Original papers

Influence of porcelain firing on changes in the marginal fit of metal-ceramic fixed partial dental prostheses fabricated with laser sintering: An in vivo study

Wpływ spiekania ceramiki na zmiany integracji brzeżnej mostów metalowo--ceramicznych wykonywanych laserową synteryzacją – badanie in vivo

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D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl.* 2020;57(2):185–190

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Funding sources
None declared

Conflict of interest
None declared

Acknowledgements
The paper has been reviewed and verified by Prof. Loai Aljerf (ORCID: https://orcid.org/0000-0002-1132-9659).

Received on September 14, 2019
Reviewed on October 15, 2019
Accepted on November 14, 2019

Published online on June 30, 2020

Cite as
Nassif QK, Alshaarani FF. Influence of porcelain firing on changes in the marginal fit of metal-ceramic fixed partial dental prostheses fabricated with laser sintering: An in vivo study. *Dent Med Probl.* 2020;57(2):185–190. doi:10.17219/dmp/114196

DOI
10.17219/dmp/114196

Abstract

Background. Marginal fit is the most important criterion in the evaluation of the clinical acceptability of fixed restorations. Due to cement solubility and plaque retention, marginal gaps are potentially harmful to both the teeth and the periodontal tissues.

Objectives. The aim of the study was to investigate the accuracy of the fit of dental metal-ceramic bridges manufactured with the use of direct metal laser sintering (DMLS), and to explore the effects of porcelain firing on the marginal, axial and occlusal fit of metal-ceramic frameworks.

Material and methods. The study involved 10 patients with 3-unit metal-ceramic restorations produced using the DMLS technique. Using the silicone replica technique, we examined the marginal, axial and occlusal fit of the dental bridges before and after ceramic firing. The Shapiro–Wilks normality test and Student's paired *t*-test were implemented to analyze the mean differences in the marginal, axial and occlusal fit of the restorations before and after ceramic firing. A 95% confidence interval (*CI*) and discrepancy values at the level of 1% and 0.1% ($p > 0.05$) were applied.

Results. All the mean values of the measurements of marginal (156.08 μm), axial (95.75 μm) and occlusal (252.83 μm) gaps were lower before ceramic veneering than after ceramic veneering, when the mean value for the marginal gap was 178.17 μm, for the axial gap – 106.75 μm and for the occlusal gap – 266.00 μm.

Conclusions. Porcelain firing caused no statistically significant differences in the discrepancy values of marginal, axial and occlusal fit. For clinical application, further improvement of the DMLS system is highly recommended. Marginal gaps in DLSM bridges significantly exceed the permissible inaccuracy values of 100–120 μm for prosthetic restorations.

Key words: laser, fitting, prosthesis, in vivo study, porcelain

Słowa kluczowe: laser, dopasowanie, proteza, badanie in vivo, ceramika

Introduction

Dental porcelain fused to metal bridges is considered the best choice in prosthetic dentistry, especially in the posterior area of the jaws, due to a high tolerance of these materials to stress.[1,2] The clinical survival of these bridges is largely dependent on the distance between the internal surface of the restoration and the external surface of the abutment.[3,4] When the marginal gap is larger than the clinically acceptable limit, it eventually can cause cement dissolution, followed by secondary caries or periodontal inflammation.[4,5]

The lost-wax technique is considered a conventional method to fabricate metal bridges.[6] The manual phases of the casting process may result in distortions in the metal framework.[4,7,8] Some of these complications could be avoided by using the computer-aided design and computer-aided manufacturing (CAD-CAM) technologies,[9,10] or the laser sintering method (an additive manufacturing technique used in fixed prosthodontics)[11,12] or casting with 3D-printed patterns.[13] The laser sintering technology uses a high-power laser beam transformed by galvano mirrors to aggregate metal powder layer by layer, making three-dimensional (3D) complex patterns. The beam is guided by the information taken from the 3D design generated by CAD software.[14,15] Laser sintering has been modified for dental use; there are several types of it, among them direct metal laser sintering (DMLS).[16,17]

The fit of dental metal-ceramic bridges depends on the accuracy of the manufacturing technique and subsequent production procedures.[18–20] Some studies have referred to the effect of the progress of porcelain firing on the fit of dental bridges.[21,22] Similarly, marginal gaps can be increased after cementation.[23,24]

Studies evaluating the effect of ceramic firing on the fit of modern metal-ceramic devices reported that the marginal gap values were influenced by ceramic firing cycles.[19,20,25,26] At the same time, other studies reported that ceramic firing had no statistically significant effect on the internal and marginal discrepancy values.[17–27]

The aim of this in vivo study was to compare the marginal, axial and occlusal fit of metal frameworks produced by means of the DMLS method before and after the application of porcelain. The hypothesis was that the marginal, axial and occlusal gaps would be increased after ceramic application.

Material and methods

The study involved 10 metal-ceramic fixed partial dentures (FPDs) obtained from 10 patients (7 men and 3 women) who visited the Department of Fixed Prosthodontics at the Faculty of Dentistry of Damascus University in Syria in May 2017. Each individual had lost a first molar. The exclusion criteria were gingival recession, chronic or acute periodontitis, poor oral health care, and a high rate of generalized caries.

This study was carried out in accordance with the Declaration of Helsinki, good clinical practice and the International Organization for Standardization standard 14155. The protocol (EC ref. No. 1574, 18/04/2017) was approved by the institutional ethics committee at the Faculty of Dentistry of Damascus University, Syria.

The molar and premolar teeth that were the abutments in this study had adequate periodontal support for a 3-unit bridge, without any mobility, and showed a clinically acceptable length after preparation. The molar and premolar abutments were prepared in accordance with the requirements of metal-ceramic prosthodontics.[28] A circumferential chamfer margin (1 mm in width) was created, and an occlusal reduction of 1.3–2.0 mm was performed. After preparing the molar and premolar abutments, impressions were made using additive siloxane (Elite HD+® Light Body Normal Set dental silicone; Zhermack SpA, Badia Polesine, Italy) and poured into a type V dental stone. Temporary bridges were fabricated with acrylic resin and cemented with eugenol-free temporary cement. The models were scanned with a 3D dental scanner (imes-icore GmbH, Eiterfeld, Germany) and the obtained data was sent to CAD software. Frameworks for dental bridges were designed with a thickness of 0.6 mm and a cement gap of 50 µm. The 3D design for the frameworks was saved as standard triangle language (STL) files for the production of Co-Cr bridges (Fig. 1) with the MYSINT100® laser sintering machine (SISMA SpA, Piovene Rocchette, Italy). All the frameworks were treated in the N 7/H dental furnace (Nabertherm GmbH, Lilienthal, Germany) for annealing after laser sintering. Then, they were trimmed, polished, steam-cleaned, and dried. After that, measurements were taken using the silicone replica technique.[29] A light-viscosity silicone material was put inside the frameworks, which were placed on the prepared abutments with finger pressure for 3 min (Fig. 2). After the silicone material hardened, the frameworks were removed from the prepared abutments. A medium-viscosity silicone material was inserted into the frameworks covered with the 1st silicon layer. After the silicone material hardened, the 2 layers of silicon were separated from the metal frameworks. Each silicone material model contained 2 abutments – one for a premolar and the other for a molar.

Each premolar abutment was sectioned first buccolingually, and then mesiodistally at the center of each surface, resulting in 4 surfaces: I – the distal surface; J – the buccal surface; K – the mesial surface; and L – the lingual surface. Each surface had 3 points for measurement (1 – occlusal; 2 – axial; and 3 – marginal), so 12 measurement points for each premolar abutment were analyzed with the BX41 light microscope (Olympus Optical Co., Ltd., Tokyo, Japan).

Fig. 1. Co-Cr bridges produced using the direct metal laser sintering (DMLS) method

Fig. 2. Silicone replica technique sample before ceramic firing

Each molar abutment was sectioned first buccolingually, then mesiodistally, and then buccomesially to linguodistally and linguomesially to bucodistally at the center of each surface, resulting in 8 surfaces: A – the distal surface; B – the distobuccal surface; C – the buccal surface; D – the buccomesial surface; E – the mesial surface; F – the mesiolingual surface; G – the lingual surface; and H– the linguodistal surface (Fig. 3). Each surface had 3 points for measurement (1 – occlusal; 2 – axial; and 3 – marginal) (Fig. 4), so 24 measurement points for each molar abutment were analyzed with the Olympus BX41 light microscope.

After the measurements were taken, the frameworks were veneered with porcelain (VMK Master® feldspar veneering; VITA Zahnfabrik H. Rauter GmbH & Co. KG, Bad Säckingen, Germany) in a dental ceramic furnace (Programat® P300/G2; Ivoclar Vivadent AG, Ellwangen, Germany) according to the manufacturer's instructions.[20] All the measurements at the 36 (24 + 12) predefined points on each bridge were repeated after ceramic veneering (Fig. 5). In total, 240 marginal, 240 axial and 240 occlusal discrepancy values were recorded.

Initially, the normal distribution of the data was confirmed using the Shapiro–Wilk test. The data was normally distributed ($p > 0.05$), so corresponding parameter tests were used. Student's paired t-test was used to study the mean differences in marginal, axial and occlusal accuracy before and after ceramic firing. The level of statistical significance was set at 0.05.

Fig. 3. Molar silicone replica divided into 8 parts and the premolar silicone replica divided into 4 parts

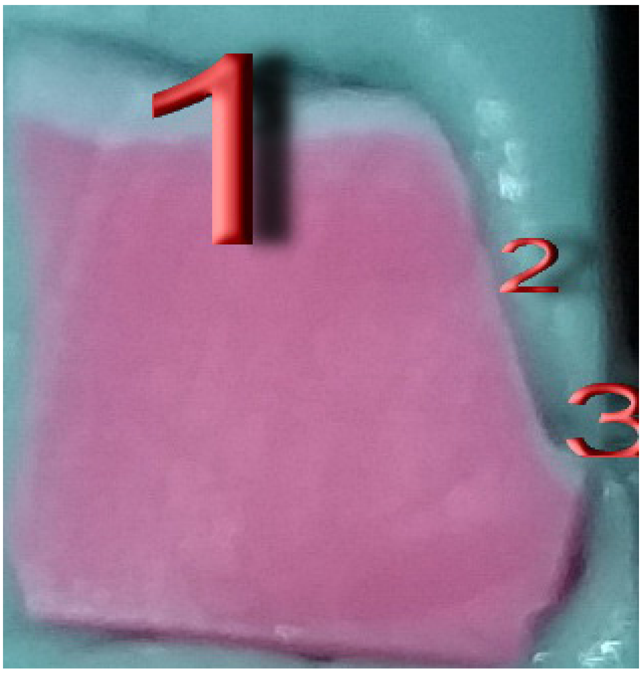

Fig. 4. Silicone replica technique sample, ready for the light microscope measurement of the occlusal (1), axial (2) and marginal (3) fit

Fig. 5. Silicone replica technique sample after ceramic firing

Results

The mean values of marginal (156.08 µm), axial (95.75 µm) and occlusal (252.83 µm) accuracy in DMLS bridges before ceramic firing were better than those after ceramic firing (178.17 µm, 106.75 µm and 266.00 µm, respectively). The comparison of the 2 phases of measurement showed that the largest values were observed in the case of the occlusal gap, whereas the axial walls were the smallest. The marginal gap was larger than the clinically acceptable range. Table 1 shows the descriptive analysis before and after ceramic firing, at 95% confidence interval (*CI*).

The Shapiro–Wilk test indicated that the study groups had a normal distribution ($p > 0.05$). Student's *t*-test was therefore used to study the mean differences in marginal, axial and occlusal accuracy before and after ceramic firing; the results, presented in Table 2, indicated that there were no statistically differences between the 2 sets of measurements at the framework marginal ($p = 0.197$), axial ($p = 0.215$) or occlusal ($p = 0.242$) regions.

Discussion

The aim of this in vivo study was to examine the adaptation accuracy of dental metal-ceramic 3-unit bridges manufactured using DMLS, and to investigate the effects of porcelain firing on the marginal, axial and occlusal fitting of metal-ceramic bridges. The null hypothesis was that the ceramic firing process has no effect on the marginal, axial and occlusal adaptation of metal-ceramic bridges.

Metal-ceramic bridges are still the best choice in posterior prosthodontic treatment due to several advantages they have, especially their proven clinical effectiveness over the long term. There are some limitations for using these devices, such as many manual steps involved in their manufacture and large marginal gaps, which are an important factor affecting the durability of metal-ceramic bridges.[5,6] Ensuring a small marginal gap and good marginal fit (a significant criterion for achieving long-term clinical success) as well as the use of the new CAD-laser sintering technique to produce metal-ceramic frameworks have become prerequisites to avoid the disadvantages of the traditional method.[11,30]

There are many ways to measure the thickness of the cement film in the marginal area, as numerous studies have indicated,[29] but in an in vivo study, the silicone replica technique is the best to facilitate studying the marginal, axial and occlusal fit of fixed bridges.[29]

The CAD-DMLS technique makes use of scanners that have a precision of 20–40 µm.[31,32] In the CAD-DMLS technique, stone model scanning and CAD software are used to define the finishing line of preparation, the path of bridge insertion and the 3D framework design. The thickness of the framework, the cement gap and the pontic design can be standardized with this technique,[10] and by using a CAD-DMLS machine that produces about 90 units per run, 450 units of crowns and bridges can be produced in 1 day.[33]

Table 1. Accuracy values for DMLS bridges for the specific locations measured at 2 stages (before and after ceramic firing)

Accuracy	Stage	*N*	*M* ±*SD* [µm]	95% *CI*	
				upper bound	lower bound
Marginal	before porcelain firing	10	156.08 ±43.25	187.02	125.14
	after porcelain firing	10	178.17 ±57.47	219.28	137.05
Axial	before porcelain firing	10	95.75 ±43.28	126.71	64.79
	after porcelain firing	10	106.75 ±32.04	129.67	83.83
Occlusal	before porcelain firing	10	252.83 ±105.37	328.21	177.45
	after porcelain firing	10	266.00 ±87.53	328.62	203.38

M – mean; *SD* – standard deviation; *CI* – confidence interval.

Table 2. Results of Student's *t*-test performed before and after the ceramic firing of DMLS bridges

Accuracy	*t*-value	*p*-value	*M* ±*SD*	95% *CI*	
				upper bound	lower bound
Marginal	−1.394	0.197	−22.08 ±50.11	−57.93	13.76
Axial	−1.335	0.215	−11.00 ±26.05	−29.64	7.64
Occlusal	−1.252	0.242	−13.17 ±33.25	−36.96	10.62

Some researchers have compared the DMLS technique with the casting method for internal and marginal fit, and have stated that the gaps in the case of DMLS frameworks are larger than the originally reported acceptable marginal fit values (125–150 μm).[34,35] In the current study, our descriptive analysis of the 2 stages – before and after ceramic firing – showed that the mean values of the marginal (156.08 μm), axial (95.75 μm) and occlusal (252.83 μm) fit before ceramic firing (i.e., after the production of the framework and before ceramic veneering) were better than those after ceramic veneering (178.17 μm, 106.75 μm and 266.00 μm, respectively) (Table 1). The results of Student's t-test revealed no statistically significant differences between the 2 stages of measurement of the marginal (p = 0.197), axial (p = 0.215) and occlusal (p = 0.242) regions (Table 2).

The null hypothesis was not rejected, since porcelain firing had no significant effects on the marginal, axial and occlusal adaptation of metal-ceramic bridges produced by means of DMLS. This result coincides with those of some other reseachers,[17,27] but contradicts Kaleli and Saraç and Önöral et al., which conducted in vitro studies.[25,26] The current study differs from previous studies in that it studied the marginal application of bridges consisting of 3 parts; and it was an in vivo study.

In our study, all the measurements before and after ceramic firing indicated that the mean value of marginal discrepancy was higher than the clinically acceptable range, which might be due to many difficulties related to clinical work. Clinical studies cannot be controlled like in vitro studies, and the authors doubt if the latter are able to match clinical realities.

Conclusions

Repeated firing had no significant influence on the marginal, axial or occlusal accuracy of metal frameworks produced using the DMLS method. For clinical application, however, further improvement of the DMLS system is urgently recommended. The marginal gaps in DLSM bridges significantly exceeded the permissible inaccuracy values of 100–120 μm for prosthetic restorations.

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