



Comparing Marginal Fitness between Overdenture Copings Produced by Three Techniques

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Article information

Received: July 17, 2021

Accepted: September 5, 2021

Available online: September 30, 2023

Keywords

Indentation hardness

Surface roughness

ZrO₂ nanoparticles

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Abstract

Aims: to compare the marginal fit of copings produced by Direct Metal Laser Sintering (DMLS), Hard metal CAM (Computer Assisted Milling), and conventional casting techniques. **Materials and Methods:** An implant abutment was used as ideal model which was scanned by 3D scanner and 8 copings of each group were fabricated from a single STL file. Each specimen was cross-sectioned into two halves and 2 points on each half were measured with digital microscope and image processing software. Readings were statistically analyzed with ANOVA test and Duncan's multiple range test. **Results:** Significant difference was found between the groups in both marginal and internal gaps. The hard metal milling group showed significantly smaller gaps than the other two groups, while no significant difference was found in fit between DMLS and conventional casting groups. **Conclusions:** within the limitations of this study, hard metal milled copings were found to have the superior fit compared to the other two groups, however, all copings in all three groups were found to have gaps within the clinically acceptable range of marginal fitness.

الخلاصة

الأهداف: تهدف الدراسة الى مقارنة التوافق الحاقى للأغطية المصنعة بطريقة تلييد المعادن بالليزر المباشر (DMLS)، والنحت بمساعدة الكمبيوتر، وتقنيات الصب التقليدية. **المواد وطرائق العمل:** تم استخدام دعامة زرعة كنموذج مثالي تم مسحه ضوئياً بواسطة الماسح الضوئي ثلاثي الأبعاد لتصنيع 8 أغطية لكل مجموعة تصنيع من ملف STL واحد. تم تقسيم كل عينة إلى نصفين متساويين وقياس نقطتين على كل نصف باستخدام مجهر رقمي وبرنامج معالجة الصور، وتم تحليل القراءات إحصائياً باستخدام اختبار ANOVA واختبار Duncan متعدد النطاق. **النتائج:** وجد اختلاف معنوي بين المجموعتين في كل من الفجوات الحاقية. أظهرت مجموعة تحت المعدن الصلب فجوات أصغر بكثير من المجموعتين الأخرين، بينما لم يتم العثور على فرق كبير في الملاءمة بين DMLS ومجموعات الصب التقليدية. وبالتالي، **الاستنتاجات:** ضمن حدود هذه الدراسة، وجد أن المواضع المطحونة من المعدن الصلب تتمتع بتوافق أفضل مقارنة بالمجموعتين الأخرين، ومع ذلك، فإن جميع المجموعات الثلاث بها فجوات ضمن النطاق المقبول سريرياً للتوافق الحاقى.

DOI: 10.33899/rdenj.2021.130791.1119 , © 2023, College of Dentistry, University of Mosul.

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INTRODUCTION

A good marginal seal is one important requirement for the long-term success of the prosthetic appliance ⁽¹⁾. A dental prosthesis with optimum marginal fit may decrease risks of biological drawbacks such as secondary caries and periodontal diseases by minimizing marginal food impaction, bacteria, and plaque formation ⁽²⁾.

The fit and misfit of crowns and metal copings, including how the fit is affected by the fabrication procedures has been widely investigated ⁽³⁾.

Using laser melting technique on single crowns and laser-sintered cobalt chromium crowns with a mean internal gap of 63 μm , a few investigations on the fit of prostheses produced in cobalt chromium alloy have shown marginal differences of 74–99 μm , with internal gaps ranging from 250 to 350 μm ^(1,3,4).

The lost wax method, which uses various metal alloys for casting, is the standard method for manufacturing the metal copings of porcelain fused to metal prostheses ⁽³⁾. Casting base metal alloys is technique-dependent, so trimming and finishing cast base metal alloys takes time in dental laboratories due to their high hardness ⁽⁴⁾.

Computer-aided design/computer-aided manufacturing (CAD/CAM) systems have been established to overcome the constraints of the traditional lost wax method. The direct metal laser sintering

(DMLS) system, which was recently created, is an additive metal fabrication method ⁽²⁾.

Metal powder is fired selectively and fused with a laser to laminate about a 20–60 μm thick layer with each shooting to build a metal structure based on information acquired from three-dimensional (3D) computer-aided design and using a data file ⁽¹⁾.

The DMLS technology has several advantages, including the ability to fabricate complicated structures quickly, the use of an automation system, and the removal of procedures such as wax pattern fabrication, investing, burn out, and casting. While traditional lost wax casting methods may waste metal during construction the sprues and other procedures, the DMLS technology could eliminate metal waste by choosing to fire the required amount. The expense of the equipment is one downside of the DMLS technology ⁽²⁾.

An ideal marginal fit promotes gingival health and prevents the luting cement from dissolving. A good interior fit improves the restorations' resilience to horizontal and vertical forces. The exact fit of any restoration is dependent on the long-term clinical success of implant-supported fixed prostheses. Any difference between the abutment and the restoration encourages bacteria to adhere, causing irritation in the soft tissues around

the implants and associated biological difficulties⁽⁵⁾. (Akçin *et al.*, 2018).

Marginal adaptation is an extremely important factor for long-term longevity and success of dental restorations^(6,7). (Grenade *et al.*, 2011; Karataşlı *et al.*, 2011).

For these reasons, numerous studies have been conducted on the marginal and internal fit of a prosthesis to determine its prognosis⁽⁸⁾. (Son *et al.*, 2019).

The goal of this in vitro study is to compare and assess the marginal fit of cobalt chromium copings made with traditional, CAM, and DMLS procedures.

MATERIALS AND METHODS

Selection of the abutment

An implant abutment (Dual Abutment, Dentium, South Korea) was chosen to be used as the standard abutment for the copings in this experiment.

The abutment was fixed on top of a block of self-curing acrylic resin (Figure 1) where the center of the abutment coincides with the center of the block. This was done by determining the interception point between the two diagonal lines drawn from each corner of the block. A surveyor was used to ensure the long-axis of the abutment was at 90 degrees, the abutment was fixed with glue until the cold cure resin reached complete setting.

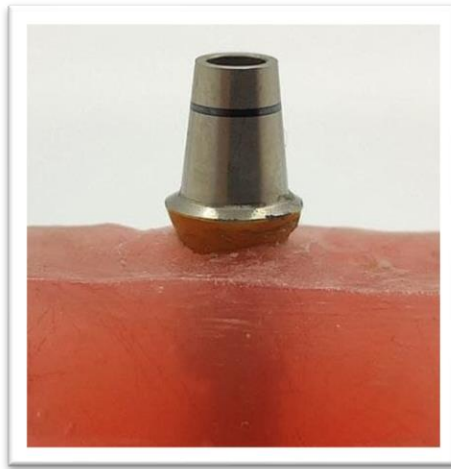


Figure (1): Implant Abutment on acrylic base

Taking the impression for master model

A plastic container was used to take an impression of the aforementioned abutment, the material used was addition silicone duplication material (Shera Duosil H, SHERA Werkstoff Technologie) ,

Germany). This material comes in two bottle system of semi fluid addition silicone, base and catalyst. The material was mixed according to the manufacturer's instructions to obtain a homogenous mixture, then the addition silicone was poured into the container in which the

abutment and the block were placed, a vibrator was used to ensure getting rid of all the trapped air bubbles because the material is in semi-fluid state and vibration was necessary.

The impression was left for 30 minutes until full setting had occurred, the block (with attached abutment) was removed, and type IV dental stone (Elite Stone, Zhermack, Italy) was used to pour the impression.

Scanning the master model

The produced stone model was scanned by 3D scanner (S600 ARTI , Zirconc Zahn , Germany) using the Zirconc Zahn scanning software (Zirconc Zahn Modeller) , and the 3D model was transferred to CAD software to design a standardized coping that is going to be used in manufacturing all of the copings used in this study. This model was used to avoid direct scanning of the metallic abutment as this procedure would have required the use of powder spray which was avoided for better standardization ⁽⁹⁾. (Lövgren et al., 2017) (Figure 2)



Figure (2): 3D Scan of the master model

The design properties were set to have a minimum metal thickness of 0.5 mm, with a cement gap of 0.050 μm, the cement gap was set to decline to zero on the margins of the copings ⁽¹⁰⁾. (Örtorp et al., 2011)

Fabrication of the copings

The fabrication techniques for the specimens to be studied in this research are the following: -

- Milled Wax technique: The conventional casting of milled wax patterns
- Hard Metal Milling: direct subtractive milling of hard Cobalt-Chrome
- Direct Metal Laser-Sintering: direct additive printing of Cobalt-

Chrome powder into the designed shape

An STL file of the finalized 3D design was sent to the laboratory to produce the 3 groups of specimens, each of the aforementioned techniques was used to produce 8 copings, with total of 24 copings.

Preparing the casts:

24 Impressions of the master model were taken with a 3D printed resin box that was used as a customized container to take the impressions and in which the impressions were poured to obtain the 24 duplications of the master cast. Addition silicone was used for the duplications. The 24 impressions were poured with type IV dental stone (Elite Stone) that is yellow in color to differentiate it from the first layer of the stone which was blue in color.

Testing Marginal fit:

“The perpendicular measurement from the internal surface of the casting to the axial wall of the preparation is called

the internal gap, and the same measurement at the margin is called the marginal gap”⁽¹¹⁾.

According to the definition, internal and marginal gaps of each coping was measured as in the following steps:

A-Seating of the copings:

Twenty-four impressions from the master model were poured with type IV dental stone (yellow color), copings were checked for proper seating then a luting agent was prepared, Zinc polycarboxylate (TGpolycem, UK), which was mixed according to manufacturer’s instructions, a micro brush was also used to spread the luting material evenly on the internal surface of the coping.

Each coping was seated with equal pressure (10 N). The pressure was controlled and standardized by utilizing an orthodontic force gague. (Figure 3). for an equal amount of time (120 seconds), which was sufficient for the luting cement to reach its initial setting time, as stated by the product leaflet.



Figure (3): An orthodontic force gauge used for seating of the coping

B-Boxing of the specimens:

After the setting had completed, the luted copings on the stone models were placed inside a 3D printed resin box, which

was custom made with determined dimensions where the center of the abutment -and the coping- coincides with the center of the box. Figure (4).



Figure (4): 3D printed resin box with determined dimensions

A layer of blue type IV dental stone was poured to bury the coping and create a block of dental stone with the coping imbedded inside, this block had fixed standardized dimensions to ensure a reproduceable sectioning of the blocks ⁽⁸⁾.

C- Cross-Sectioning the specimens

A cutting machine (Figure 5&6) was used to dissect the blocks at the midline to obtain two identical halves of each block, the block was held in place by fixing it on a die stone base which was held on magnet table fixed on the cutting machine. Each half of each specimen (total 48 halves classified into 3 groups) was cleaned with a soft brush to remove the debris and dust.



Figure (5): Cross-Sectioning the stone block with coping inside of it

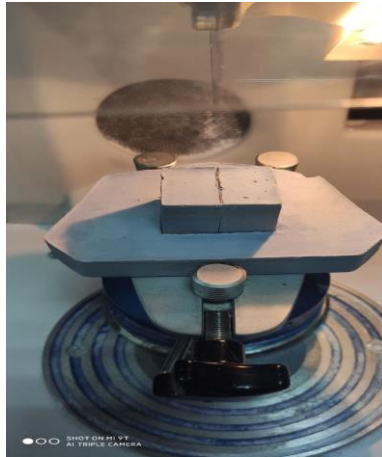


Figure (6): Cross-Sectioning the stone block with coping inside of it

D- Examination under microscope

Each half was placed under a digital microscope (Koolectron, China) to be examined, under the power of 40X magnification ⁽¹²⁾. (Beuer et al., 2009)

Two points in each half-block were examined and recorded using ImageJ image processing software ^(14,15). A software dedicated for image analysis, the used computer was Acer AN515, by Acer Inc., China.

The cement gap was measured on each point mentioned above and the reading in μm was recorded, the recorded

gap values were then transferred to statistical analysis.

RESULTS

Readings from the digital microscopy

The marginal gap of each specimen was calculated by taking two readings from each half of the block, resulting in 4 marginal gap readings for each specimen. The mean of these two readings was calculated and a single marginal gap value for each specimen was produced. So, we have 8 values from each group of copings (N=8). As shown in Table (1).

The measurement unit is the micrometer (1/1000 mm)

Table (1): Measurements of marginal gaps of the study specimens. Each value in the table is the mean of 4 marginal gap readings per specimen

	Mg C	Mg M	Mg L
1	61.0	53.8	66.5
2	79.0	61.8	73.2
3	78.7	55.5	78.3
4	59.7	42.8	76.2
5	61.6	53.4	76.5
6	77.7	50.2	59.9
7	88.9	59.7	64.7
8	66.5	60.6	72.0

Mg= Marginal gap; C= Casting Technique, M= Milling Technique; L= DMLS technique
All Values are in μm

Tests of Normality for marginal gap:

The obtained values were subjected to normality test; Shapiro-Wilk test, the

values were found to follow the normal distribution, shown in (Table 2).

Table (2): Tests of Normality

Groups	Shapiro-Wilk		
	Statistic	df	Sig.
MgC	.886	8	.217
MgM	.928	8	.502
MgL	.924	8	.460

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

Descriptive Statistics for marginal gap:

Descriptive statistics were applied to the three groups of values, according to the

experimental design of this study. Showing the means and the standard deviations and standards of errors. (Table 3)

Table (3) : Descriptive stats. For marginal gap calculation

	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
MgC	8	71.6375	10.83406	3.83042	59.70	88.90
MgM	8	54.7250	6.27028	2.21688	42.80	61.80
MgL	8	70.9125	6.54117	2.31265	59.90	78.30
Total	24	65.7583	11.14973	2.27593	42.80	88.90

MgC= Marginal gap of Cast Specimens; MgM= Marginal gap of Milled Specimens; MgL=Marginal gap of specimens produced by DMLS, All Values are in μm

Analysis of Variance (ANOVA) for marginal gap:

The one-way analysis of variance was applied to the values, the ANOVA test result showed significance at $P < 0.05$ in

marginal fit between groups; The Duncan's multiple range test was performed to further investigate this difference. (Table 4).

Table (4): One-way analysis of variance (ANOVA) test for marginal gaps.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1462.916	2	731.458	11.000	.001
Within Groups	1396.363	21	66.493		
Total	2859.278	23			

Duncan's Multiple Range Test for marginal gap

Duncan's Test Showed the marginal gap in Milling group was significantly

lower, there was no significant difference in the marginal gaps between DMLS copings & Cast copings (Figure 7).

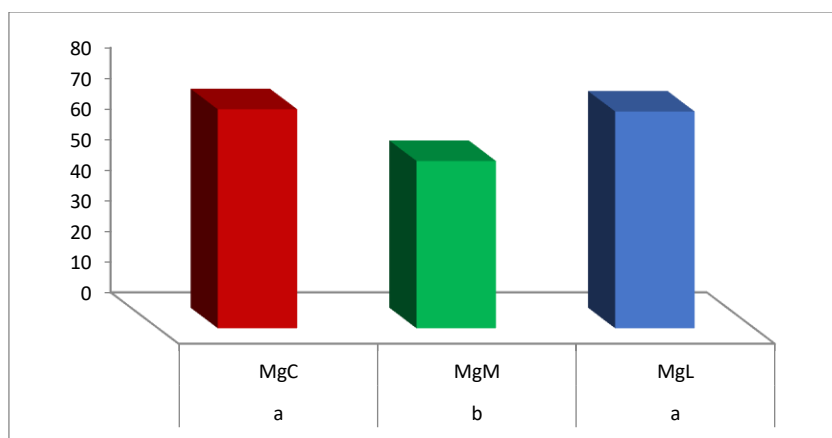


Figure (7) Duncan's test of Marginal Gap

MgC= Casting Technique, MgM= Milling Technique; MgL= DMLS technique

DISCUSSION

The results for marginal gap measurement or marginal fit in this research proved to be significantly superior in copings produced by milling of hard metal to those produced by the other two techniques, the DMLS and the conventional casting. While no significant difference was recorded in marginal gap between the DMLS & conventional copings.

Kim *et al.* (2014), consistent with this research, proved that the restorations

and metallic infrastructures have the best fit compared to conventional and the DMLS techniques, Kim *et al.* research used 3D analysis of the gaps between the restorations and abutments in vitro setting, a method that is considered among the more accurate methods ⁽¹⁵⁾.

Kim *et al.*, (2018), In a different study and a different team, also found the marginal fit of milled copings to be the best compared to other copings ⁽¹⁶⁾.

A clinical research was conducted in 2014 by Tamac *et al.* in which 42 single

crowns were examined found no significant difference in both marginal fit and internal adaptation of crowns produced by either DMLS or conventional casting. This is consistent with the results of this research. It was also reported that the cement gaps were larger in occlusal areas, another finding that is confirmed by this research⁽¹³⁾. Another clinical research by Quante *et al.* (2008), found the same result⁽¹⁷⁾.

As for the superiority in fit in milled metal copings, a study by Papadiochou & Pissiotis (2018), found no clear evidence to prove the superiority of milling to other conventional and DMLS techniques, but generally found that most restorations and infrastructures produced by CAM exhibited smaller discrepancies⁽¹⁸⁾.

Yang *et al.* (2021) found No statistically significant differences were found between single metal copings fabricated via selective laser sintering and lost-wax casting. Selective laser sintering - however- can satisfy the clinical requirement for single metal copings, which perfectly matches the conclusion of this research⁽¹⁹⁾. Same result was found by Huang *et al* in 2015.⁽²⁰⁾

Ullattuthodi *et al.*, (2017) found similar result to this research, as no significant difference was found between DMLS and conventionally manufactured copings in marginal gap, which agrees with this research in this particular part⁽²¹⁾.

Gaikwad *et al.* (2015) , in contrast to this research, found a significant

difference in marginal fit and axial fit between the conventional technique and the DMLS technique in favor of the latter⁽²²⁾.

Yildirim & Paken (2019), Disagree with this research regarding marginal fit as they found copings produced by milling to have larger gaps than copings manufactured by the other two techniques, However, they found the fitness to be better in the axial wall areas of the milled copings⁽²³⁾.

Despite all the agreements and disagreements in studies, and despite the significant differences and the superiority of hard metal milling that was found in this particular research, all the techniques proved to have a clinically acceptable marginal fit, McLean and von Fraunhofer (1971) reported that marginal discrepancies up to 120 μm were acceptable after clinically examining over 1000 metal ceramic crowns⁽²⁴⁾. Other clinicians considered a marginal fit of up to 100 μm to be clinically acceptable with regard to the longevity of the restorations (Kashani *et al.*, 1981)⁽²⁵⁾.

Declaration of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript

CONCLUSION

1. Marginal fitting in copings produced by hard metal milling is superior to those produced by conventional casting and DMLS technique.
2. There is no difference in marginal fitting and internal adaptation between copings manufactured by DMLS & conventional casting.
3. The results of all three groups show clinically acceptable marginal fit.

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