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An Alternative Section Method for Casting and Posterior Laser Welding of Metallic Frameworks for an Implant-Supported Prosthesis

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Abstract

Purpose: The aim of this study was to compare the accuracy of fit of three types of implant-supported frameworks cast in Ni-Cr alloy: specifically, a framework cast as one piece compared to frameworks cast separately in sections to the transverse or the diagonal axis, and later laser welded.
Materials and Methods: Three sets of similar implant-supported frameworks were constructed. The first group of six 3-unit implant-supported frameworks were cast as one piece, the second group of six were sectioned in the transverse axis of the pontic region prior to casting, and the last group of six were sectioned in the diagonal axis of the pontic region prior to casting. The sectioned frameworks were positioned in the matrix (10 N·cm torque) and laser welded. To evaluate passive fit, readings were made with an optical microscope with both screws tightened and with only one-screw tightened. Data were submitted to ANOVA and Tukey–Kramer's test ($p < 0.05$).
Results: When both screws were tightened, no differences were found between the three groups ($p > 0.05$). In the single-screw-tightened test, with readings made opposite to the tightened side, the group cast as one piece ($57.02 \pm 33.48\ \mu$m) was significantly different ($p < 0.05$) from the group sectioned diagonally ($18.92 \pm 4.75\ \mu$m) but no different ($p > 0.05$) from the group transversally sectioned ($31.42 \pm 20.68\ \mu$m). On the tightened side, no significant differences were found between the groups ($p > 0.05$).
Conclusions: Results of this study showed that casting diagonally sectioned frameworks lowers misfit levels of prosthetic implant-supported frameworks and also improves the levels of passivity to the same frameworks when compared to structures cast as one piece.

Implant-supported prostheses should passively fit on implant abutments. Ill-fitting frameworks may overload the implants, possibly causing fracture or loss of the gold screws or even the implants. Such an implant may also affect biological structures, causing marginal bone loss and compromising osseointegration.[1–3] The literature suggests that complete passivity has not been accomplished in the past three decades.[4] Some authors have arbitrarily suggested that castings with discrepancies exceeding 30 μm in over 10% of the circumference of the abutment-to-gold cylinder should be considered unacceptable.[5] On the other hand, others have proposed that a maximum of half a screw turn (the distance between two consecutive threads of a gold screw), which corresponds to a vertical misfit gap of approximately 150 μm, should be considered clinically acceptable, since such a gap will not cause problems with the patient's rehabilitation over time.[6]

Distortion may occur during the process of fabricating the prosthesis frameworks. Factors that may contribute to such distortions include the type of technique and impression material used to obtain the master model or make the wax pattern, as well as casting procedures used. Procedures such as use of laser welding and electroerosion can be adopted to minimize such distortions. Laser welding has several advantages: it saves lab time, because the appliance is made by applying directly on the master model and, potentially, all materials used in prosthodontics are suitable for welding, especially titanium. In addition, the resistance of the welded unions is comparable to the fracture resistance of the cast alloy and can be accomplished in difficult to reach areas or after application of porcelain or acrylic resin without damaging esthetic material coverings.[7]

Laser welding also has some disadvantages, such as the need for an argon atmosphere, difficulties in welding materials with high thermal conductibility, and the possibility of porosity formation in the welded region due to rapid solidification.[8] Better scientific documentation of the precision of fit of implant-supported frameworks is needed. The purpose of this study was to evaluate the accuracy of fit of framework interfaces cast in Ni-Cr alloy by casting differently sectioned frameworks (transversal and diagonal axes) and comparing them with one-piece castings.

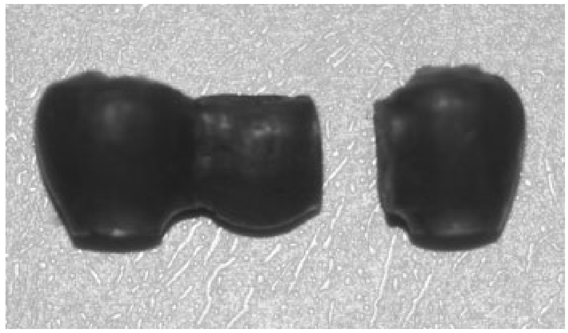

Figure 1 Transversal axis sectioned waxed framework, before casting.

Materials and methods

The methodology used in this study was the same as described in previously published work.[9] A partially edentulous maxillary segment to be restored with a 3-unit fixed partial denture (FPD), screw retained on implants placed in the second premolar and second molar area, was simulated. A metal matrix was machined containing two orifices in the same position as the replicas in the definitive cast, and two internal hex cylinder implants (3.75-mm diameter × 11.5-mm length, Titamax II, Neodent Implante Osseointegrável, Curitiba, Brazil), parallel to each other were fixed with cyanoacrylate adhesive (Super Bonder; Loctite Brasil Ltd., Itapevi, Brazil). A conical abutment with a height of 3 mm (Conical Mini Pilar II 4.3, Neodent Implante Osseointegrável) was adapted over each implant and tightened to 20 N·cm[10] using a torque controller [DEA 028 (SN 4900), Nobel Biocare, Gothenburg, Sweden]. This model served as the master cast for all fabricated specimens and as an index for measuring the accuracy of the casting and soldering procedures.

Plastic cylinders were placed and retained using prosthetic screws (Conical Mini Pilar 4.1 Tilite, Neodent Implante Osseointegrável). Cylinder bonding was achieved with an acrylic resin (Pattern Resin LS, GC America Inc., Alsip, IL), and a 3-unit FPD, supported by two implants, was completed with sculpture wax (PK, Kota Ind. e Com. Ltd., São Paulo, Brazil). Additional frameworks, with the same dimensions as the first waxed prosthesis, were fabricated using a split mold filled with heated sculpture wax. Six wax patterns were made for each of the three groups. The groups to be sectioned were not bonded with acrylic resin, so as to facilitate sectioning of the specimens, since all specimens were waxed as one-piece castings to be later sectioned. Groups were:

- G1: one-piece castings (control group);
- G2: frameworks transversely sectioned in the pontic area (Fig 1); and
- G3: frameworks diagonally sectioned in the pontic area (Fig 2).

All groups were cast in Ni-Cr alloy (VeraBond II, Aalba Dent. Inc., Cordelia, CA).

Castings were made using the Discovery Plasma machine (EDG Equipamentos e Controles Ltda., São Carlos, Brazil), employing an electric arc to melt the alloys and most of the base metals in an argon atmosphere, and injecting the metal into the mold by vacuum pressure. After casting, the test specimens were divested and subjected to airborne-particle abrasion with 100-μm alumina oxide (80 psi = 5.62 kgf/cm^2).

The two components of each framework were then screwed to the implant abutments with 10 N·cm torque and laser welded (Desktop Laser, Pforzheim, Dentaurum, Germany). The laser-welding machine was then programmed to 300 V, pulse duration of 9.0 ms and welding spot diameter of 0.78 mm.[8] Specimens were prewelded at four diametrically opposed points around the region to be welded, resulting in a significant reduction in the distortions caused by the welding process.

Specimens were then evaluated for passive fit. For the readings, first the screw located on the corresponding second premolar of the framework was tightened manually to the point where only the first fixation of the screw in the thread was felt, as described for the one-screw test[11] (Fig 3). The gaps between the abutment and the framework were measured on both sides, and labeled as the tightened side (second premolar) and the opposite side (second molar). Then the screw tightening location was changed to the other abutment (second molar), and the second reading was made, on both sides (tightened, opposite). For the third reading, both screws were positioned and tightened to 10 N·cm[10] using a torque-controller device (Nobel Biocare) (Fig 4). Readings were performed with an optical comparator microscope (No 18938, Nikon Corp., Tokyo, Japan) at 15× magnification, with buccal, lingual, and proximal aspects measured for each condition. Three readings were obtained for each location, for a total of 12 points from each cylinder for each condition.

The specimen base was designed to allow for readings of the proximal aspect in both implants. For each condition, ANOVA was applied for two criteria (material, treatment) to verify group

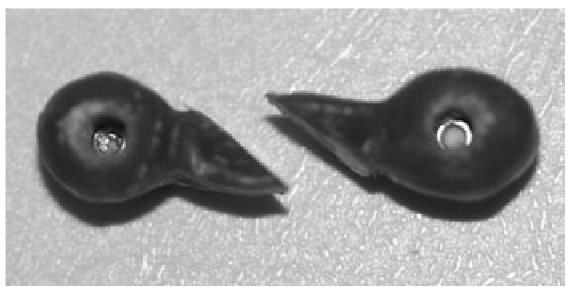

Figure 2 Diagonal axis sectioned waxed framework, before casting.

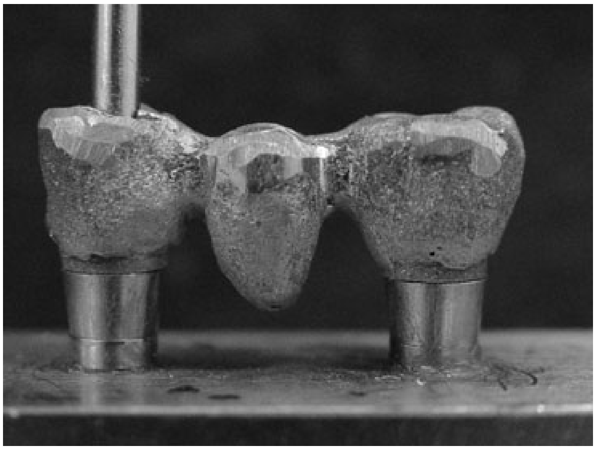

Figure 3 One-screw test showing gaps between abutments/ framework.

homogeneity. When ANOVA indicated a statistically significant difference ($p < 0.05$), Tukey–Kramer's multiple-range test was used for individual comparisons. Data were processed using statistical software JMP 6.0 (SAS Institute Inc., Cary, NC).

Results

For all three groups, ANOVA and Tukey–Kramer's test showed no significant differences between the interfaces, when analyzed with both screws tightened ($p > 0.05$). In the single-screw-tightened test with readings made opposite to the tightened side, results showed that the group cast as one piece was significantly different ($p < 0.05$) from the diagonally sectioned group, but was not different ($p > 0.05$) from the transversally sectioned group. On the tightened side, all groups were statistically the same ($p > 0.05$) (Table 1, Fig 5).

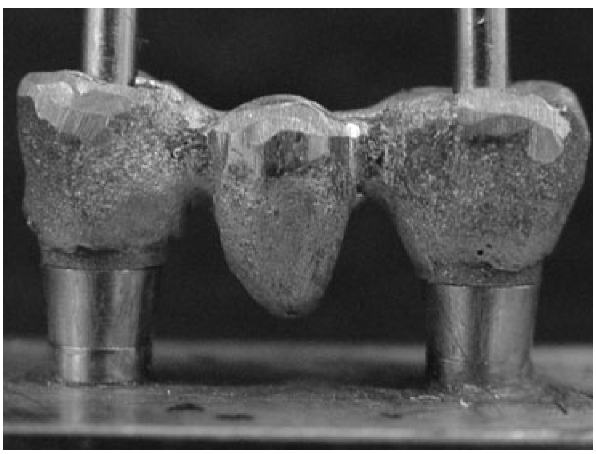

Figure 4 Abutments/framework gaps with two-screw tightened condition.

Table 1 Means (SD) and Tukey–Kramer's test results of abutment/frameworks' interfacial gaps (μm) for all groups and under all reading conditions

	Both screws tightened	Tightened side	Opposite side
One-piece	11.18 ± 2.54 A	12.73 ± 4.86 A	57.02 ± 33.48 A
Transversal	19.19 ± 11.83 A	17.22 ± 7.98 A	31.42 ± 20.68 AB
Diagonal	10.08 ± 3.73 A	9.69 ± 2.32 A	18.92± 4.75 B

Critical value,3.25714; $p < 0.05$.
Levels with the same letter are not significantly different by Tukey–Kramer's test.

Discussion

This study aimed to evaluate whether significant improvements could be made in the accuracy of fit of implant-supported frameworks, using laser welding as a correction method, and a new method of framework sectioning as a variable, altering the traditional method of transverse sectioning to a section on the diagonal axis of the framework in the pontic region.

Because laser energy can be focused in a small area, the heating and oxidation effects of the welding process itself are minimized and concentrated in the region of the welded area.[12] An advantage of laser welding is the possibility of joining a framework without the need for additional welding material or when the need for extra material occurs, the same alloy used for casting can be used in the welding process, thus retaining the characteristics of the original alloy without lowering corrosion resistance or reducing the strength of the welded union.[8]

The main factor in this study relating to the significant improvement in the vertical fit levels and passivity on the diagonally sectioned group was the greater proximity of the sectioned areas, facilitating the welding procedure and reducing the volume of fused metal needed between the sectioned areas. Changing the direction of metal contraction (not forcing the abutments to one another's direction) may also have helped improve fit.

In the group with the casting cut in the transverse axis, the opening between the surfaces to be welded required a higher quantity of laser pulses and, in some cases, the addition of extra metal, resulting in a higher susceptibility to operator flaws, which along with the physical characteristics of the alloy itself, can be statistically detected by the high-standard-deviation values for the group.

To make sections of the waxed frameworks, such as the ones used for this study, the protocol had to be changed (union of the cylinders with acrylic resin and later waxing of the framework) for groups G2 and G3, because such sections could not be precisely made with the presence of acrylic resin, so the union with resin was not made. The passivity test was made, however, correcting the specimens when needed before casting.

Discrepancies in levels of fit varying from 25 to 160 μm are reported in many published studies.[13–15] Compared to the discrepancies found in different kinds of crowns and FPDs, the results shown in this work are acceptable.

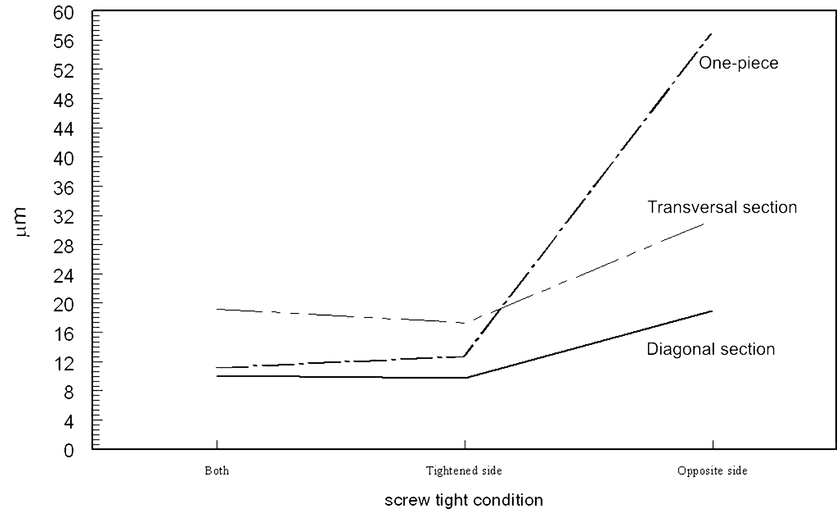

Figure 5 Groups' behavior under different screw tightening conditions

Significant improvement was shown by the separately cast and diagonally sectioned frameworks, as compared to the control group with its cast as one-piece framework and the second group with its vertically sectioned framework. When only one screw was tightened, and the opposite side was analyzed, this improvement was apparent, demonstrating the greater passivity of the third group after laser welding. Complete passivity however, cannot be reported. This finding is consistent with results found in previous studies examining the lack of complete passivity with frameworks cast as one piece.[16,17] On the tightened side, all groups were statistically the same.

When considering the success of implant prosthetic rehabilitation, there are many areas that can lead to failure. The problems and failure can relate to inadequate fit and misfit of the implant prosthesis, with screws and intermediate abutments loosening, as a result of framework/implant interface misfit.[18] The relationship between vertical misfit and levels of passivity will often result in mechanical screw-loosening problems and can cause loss of implants.[19-21] Other problems include fracture of the framework or esthetic material,[21] as well as bone loss problems.[1] One of the ways to eliminate misfit torque and associated problems is to section the implant/prosthesis transversely with a diagonal section through the framework before casting. This will increase the accuracy of fit and passivity and help create a successful prosthetic rehabilitation.

Conclusion

The results of this study suggest that diagonally sectioning frameworks lowers levels of prosthetic misfit in implant-supported frameworks and also significantly improves passivity when compared to one-piece castings.

Acknowledgments

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