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Lost-wax or laser sintering? Findings on marginal and internal adaptation of metallic copings

Cera perdida ou sinterização à laser? Achados sobre adaptação marginal e interna de copings metálicos

¿Cera perdida o sinterización láser? Conclusiones sobre adaptación marginal e interna de infraestructuras metálicas

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Lucas José de Azevedo-Silva
ORCID: https://orcid.org/0000-0002-6636-8022
University of São Paulo, Brazil
E-mail: lucasjazevedos@usp.br
Brunna Mota Ferrairo
ORCID: https://orcid.org/0000-0002-8121-3002
University of São Paulo, Brazil
E-mail: brunna.ferrairo@gmail.com
Renato José Berro-Filho
ORCID: https://orcid.org/0000-0002-9667-1022
University of São Paulo, Brazil
E-mail: renatoberro@gmail.com
Fernanda Ferruzzi Lima
ORCID: https://orcid.org/0000-0003-0212-7067
Ingá University Center, Brazil
Maringá State University, Brazil
E-mail: fer.ferruzzi@gmail.com
José Henrique Rubo
ORCID: https://orcid.org/0000-0003-1595-845X
University of São Paulo, Brazil
E-mail: jrubo@usp.br

Abstract
Marginal and internal adaptation are parameters of crucial importance to the success of prosthetic crowns. Automatized process creates an expectative of superior or equivalent results compared to restorations manufactured by conventional lost-wax technique. The purpose of this study was to evaluate the marginal adaptation and internal adaptation (cement space) of metal-ceramic crown copings produced by lost-wax (LW) and direct metal laser sintering (DMLS) techniques. An artificial lower first molar was prepared for a full crown, duplicated in plaster and scanned. Twenty metal-ceramic crown copings were fabricated in cobalt-chromium by the two techniques (n=10). The copings were filled with low viscosity silicone and seated on the prepared tooth, resulting in a replica of the internal space. The pellicle formed was embedded in heavy body silicone, sectioned and captured by means of a stereomicroscope at 50x magnification, according to replica technique (RT). Shapiro-Wilk test followed by Holm-Sidak test were used for statistical analysis (α=.05). Marginal adaptation presented no difference between LW (101.5 ± 41.6) and DMLS (86.3 ± 39.9) groups (p=0.24). Conventional LW technique showed significantly lower occlusal ($p<0.008$) and axial spaces ($p<0.03$). Measurements of all regions showed numerically larger adaptation values than that defined during design for DMLS group. Both the LW technique and the DMLS technique are within the clinically acceptable.
Keywords: Replica technique; CAD-CAM; Crowns; Marginal adaptation.

Resumo
Adaptação marginal e interna são parâmetros de crucial importância para o sucesso das coroas protéticas. O processo automatizado cria uma expectativa de resultados superiores ou equivalentes em comparação com as restaurações fabricadas pela técnica convencional de cera perdida. O objetivo deste estudo foi avaliar a adaptação marginal e adaptação interna (espaço de cimentação) de infra-estruturas (IE) de coroas metalocerâmicas produzidos pela técnica da cera perdida (CP) e de sinterização direta de metal à laser (SL). Um primeiro molar inferior artificial foi preparado para uma coroa completa, duplicado em gesso e escaneado. Vinte copings metálicos para coroa metalocerâmica foram confeccionados em cobalto-cromo pelas duas técnicas (n = 10). As IE foram preenchidas com silicone de baixa viscosidade e assentadas no dente preparado, resultando em uma réplica do espaço interno. A película formada foi

embebida em silicone pesado, seccionada e capturada por meio de estereomicroscópio com aumento de 50x, conforme a técnica de réplica (TR). O teste de Shapiro-Wilk seguido pelo teste de Holm-Sidak foram usados para análise estatística (α = 0,05). Adaptação marginal não apresentou diferença entre os grupos CP (101,5 ± 41,6) e SL (86,3 ± 39,9) (p=0,24). A técnica convencional apresentou espaços oclusais (p<0,008) e axiais (p<0,03) significativamente menores. Todas as regiões apresentaram valores de adaptação numericamente maiores do que os definidos durante o projeto para o grupo SL. Tanto a técnica CP quanto a técnica SL se apresentaram dentro do clinicamente aceitável.
Palavras-chave: Técnica da réplica; CAD-CAM; Coroas; Adaptação marginal.

Resumen
El ajuste marginal e interno son parámetros cruciales para el éxito de las coronas protésicas. El proceso automatizado crea una expectativa de resultados superiores oequivalentes en comparación con las restauraciones fabricadas con la técnica convencional de cera perdida. El objetivo de este estudio fue evaluar la adaptación marginal y la adaptación interna (espacio de cementación) de la infraestructura (IE) de coronas de metal-cerámica producidas por la técnica de cera perdida (CP) y sinterización directa por láser de metales (SL). Se preparó un primer molar mandibular artificial para una corona completa, se duplicó en yeso y se escaneó. Se realizaron veinte cofias metálicas para coronas metalcerámicas en cobalto-cromo mediante las dos técnicas (n = 10). Los IEs se rellenaron con silicona de baja viscosidad y se asentaron sobre el diente preparado, lo que resultó en una réplica del espacio interno. La película formada se incrustó en silicona pesada, se seccionó y se capturó utilizando un microscopio estereoscópico con un aumento de 50x, según la técnica de réplica (TR). Para el análisis estadístico se utilizó la prueba de Shapiro-Wilk seguida de la prueba de Holm-Sidak (α = 0.05). La adaptación marginal no difirió entre los grupos CP (101,5 ± 41,6) y SL (86,3 ± 39,9) (p = 0,24). La técnica convencional mostró espacios oclusales (p <0,008) y axiales (p <0,03) significativamente más pequeños. Todas las regiones presentaron valores de adaptación numéricamente superiores a los definidos durante el proyecto para el grupo SL. Tanto la técnica CP como la técnica SL fueron clínicamente aceptables.
Palabras clave: Técnica de replicación; CAD-CAM; Coronas; Adaptación marginal.

1. Introduction

For over 40 years, metal-ceramic crowns remain the gold standard of prosthetic dentistry (Pjetursson et al. 2007) and are widely used despite the metal-free trend. In the conventional casting process, the laboratory steps are prolonged, subject to human bias and to material distortion, reflecting on the final quality of the prostheses. New methods have been developed to improve their manufacture technique and minimalize those complications. Computer-aided design (CAD) and manufacturing (CAM) was developed in order to provide restorations with higher resistance, aesthetic and accuracy using a cheapest, fastest and easiest method (Belli et al. 2017) by additive or subtractive methods (Quante et al., 2008).

Direct metal laser sintering (DMLS) technique is responsible for producing metal prosthetic parts in automatized additive method, mostly using cobalt-chromium (CoCr) alloy powder that are sintered by a laser (Santos et al. 2019). The milling process is a method where design-guided drills subtractively carve the material, e.g. dental ceramic, resin, metal or wax, which will be conventionally cast later (Park et al. 2017; Hamza et al. 2013).

Regardless of the prosthesis manufacture, the marginal and internal adaptation parameters are significant for its clinical longevity (Syrek et al. 2010; Reich et al. 2005). While the conventional technique presents weak points during its process, the automation of the production and the digital control of the parameters seem to be good solutions to these problems (Syrek et al. 2010; Reich et al. 2005; Gonzalo et al. 2009). However, some studies have shown similar results regarding the adaptation of crowns made by CAD-CAM systems compared to conventional technique (Gonzalo et al. 2009; Ram, Ranadive & Nadgere, 2019).

Since the measurement of the adaptation parameters is not clinically possible, it is necessary to use in vitro techniques for evaluation. The replica technique is a one of the various techniques described in literature used to assess the marginal and internal fit of a restorations (Mai et al. 2017). The restoration fit is evaluated at predetermined locations (Hamza et al. 2013; Mai et al. 2017). Considered a simple technique, currently studies have shown that the results of this technique are similar to those found in more advanced and expensive techniques (Hamza et al. 2013; Mai et al. 2017).

The purpose of this in vitro study was to elucidate the questionable association of automation with precision, comparing the marginal adaptation and internal fit of metal-ceramic crown copings produced by lost-wax technique (LW) and DMLS, using replica technique. The null hypothesis was that marginal and internal spaces would not differ between the fabrication methods.

2. Material and Methods

Tooth preparation and cast fabrication

An artificial lower first molar was prepared for a complete metal-ceramic crown and received an impression with polyvinyl siloxane material (Express, 3M ESPE) using the double impression technique. The plaster model was made with type IV special CAD-CAM stone (CAM-base, Dentona AG).

Copings Fabrication

DMLS technique

The plaster model was digitalized by scanner (Ceramill Map, Arman-Girbach) and the copings were designed (Ceramill Mind, Amann Girrbach), establishing the space for the cementing agent of 50 µm. Ten copings were laser sintered (EOSINT M280, EOS GmbH) in CoCr alloy.

LW technique

Using the same design and parameters as the Ceramill Mind, 10 patterns were milled (Ceramill Motion, Amann Girrbach) into wax (Ceramill Wax, Amann Girrbach) and cast by the conventional lost-wax technique.

Replica Technique

Replicas of the interspace between the inner surface of the crown and the tooth, were made as described by Molin and Karlsson, 1993. Some details have been added to the technique, such as the removal of silicone leakage on the dental margin before polymerization, avoiding laceration, and the use of a device for standardization of the insertion position of the master model, optimizing segmentation and giving greater homogeneity to the sample (Figure 1).

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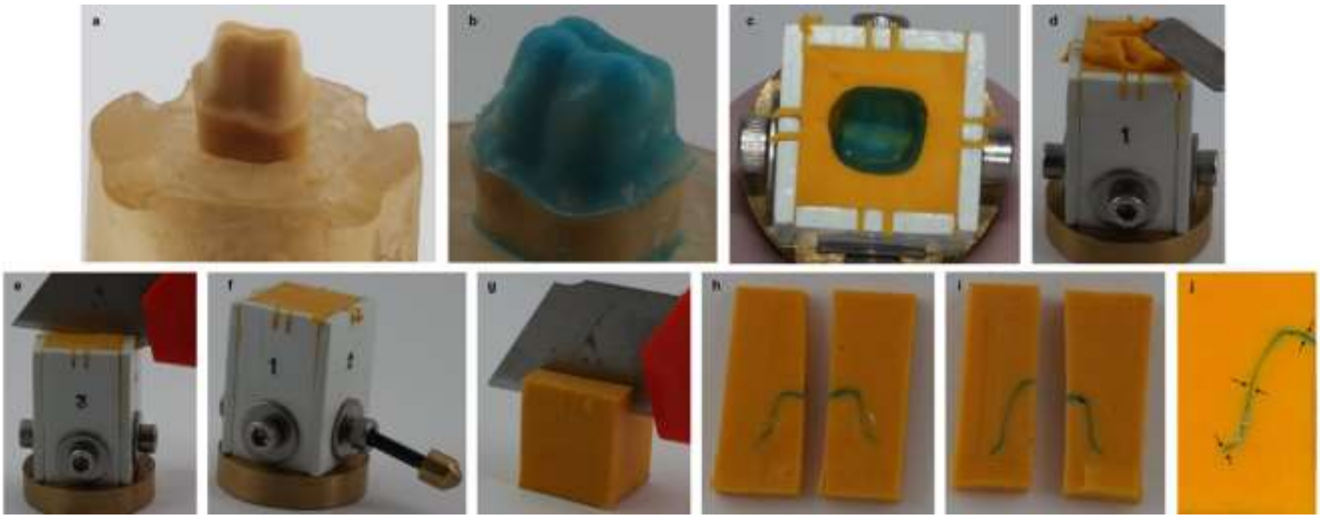
Figure 1. Replica technique. A) Master Model; B) Light silicone film; C) Inclusion of the film in dense silicon mass; D) Filling the inner portion of the film with dense silicone mass; E) Beginning of section; F) Opening of the matrix to continue the section; G) Sectioning; H and I) Examples of films included in dense mass, and; J) Regions of analysis.



Source: Authors.

Film thickness was captured by means of a stereomicroscope (MZ6, Leica) at 50x magnification factor, with a built-in charge-coupled camera (Hitachi CCTV HV-720E, Hitachi). The software Image J was used to measure the AMD, according to Holmes et al. 1992, and cement space at occlusal and axial regions.

Statistical Analysis

The Shapiro-Wilk test detected that the sample had no normal distribution. Thus, the statistical analysis was performed through the Holm-Sidak test.

3. Results

Cementation space means were 101,5 (±41,6) μm for the conventionally lost wax group and 86,3+39,9 μm for the DMLS group, no statistical difference was found (P=0.24). For internal adaptation, in the axial and occlusal cement space, significantly lower values were found in conventional LW copings (p <0.035), as shown in Table 1. Occlusal region showed higher cement space values than the other regions analyzed (p<0.008). All measurements presented values quite different from the 50 μm established as cement space in CAD software.

Table 1. Adaptation analysis considering different group and region (μm).

	Group	
	Conventional	Laser Sinthered
Axial	81.1+31.5 Aa	108.3 + 41.7 Ba
Marginal	101.5+41.6 Aa	86.3+39.9 Aa
Oclusal	248.8+ 58.9 Ab	282.9 +102.2 Bb

Source: Authors.

Capital letters represent comparison between lines and lowercase represent comparison between columns. Means with the same superscript letter are not significantly different using post hoc Tukey honestly significant difference test (p < 0.05). There was no difference between the groups, which is represented by the capital letter.

4. Discussion

The purpose of this study was to evaluate the marginal and internal adaptation of metal-ceramic crown copings produced by lost-wax and DMLS techniques. Considering adaptation as a subjective concept, the present study will consider marginal adaptation as the marginal gap and internal adaptation as the cement space of the copings. Conventional lost-wax technique presented lower cement space than direct metal laser sintering, what is interpreted as better internal adaptation. Marginal adaptation was statistically similar for both techniques. Therefore, the null hypothesis that no significant difference would be found about marginal and internal adaptation between the two methods was partially rejected.

The study of marginal and internal adaptation of prosthetic crowns is of great importance and several methods to measure it have been developed over time. Direct-view, cross-sectioning, profile projector, silicone replica and µCT (microcomputed tomography) are the most used techniques in the literature (Laurent et al. 2008). The replica technique is a low cost and speed method, but its main advantage is the non-destruction of the restorations, what makes this technique a validate methodology for clinical evaluation of indirect restorations prior to cementation (Dahl et al., 2017).

The evaluation of pre-determined sites might be considered a limitation of this technique, since the marginal adaptation is not thoroughly assessed. Considering there are possible flaws that can be incorporated during the process (Frasson et al., 1985), some cautions have been taken in this study. Excess of silicone leakage on the dental margin was removed before polymerization, avoiding laceration. The use of a device for standardization of the insertion position of the master model optimized the segmentation of the replica and provided greater homogeneity to the sample. In addition, all replicas were made and evaluated by a single operator.

A recent study (Ferrairo et al. 2021) found no difference between replica technique and µCT when evaluating the marginal adaptation and internal space in crowns produced by four CAD/CAM systems. This fact, increases the relevance and confers confidence in the results found through the replica technique, used in the present study.

The process to produce metallic copings is changing and the digitalization of the laboratory steps is being spread. However, there are few studies evaluating their quality and adaptation (Gonzalo et al. 2009; Dahl et al., 2017; Ucar et al. 2009; Tamac et al., 2014; Lövgren et al. 2017; Holmes et al. 1992). The acceptable means of marginal adaptation are defined in the literature at around 50 µm (McLean & Von Fraunhofer, 1971), but it is also well defined that a mean marginal gap size of about 100 µm (Ucar et al. 2009; Bjorn et al., 1970) is acceptable without impairing the longevity of the cementation (Ucar et al. 2009). Unsatisfactory marginal fit leads to bacterial accumulation (Bjorn et al., 1970), increasing the risk of carious lesions (Karlsson, 1986; Bergenholtz et al. 1982) and can cause microleakage and endodontic inflammation (Abou Tara et al. 2011). A sufficient cement space must be present to allow crown seating and some frictional retention in axial walls. This space is usually varying between 50 and 150µm (Ferrairo et al. 2021).

In the present study, mean marginal gap was above the parameter defined during CAD, however under the clinically accepted values (Ucar et al. 2009; Bjorn et al., 1970). Although DMLS copings presented smaller marginal gaps, there was no significant difference when compared to the conventionally manufactured copings. Internal space, however, was significantly larger for DMLS copings, what can be attributed to the rough surface characteristics of the copings, since we did not perform any finishing or internal adjustment. This fact is the main limitation of the present study. Laser sintered group presented higher standard deviation. Although these parameters do not describe precisely the sample, it illustrates the reproducibility of each manufacturing method, suggesting higher variability and less precision for DMLS.

Previous studies used different methodologies for evaluating the internal adaptation of copings report similar results. Ucar et al. 2009 used light-body addition silicone that simulating a cement material for evaluation of crowns fit. The study found no significant difference comparing the alloy groups, however considered the technique as a convenient methodology for this evaluation. Tamac et al. 2014, measured the adaptation in different areas using the replica technique and found significantly larger gaps in DMLS restorations when compared to others.

Although significant differences on marginal adaptation obtained from different manufacturing methods were not found, it is important to note that the gap values in these publications were numerically different, and the DMLS resulted in larger gaps than the conventional method (Tamac et al., 2014). Just like our results, the higher means were found in oclusal region in both techniques.

Other studies demonstrate no difference between conventional or laser sintered technique both in laboratory (Holmes et al. 1992) or in clinic trials (McLean & Von Fraunhofer, 1971), what suggests the literature is still scarce, and there is no evidence that one manufacture method is superior to the other. It is already known the limitations regarding the evaluation of these parameters in patients. However, more studies are necessary to elucidate if differences in marginal and internal adaptation might be clinically relevant or whether small discrepancies would not interfere with the clinical outcome.

5. Conclusion

Within the limitations of this study, the following conclusions were that: Direct metal laser sintering produces copings with smaller internal space than conventional lost-wax technique. Both manufacturing methods present comparable marginal adaptation, with clinically acceptable marginal gaps. These findings suggest that both manufacturing techniques can achieve results that are within clinically expected. Thus, they are considered suitable methodologies for making metallic infrastructures. Clinical studies addressing the performance evaluation and comparison of the two types of methodologies is suggested.

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