Acta Odontologica Scandinavica, 2011; 69: 238–242

informa
healthcare

ORIGINAL ARTICLE

Misfit of pure titanium frameworks: Effect of veneer coverage and spark erosion process

MARCIA MIKA NAKAOKA, JULIANA MARIA COSTA NUÑEZ-PANTOJA, JESSICA MIE FERREIRA KOYAMA TAKAHASHI, RAFAEL LEONARDO XEDIEK CONSANI & MARCELO FERRAZ MESQUITA

Department of Prosthodontics and Periodontology, Piracicaba Dental School, Campinas State University, Piracicaba, São Paulo, Brazil

Abstract

Objective. The purpose of this study was to evaluate the influence of veneer application on the misfit level of implant-supported frameworks. ***Materials and Methods.*** Thirty commercially pure titanium (Tritan, Dentaurum, Pforzheim, Germany) frameworks were fabricated from a metallic index containing five Branemark-type multi-unit abutments. Analogs of the abutments were positioned into the framework to manufacture an index for each framework, which permitted the evaluation of the marginal gap caused only by the veneer coverage. The frameworks were grouped ($n = 10$) in the following manner: (G1) heat-cured acrylic resin (Clássico, Clássico, São Paulo, Brazil); (G2) light-cured resin (Versyo.com, Heraeus Kulzer, Brazil); and (G3) porcelain (Triceram, Dentaurum, Pforzheim, Germany). Marginal refinement with spark erosion was then conducted. The marginal gap was verified before and after the veneer coverage and the spark erosion procedure, following the single screw test protocol (tightening force of 10 Ncm). Data were submitted to an analysis of variance (ANOVA) in a split-plot design for repeated measurements followed by a Tukey test ($p = 0.05$). ***Results.*** The veneer application was associated with a significant increase in the mean misfit values of all groups. The lowest values were presented by G2. After the spark erosion process, the mean misfit value decreased only on G3. ***Conclusions.*** Heat-cured acrylic resin and porcelain produced the highest values of marginal gaps, whereas light-cured acrylic resin produced the lowest. In addition, the spark erosion process was effective only in the marginal gap of the porcelain application group.

Key Words: *Acrylic resins, ceramics, dental implant prosthesis, prosthesis fitting, titanium structures*

Introduction

Over the years, implant-supported rehabilitations have proved to be successful alternatives to treat partially and completely edentulous patients [1–6]. Initially, prosthetic frameworks supported by implants were made from precious metals. However, due to the high cost, they were replaced by semi-precious metals. Currently, titanium is considered to be an interesting option for frameworks castings. It is biocompatible and has excellent corrosion resistance, even in harsh environments, such as the oral cavity [7]. In addition to a relatively low cost, density and thermal conductibility, the desirable physical and mechanical properties of titanium make it an advantageous option for dental prosthesis use [8,9].

Implant-supported prostheses should fit the implants well. Poorly adapted prostheses can lead to fractures of frameworks by mechanical failure or bone resorption [2,10–13]. Results of longitudinal clinical studies have shown that clinical complications that occur in implant-supported prostheses are generally related to the marginal misfit that may be present, especially when multiple implants are involved [2,4,5,14]. Distortions in frameworks might be caused by different procedures, including waxing, investing and casting [15]. Irregularities at both the edges and internal portions of UCLA abutments and the base seating of prosthetic screws can also cause marginal misfit [16–18].

In conventional prostheses, the ceramic application procedure is known to increase framework distortion

Correspondence: Juliana Maria Costa Nuñez-Pantoja, Piracicaba Dental School – UNICAMP, Departament of Prosthodontics and Periodontology, Av. Limeira 901 Caixa Postal 52 CEP 13414-018 Piracicaba, São Paulo, Brazil. Tel: +55 19 21065297. Fax: +55 19 2106 5218. E-mail: julynunez@terra.com.br

(Received 9 August 2010; accepted 7 December 2010)

ISSN 0001-6357 print/ISSN 1502-3850 online
DOI: 10.3109/00016357.2011.554860

[19–23]. According to Byrne et al. [24], it also occurs in implant-supported prostheses. The cause of this distortion can be due to ceramic contraction during firing cycle or differences between the thermal coefficients of the ceramic and the alloys [25].

Thermo-activated acrylic-resin application, widely used on implant-supported fixed frameworks, can also promote misfit in implant-supported prostheses [3–6,26]. Recently, a light-cured resin was introduced into the market which, according to the manufacturer, would not be affected by temperature changes because it is not a thermoplastic resin. This allows it to avoid framework distortion.

To prevent misfit, several correction techniques can be performed. In some cases, it is necessary to section the framework and weld it back [12,18]. In other cases, the spark erosion technique, which involves mild electrical discharges between the electrode (anode) and metal restoration (cathode), with ions transference, can be used [18]. The advantage of this technique is that it permits the refinement of the edges, providing better levels of cervical fit after the aesthetic veneering application without promoting reduction of the frameworks' resistance [16,17,27].

Few researchers have investigated the influence of aesthetic veneer application on the marginal misfit of fixed prostheses. In addition, the effect of after-coating spark erosion treatment on marginal misfit values remains unclear. Thus, this research was performed to fill these gaps in the literature.

Materials and methods

A master model was created from metal matrix, which simulated the clinical implantation of five implants (platform of 4.1 mm) with multiunit-type abutment transfers (Conexão Sistema de Próteses, São Paulo, SP, Brazil). The impression transfers were screwed over the abutments and tied together with dental floss and acrylic resin (Pattern–GC América, Alsip, IL, USA). The impression was taken with polyether (Impregum Soft, 3M ESPE, São Paulo, Brazil) and a gypsum model was obtained.

Over the model, two framework patterns were waxed: one to receive resin coverage and the other to receive ceramic veneer (Figure 1). After an analysis of their adaptation, these patterns were duplicated with industrial silicone [20], which was filled with liquified wax (Kota - Indústria e Comércio, São Paulo, Brazil). After waxing all frameworks, the adaptation level was checked again. These frameworks were casted in commercially pure titanium (Tritan, Dentaurum, Pforzheim, Germany) in a Rematitan casting machine (Dentaurum, Pforzheim, Germany).

After all frameworks were casted, finished and polished, a type-IV gypsum index was made for each framework to isolate the effect of veneer application over the marginal misfit. Subsequently, gap measurements were taken using a travelling microscope (120×) (STN – Olympus Optical Co. Ltd, Tokyo, Japan). The analyses were performed at the central and bilateral distal implants after tightening the prosthetic screw (10 Ncm) of the most distal implant at both extremities [18,25,26,28]. Analyses were conducted three times in each abutment/prosthesis interface on diametrically opposed buccal and lingual regions.

Thirty frameworks were manufactured, with 20 based on the design for resin application (Figure 1A) and 10 based on the other design (Figure 1B). These frameworks were distributed into three groups (n = 10): (G1) heat-cured acrylic resin (Clássico, Clássico, Sao Paulo, Brazil); (G2) light-cured resin (Versyo.com, Heraeus Kulzer, Brazil); and (G3) porcelain application (Triceram, Dentaurum, Pforzheim, Germany). To standardize the prostheses' occlusal pattern, a master design was obtained and reproduced in all frameworks.

The G1 frameworks were invested in a metal flask with a silicon wall (Zetalabor, Zhermack, Rovigo, Italy), duplicating the master occlusal design. The acrylic resin was manipulated, poured into it and polymerized according to the manufacturer's instructions. The prostheses were deflasked, finished, polished and stored in water for 48 h. The G2 frameworks' coating was obtained with the help of a translucent light-cured resin wall. The veneer resin was injected into the mold and polymerized with Heralight (Heraeus Kulzer, São Paulo, SP, Brazil). Finally, for the G3 frameworks, the ceramic veneer

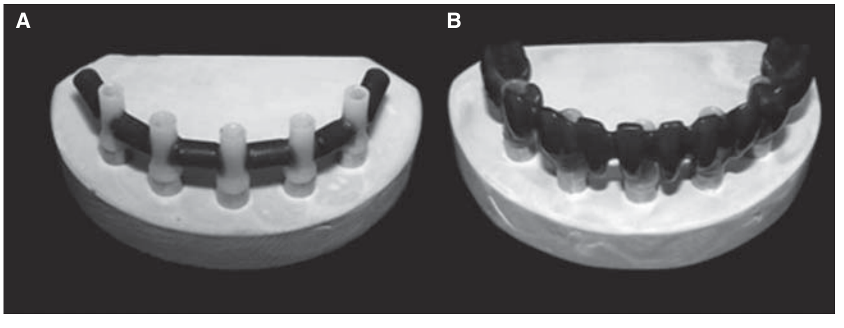

Figure 1. Framework patterns waxed: (A) for resin coverage, (B) for ceramic veneering.

was applied, fired, finished and polished as recommended by the manufacturer. Marginal misfit measurements were taken again after each veneer material was applied, following the same protocol previously described.

All groups were submitted to a spark erosion process for 2 h in a Tel Med Technologies machine (Port Huron, Michigan) using another gypsum index with invested copper implant analogs and wires to transmit electrical current. At the end of the spark erosion process, the misfit levels were re-evaluated.

The data were submitted to an exploratory analysis and an ANOVA with a split-plot design for repeated measurements, followed by a Tukey test ($p = 0.05$) (SAS version 9.1, SAS Institute, Cary, NC).

Results

Table I shows the mean values and standard deviation of misfit level (μm) between treatments and periods. Initially, there was no statistically significant difference between the groups. However, after veneering application, all groups showed increased misfit values. Moreover, the heat-cured acrylic resin and ceramic groups had higher misfit values than the light-cured resin group (Figure 2). After the spark erosion process, the same differences between groups (treatments) were observed. This process decreased the misfit level only in the ceramic application.

Discussion

Marginal misfit in implant-supported frameworks is a clinical reality. Potential distortion can be created at any step of implant-supported prostheses manufacturing [25,29]. Misfit values ranging from 10–150 μm are considered to be clinically acceptable [25]. Although the preceding values were reported and used as references, these values seem to be empirical values [29].

Analyses of misfit levels were conducted in the gypsum index with the goal of evaluating the misfit level associated with the veneer application. The analyses were performed when there was a complete absence of juxtaposition of the marginal surfaces [30]. Minimal values of misfit level were found in all groups in the initial period after the frameworks were casted, which indicates good standardization of specimens prior to the veneer application. After the veneer application, these levels increased in all groups. The light-cured resin group exhibited a lower level of misfit than the other two groups ($p < 0.0001$), with values lower than 150 μm.

Based on the reference values of clinically acceptable marginal misfit, it can be assumed that the light-cured resin generated less marginal misfit than the other veneering materials. It is likely that this coating material causes the fewest biological complications in the surrounding tissues and has fewer mechanical failures of the prostheses and implant system [11,29].

The increase in marginal misfit values of heat-cured resin groups ($p < 0.0001$) probably occurred due to the tension induced by the acrylic resin during curing. Numerous variables can affect the dimensional changes of heat-cured acrylic resins, including polymerization shrinkage, which occurs as the polymer chains are formed; thermal contraction, which can be observed during the cooling process; and the different processing methods [31].

The ceramic application was also associated with a significant increase in marginal misfit values ($p < 0.0001$). These findings are consistent with previous reports [19–21]. During ceramic application, framework distortion occurs due to the contraction of the ceramic, contamination by ceramic on the inner surface of framework and contamination of the casting process, which modifies the metal melting point and its resilience [19,20]. These distortions may occur in a more pronounced manner in the glaze and oxidation phases as a result of the higher sintering temperature during these phases and release of internal stress from the casting process [19]. Differences in these phases were not evaluated in the present study.

The group that received light-cured resin as an aesthetic coverage had the lowest values of marginal misfit in this study. It is probably that these levels occurred as a consequence of less polymerization shrinkage of this material compared to heated frameworks. According to the manufacturer, the light-cured resin contains 2,2 bis[4-(2-hydroxy-3-methacryloyloxypropoxy)-phenyl]propane (Bis-GMA) monomer in its composition, rather than the conventional

Table I. Mean (SD) values of misfit level (μm)—comparison between treatment and time.

	Period		
Treatment	Initial	After veneering application	After EDM
Heat-cured acrylic resin	29.81 (10.66)^{a,B}	221.7 (14.11)^{a,A}	198.68 (34.19)^{a,A}
Light-cured resin	35.3 (12.15)^{a,B}	81.91 (15.71)^{b,A}	62.03 (17.73)^{b,AB}
Ceramic	44.75 (13.73)^{a,C}	233.99 (39.18)^{a,A}	161.16 (36.59)^{a,B}

Mean values followed by the same letter are not significantly different (Anova/Tukey, $\alpha = 0.05$). Capital letters compare periods of a treatment and lower case letters compare treatment in the same period.

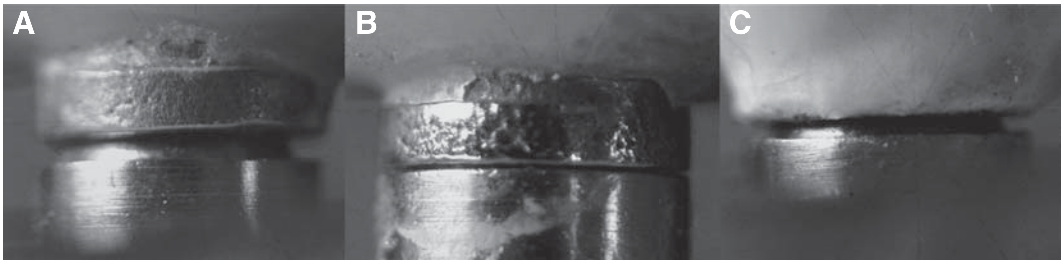

Figure 2. Misfit of the frameworks to the analog platform: (A) heat-cured acrylic resin, (B) light-cured acrylic resin, (C) porcelain.

methyl methacrylate, which reduces the materials' contraction. The Bis-GMA monomer has heavier molecules that minimize the resins' shrinkage during the formation of the polymeric chain [32]. Further, packing and flasking procedures are not necessary during laboratory processing of this material, which reduces the known risk of denture distortion [33].

Several procedures have been employed to minimize the misfit of frameworks [18,28,30]. When a fixed prosthesis does not have a satisfactory fit, it should be submitted to misfit correction employing welding procedures [3–6,26]. However, in the present study, the misfit levels were originated by the aesthetic veneer application. Therefore, in order to perform the welding corrections, it is necessary to remove part of the aesthetic cover, compromising the integrity of the prosthesis.

As an alternative to the conventional welding procedure, a refinement of the frameworks' edges could be performed with a spark erosion treatment. The use of this procedure to reduce marginal misfit has proved to be effective and is recommended and supported by several studies [18,25,27,28,30]. This process removes the excessive metal using a series of sparks in a liquid environment under strictly controlled conditions [28,30].

After the spark erosion process, a significant misfit reduction was found in the group submitted to ceramic application treatment ($p < 0.0001$). The positive effect of spark erosion over these prostheses may have been due to the removal of small portions of ceramic that might have accidentally contaminated the inner surface of the frameworks. Nevertheless, the lack of effect of spark erosion on the resin groups might have been due to the insufficient eroding time applied to the prostheses. Because the aesthetic veneer of these groups was applied with the frameworks screwed to the implant analogs, little inner contamination was expected to occur. Therefore, it would be anticipated that the marginal misfit showed by the prostheses would be a consequence of the curing method and veneer shrinkage and the ineffective behavior of the spark erosion treatment.

In addition, the plastic burnout drums that are used to cast the frameworks can create defects in the frameworks' margin that are often difficult to correct. The standardized 2-h spark erosion treatment might not have been enough to correct the original defects in the titanium frameworks. This time interval was selected to prevent excessive wear and damage to the frameworks; however, it can be assumed that the time allotted was insufficient to cause any change in the titanium frameworks. Therefore, additional studies are warranted so that the spark erosion treatment protocol for dentistry can be determined.

Unfortunately, a completely passive fitting prosthesis is not yet possible. Yet, the results of the present study showed that light-cured resin coverage can be originate prostheses with lower misfit compared to ceramic and heat-cured acrylic resin ones. Further, although the spark erosion technique has been widely recommended, there is still a need to create a protocol for its use to obtain maximum efficiency.

Acknowledgement

This study was supported by FAPESP (Grant n° 04/13629-5).

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

[1] Aparicio C. A new method to routinely achieve passive fit of ceramometal prostheses over Branemark osseointegrated implants: a two-year report. Int J Periodontics Restorative Dent 1994;14:404–19.
[2] Carlson B, Carlsson GE. Prosthodontic complications in osseointegrated dental implant treatment. Int J Oral Maxillofac Implants 1994;9:90–4.
[3] Jemt T. Fixed implant-supported prostheses in the edentulous maxilla. A five-year follow-up report. Clin Oral Implants Res 1994;5:142–7.
[4] Jemt T, Book K. Prosthesis misfit and marginal bone loss in edentulous implant patients. Int J Oral Maxillofac Implants 1996;11:620–5.
[5] Jemt T, Back T, Petersson A. Precision of CNC-milled titanium frameworks for implant treatment in the edentulous jaw. Int J Prosthodont 1999;12:209–15.
[6] Jemt T, Bergendal B, Arvidson K, Bergendal T, Karlsson LD, Linden B, et al. Implant-supported welded titanium frameworks in the edentulous maxilla: a 5-year prospective multicenter study. Int J Prosthodont 2002;15:544–8.
[7] Wang RR, Fenton A. Titanium for prosthodontic applications: a review of the literature. Quintessence Int 1996;27:401–8.

[8] Parr GR, Gardner LK, Toth RW. Titanium: the mystery metal of implant dentistry. Dental materials aspects. J Prosthet Dent 1985;54:410–14.
[9] Lautenschlager EP, Monaghan P. Titanium and titanium alloys as dental materials. Int Dent J 1993;43: 245–53.
[10] Jemt T, Lekholm U. Oral implant treatment in posterior partially edentulous jaws: a 5-year follow-up report. Int J Oral Maxillofac Implants 1993;8:635–40.
[11] Kan JY, Rungcharassaeng K, Bohsali K, Goodacre CJ, Lang BR. Clinical methods for evaluating implant framework fit. J Prosthet Dent 1999;81:7–13.
[12] Sahin S, Cehreli MC. The significance of passive framework fit in implant prosthodontics: current status. Implant Dent 2001;10:85–92.
[13] Zervas PJ, Papazoglou E, Beck FM, Carr AB. Distortion of three-unit implant frameworks during casting, soldering, and simulated porcelain firings. J Prosthodont 1999;8:171–9.
[14] Skalak R. Biomechanical considerations in osseointegrated prostheses. J Prosthet Dent 1983;49:843–8.
[15] Schiffleger BE, Ziebert GJ, Dhuru VB, Brantley WA, Sigaroudi K. Comparison of accuracy of multiunit one-piece castings. J Prosthet Dent 1985;54:770–6.
[16] Schmitt SM, Chance DA, Cronin RJ. Refining cast implant-retained restorations by electrical discharge machining. J Prosthet Dent 1995;73:280–3.
[17] Evans DB. Correcting the fit of implant-retained restorations by electric discharge machining. J Prosthet Dent 1997;77: 212–15.
[18] Silva TB, De Arruda Nobilo MA, Pessanha Henriques GE, Mesquita MF, Guimaraes MB. Influence of laser-welding and electroerosion on passive fit of implant-supported prosthesis. Stomatologija 2008;10:96–100.
[19] Faucher RR, Nicholls JI. Distortion related to margin design in porcelain-fused-to-metal restorations. J Prosthet Dent 1980;43:149–55.
[20] Bridger DV, Nicholls JI. Distortion of ceramometal fixed partial dentures during the firing cycle. J Prosthet Dent 1981;45:507–14.
[21] Buchanan WT, Svare CW, Turner KA. The effect of repeated firings and strength on marginal distortion in two ceramometal systems. J Prosthet Dent 1981;45:502–6.
[22] Anusavice KJ, Okabe T, Galloway SE, Hoyt DJ, Morse PK. Flexure test evaluation of presoldered base metal alloys. J Prosthet Dent 1985;54:507–17.
[23] Papazoglou E, Brantley WA, Johnston WM. Evaluation of high-temperature distortion of high-palladium metal-ceramic crowns. J Prosthet Dent 2001;85:133–40.
[24] Byrne D, Houston F, Cleary R, Claffey N. The fit of cast and premachined implant abutments. J Prosthet Dent 1998;80: 184–92.
[25] Romero GG, Engelmeier R, Powers JM, Canterbury AA. Accuracy of three corrective techniques for implant bar fabrication. J Prosthet Dent 2000;84:602–7.
[26] Jemt T. Failures and complications in 391 consecutively inserted fixed prostheses supported by Branemark implants in edentulous jaws: a study of treatment from the time of prosthesis placement to the first annual checkup. Int J Oral Maxillofac Implants 1991;6:270–6.
[27] Rubeling G. New techniques in spark erosion: the solution to an accurately fitting screw-retained implant restoration. Quintessence Int 1999;30:38–48.
[28] Sartori IA, Ribeiro RF, Francischone CE, de Mattos Mda G. In vitro comparative analysis of the fit of gold alloy or commercially pure titanium implant-supported prostheses before and after electroerosion. J Prosthet Dent 2004;92:132–8.
[29] Spazzin AO, Henriques GE, de Arruda Nobilo MA, Consani RL, Correr-Sobrinho L, Mesquita MF. Influence of prosthetic screw material on joint stability in passive and non-passive implant-supported dentures. Open Dent J 2009; 3:245–9.
[30] Contreras EF, Henriques GE, Giolo SR, Nobilo MA. Fit of cast commercially pure titanium and Ti-6Al-4V alloy crowns before and after marginal refinement by electrical discharge machining. J Prosthet Dent 2002;88:467–72.
[31] Seo RS, Vergani CE, Pavarina AC, Compagnoni MA, Machado AL. Influence of microwave disinfection on the dimensional stability of intact and relined acrylic resin denture bases. J Prosthet Dent 2007;98:216–23.
[32] Bowen RL. Properties of a silica-reinforced polymer for dental restorations. J Am Dent Assoc 1963;66:57–64.
[33] Faot F, da Silva WJ, da Rosa RS, Del Bel Cury AA, Garcia RC. Strength of denture base resins repaired with auto- and visible light-polymerized materials. J Prosthodont 2009;18:496–502.