High temperature dimensional alterations of implant supported frameworks

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Abstract
The present in vitro study was designed to evaluate the effect of high temperature firing cycles used for application of porcelain veneer in the misfit of implant supported frameworks, and the effect of a pre-heating treatment on the dimensional alterations of implant supported frameworks. The investigation was conducted based on the results given by 14 nickel-chromium (06 elements) metal structures. Half of the structures formed the control group and were exposed to simulated porcelain firings. The other half formed the test group, and were submitted to a pre-heating treatment with the implant frameworks embedded in investment, before the porcelain firing simulation. The marginal misfit measurements in both groups were made before and after the porcelain firing simulation, by using a scanning electron microscope. The results were submitted to statistical analysis of variance. The multiple comparisons were made by means of the Bonferroni “t” test. For the frameworks produced in the usual manner, without the pre-heating treatment (control group), misfit deteriorates during the high temperature firing cycles employed for porcelain application. In the test group, pre-heating treatment did not change the final metal distortion resulting from the porcelain firing cycles, and the greatest amount of the distortion took place before the conventional porcelain firing cycles.

Key Words:
dental implants; osseointegration; implant-supported dental prosthesis; metal ceramic alloys

Received for publication: June 01, 2004
Accepted: January 25, 2005
Introduction
The osseointegration technique decisively interfered in dentistry and its current perspectives, markedly improving the quality of life of edentulous patients. Osseointegrated implants used for prosthetic rehabilitation have shown consistent clinical success supported by literature, and represent a considerable positive impact in the psychosocial status of those patients.

A precise fit between an implant abutment and a superstructure, determining the absence of bone tension, without the occlusal load, is an important factor for the long-term success of implant-supported restorations.

Considering the fact that implants are completely surrounded by bone, and that the interface is not elastic, a minimum movement is observed due to bone deformation under loading. Accordingly, it must be anticipated that stress introduced into the implant system as the result of prosthesis misfit may be present many years after placement because of the ankylosic character of the osseointegration.

The present findings support the concern for precision of frameworks with regard to various aspects of fatigue in the long-term perspective.

Fixed prostheses without a passive fit to osseointegrated implants can potentially result in loosening of screw joints, fatigue fractures of components, marginal peri-implant bone loss, and delay loss of osseointegration.

It has been widely observed that the “as cast” fit of metal ceramic restorations deteriorates during the high temperature firing cycles employed for porcelain veneer application, and that the timing of the deformation is such that most of it occurs during the initial firing cycle (oxidation), before the porcelain application.

A currently popular theory indicates that the release of solidification stresses may be the primary etiologic factor in the deformation of metal ceramics during thermal cycling. Some authors demonstrated that a pre-heating treatment of invested castings resulted in a significant reduction in the thermal cycling distortion of the alloy. The present in vitro study was designed to examine the effect of high temperature firing cycles used for application of porcelain veneer in the misfit of implant supported frameworks and the effect of a pre-heating treatment on the dimensional alterations of implant supported frameworks.

Material and Methods
The condition simulated for evaluation in this investigation was a mandibular anterior quadrant to be restored with a six-unit FPD screw-retained on implants. An acrylic resin model (Fig.1) was fabricated with two external hex cylinder implants (4.0 mm diameter, 15.0 mm length; Master Screw – Conexão Sistemas de Prótese – São Paulo, Brazil) placed in the right and left canine area (sites 33 and 43), parallel and 22 mm apart from each other from center to center. This model served as an index for the marginal misfit measurements. Abutments were connected to the implants (Micruscone – 138023 – Conexão Sistemas de Prótese – São Paulo, Brazil) by fastening screws with a torque wrench using 20Ncm torque. Impression posts (141000 – Conexão Sistemas de Prótese – São Paulo, Brazil) were attached to the abutments, and a silicone impression (Express – 3M – São Paulo, Brazil) was made using a custom resin tray suitable for the master cast. After the impression posts and the abutment analogs (143000 - Conexão Sistemas de Prótese – São Paulo, Brazil) were connected, they were returned to the impression, which was poured in stone (Durone – Dentsply – Petrópolis, Brazil) to make the working cast.

Sixteen implant-supported frameworks were fabricated on the working cast. For the fabrication of standardized wax pattern for the FPD, the castable plastic cylinders (149001 – Conexão Sistemas de Prótese – São Paulo, Brazil) were placed on the analogs and hand tightened until resistance was felt. Teeth were fashioned in inlay wax in an anatomically correct manner. A condensation silicone mold (Express – 3M – São Paulo, Brazil) was fashioned over this FPD wax pattern to allow for multiple FPD pattern replications.

The investment, burnout and casting techniques were standardized. Patterns were sprued and invested in pairs in a phosphate-bonded investment (Belavest SH – Bego – Bremen, Germany) according to a one piece casting technique. Following bench curing and burnout, the investment rings were cast in a nickel-chromium alloy (Wironia - Bego– Bremen – Germany).

Eight frameworks (Fig.2) were randomly selected as the control group (C). After cooling at room temperature, the divesting was completed in the usual manner with minimum use of aluminum oxide air abrasives on critical interfaces.

One FPD was discarded because of casting problems. Burs were used under laboratory microscope to eliminate internal casting inaccuracy. Protective polishing caps (abutment analogs - 143000 - Conexão Sistemas de Prótese – São Paulo, Brazil) covered the interfaces and reduced the risk of inaccuracy.

The other eight frameworks formed the pre-heated test group (T). The castings, in their original investment, were allowed to cool to room temperature, and were then pre-heated in a porcelain oven (Vacumat 40 – Vita – Bad Säckingen, Germany) according to the manufacturer’s recommendations for the first alloy thermal cycle (opaque cycle: from 600°C to 950°C with a heating rate of 55°C/min under partial vacuum; the high temperature of 950°C was held for 2 min.). After this pre-heating treatment, the frameworks were allowed to cool to room temperature, divested, and handled the same way previously described in the control group. One of the frameworks was also discarded.
The fourteen frameworks, from both groups, were exposed to six simulated porcelain-firing cycles (two opaque firings, three body firings, and one glaze firing). However, the porcelain was not applied. Opaque cycles were from 600°C to 950°C with a heating rate of 55°C/min under partial vacuum (720mm Hg). The high temperature of 950°C was held for 2 min for the first opaque layer, and 1 min for the second layer. The first body cycle was from 600°C to 930°C with a heating rate of 55°C/min under partial vacuum (720mm Hg). The high temperature of 930°C was held for 1 min. The second and the third body cycles were identical to the first, except for the final temperature which was 920°C. Glaze cycle was from 600°C to 910°C with a heating rate of 55°C/min in air, and the highest temperature was held for 1 min. All samples were allowed to cool to room temperature before the next firing cycle began.

The marginal misfit measurements were made using a scanning electron microscope (XL 30 – Philips – Eindhoven, Holland). Six marks were made in each abutment (Fig.3) to standardize the microscope measurement points. Three were made in the buccal surface and three on the lingual surface, adding up twelve reading points for each framework.

The frameworks were positioned on the abutments of the acrylic resin model by fastening titanium screws with an adapted torque wrench using 2N/cm torque (400000 Conexão Sistemas de Prótese – São Paulo, Brazil). In either group, the vertical measurements were taken in two moments: Moment 1 (M1)- measurements were made before the porcelain firing cycles; Moment 2 (M2) - measurements were made after the porcelain firing cycles. The marginal gap size was measured in micrometers, under 200X microscope magnification.

The results were compiled and submitted to one-way analysis of variance (ANOVA). The multiple comparisons were made by means of the Bonferroni “t” test.

### Results

The means and standard deviations of vertical misfit values for the two groups in M1 and M2 measurement moments are presented in Table 1. The misfit in the control group deteriorated during the high temperature firing cycles employed for simulated porcelain veneer application (from 41.73 µm to 54.11 µm). The misfit in the test group did not change significantly before and after the high temperature firing cycles employed for simulated porcelain application (from 55.22 µm to 58.71 µm).

The vertical misfit values were analyzed by one-way analysis of variance ($\alpha = 5\%$). Significant differences were found among the structures ($1$-way ANOVA, $F_{(3, 24)} = 3.36; \ p = 0.0355 < 0.05$). Bonferroni independent “t” test was used for the individual comparisons (table 2). The pre-heating treatment did not change the final metal distortion.
resulting from the porcelain firing cycles in the test group, since the values of misfit in the groups CM2 and TM2 show statistical equivalence. The significant difference (P < .05) was found among the structures in the first measurement moment (CM1 X TM1). The vertical misfit for test group before (TM1) and control group after (CM2) the porcelain firing cycles show statistical equivalence.

Table 1 – Means and standard deviations of vertical misfit values (in micrometers) for the two groups in both measurement moments

<table>
<thead>
<tr>
<th>GROUP</th>
<th>N</th>
<th>MEANS</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTROL M1</td>
<td>7</td>
<td>41.73</td>
<td>9.37</td>
</tr>
<tr>
<td>CONTROL M2</td>
<td>7</td>
<td>54.11</td>
<td>12.91</td>
</tr>
<tr>
<td>TEST M1</td>
<td>7</td>
<td>55.22</td>
<td>10.63</td>
</tr>
<tr>
<td>TEST M2</td>
<td>7</td>
<td>58.71</td>
<td>9.5</td>
</tr>
</tbody>
</table>

Table 2. Statistical Analysis by the Bonferroni independent “t” test.

<table>
<thead>
<tr>
<th>COMPARISONS</th>
<th>TEST VALUE</th>
<th>CRITICAL VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>TM1 X CM1</td>
<td>0.0134</td>
<td>0.0167</td>
</tr>
<tr>
<td>CM2 X TM1</td>
<td>0.4239*</td>
<td>0.0167</td>
</tr>
<tr>
<td>CM2 X TM2</td>
<td>0.2147*</td>
<td>0.0167</td>
</tr>
</tbody>
</table>

* - Statistical equivalence

Discussion
Osseointegrated implants supporting fixed prostheses are exposed to both dynamic and static loading. Dynamic forces on the implants may arise due to chewing and may reach various magnitudes. Static loading, on the other hand, may be induced by the tension in the bridge locking screws when securing a misfit framework to the implant. The vertical misfit for test group before (TM1) and control group after (CM2) the porcelain firing cycles show statistical equivalence.

Previous investigations found that porcelain application had no effect on casting distortion9,25-28; thus, the presence of the ceramic would not modify the results of this research. In the control group frameworks were produced in the usual manner, and no pre-heating treatment was applied. The misfit in this group deteriorated during the high temperature firing cycles employed for simulated porcelain veneer application (from 41.73 μm to 54.11 μm). This result corroborates other findings8,9,10, showing that frameworks misfit deteriorates during the high temperature firing cycles employed for porcelain application.

In the test group, before the usual firing cycles for porcelain application, frameworks were submitted to a pre-heating treatment. The castings, in their original investment were heated in a porcelain oven according to the manufacturer’s recommendations for the first alloy thermal cycle (opaque cycle). Some authors11-13 concluded that a pre-heating treatment of invested castings might control the thermal cycling distortion of the alloy. In the present investigation, the pre-heating treatment did not change the final distortion resulting from the porcelain firing cycles in the test group, since the final values of misfit in the control and test groups (CM2 and TM2) showed statistical equivalence.

However, the misfit in the test group did not change to bending reduces the risks of mechanical overloading for the retaining screws, especially for the cantilevered superstructures22-23.

Based on previous articles1-2,6,20,24, which indicate a certain biological tolerance in the living bone for prosthetic misfits, the vertical gaps recorded in this study would probably not lead to clinical problems, even with the frameworks being fabricated by a one-piece cast method instead of the soldering method which would markedly improve the marginal fit25,21.

The seating force used to place the samples on the master cast has an important effect on the vertical misfit. The use of a torque driver, even with the lowest torque available (10N/cm), may considerably narrow the vertical misfit gaps at the abutment-framework interface25,14,19. Marginal misfit investigations, in which screws are fastened by hand, always by the same investigator, until the first resistance is met6,15, allows a more real fit evaluation, since no attempt is made to narrow the vertical misfit gaps. However, it seems to be a risky protocol, due to the wide variation in the ability of the clinicians to perceive torque, making difficult the standardization of the screw tightening procedure prior to microscope measurements. In the present study, a special torque driver was fabricated, reducing the torque to 02N/cm. This way, it was standardized the screw tightening with a seating force that did not considerably influence the vertical misfit gaps. It is important to stand out that this seating force (02N/cm) was used specifically for this in vitro investigation, and must not be used clinically.

The popularity of base metal alloys (nickel-chromium and cobalt-chromium) has dramatically increased in recent years because of their advantageous mechanical properties and due to the high cost of gold and palladium. The superior yield strength (resistance to permanent deformation), and higher elastic modulus (rigidity) allow a more uniform stress distribution within the framework, providing a more efficient and durable load transfer. The use of a more rigid material for the framework of osseointegrated prosthesis decreases the stress within the prosthesis retaining screws. This probably means that the high resistance of the framework...
significantly before and after the high temperature firing cycles employed for simulated porcelain application (from 55.22 µm to 58.71 µm). As the misfit in the test group before the firing cycles (TM1- 55.22 µm) was statistically similar to the misfit in the control group (without pre-heating treatment) after the firing cycles (CM2- 54.11 µm), it can be assumed that almost all the dimensional alterations in the test group occurred before the porcelain firings, produced by the pre-heating treatment.

This observation in the test group confirms earlier investigations that found that the greatest amount of distortion takes place during the first firing cycle of the metal structures, and minimal distortion takes place during the other firing cycles. The authors attribute this distortion to the release of stress built into the framework during casting solidification. They recommended the pre-heating treatment of metal-ceramic castings before intraoral fit evaluation to achieve better-fitting prostheses. Based on our findings, their recommendations can be extended to implant supported FPDs. The greatest amount of distortion will take place before clinical try out, and this procedure will minimize the unworkable post-ceramic distortions.

Although the concept of passive fit provides necessary theoretical ideals, the realization of passive fit is not possible. Clinically acceptable fit of the implant framework to the intraoral abutments has yet to be defined by the dental community. Accessible methods to improve and evaluate fit are needed. Clinical relevance is the ultimate test of any technique utilized in prosthodontics. Therefore, it seems prudent that the results of this investigation be applied to appropriate clinical methodologies to verify if they significantly improve the fit of implant frameworks. Under the specific conditions of the experiment, the following conclusions were drawn: (01) for the frameworks produced in the usual manner, without the pre-heating treatment, misfit deteriorated during the high temperature firing cycles employed for porcelain application; (02) the pre-heating treatment did not change the final metal distortion resulting from the porcelain firing cycles, and (03) with the pre-heating treatment, the greatest amount of the metal distortion took place before the conventional porcelain firing cycles.

Acknowledgments
The authors would like to express their gratitude to José Luiz Batista for his help in manufacturing the frameworks. All equipment and materials used in this research were kindly supplied by CONEXÃO and WILCOS Companies. Dr. Sergio Freitas performed statistical analyses.

References

