are other variables that must still be studied until optimization of these procedures is achieved. It is also suggested that in future studies, horizontal fit among components be analyzed.

Conclusions

Considering the results obtained with the methodology used in this study, it was concluded that there was no significant difference in the vertical fit of metal frameworks when the screws received different tightening forces (manual, 10, or 20 Ncm) before laser welding.

Acknowledgments

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References