

Evaluation of Discrepancy in Marginal Adaptation of CO-CR Metal Copings Fabricated by Conventional Casting, CAD/CAM and Direct Metal Laser Sintering – A Comparative In-Vitro Study

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Abstract

Aim and Objectives: The purpose of this study was to assess and contrast the marginal fit of Co-Cr metal copings made using Direct Metal Laser Sintering (DMLS), CAD/CAM, and conventional casting.

Methodology: An in-vitro study was carried out using 30 metal copings (n=10 per group) fabricated via the three techniques. Standardized tooth preparations on a typodont model were used to produce final casts. Gaps at the margins were measured at fixed points i.e. buccal and lingual using a stereomicroscope. Data were analyzed using ANOVA and Tukey's post hoc test (SPSS v21).

Results: DMLS exhibited the least marginal discrepancy (22.05 μ m), followed by CAD/CAM (32.45 μ m), while conventional casting showed the highest (61.95 μ m). All the three groups were showing statistically significant differences ($p < 0.001$).

Conclusion: All techniques produced clinically acceptable results, However, DMLS showed the best marginal fit, followed by CAD/CAM, with conventional casting being the least accurate.

Keywords: DMLS, CAD/CAM, conventional casting, marginal fit, stereomicroscope.

INTRODUCTION

In restorative dentistry, fixed prosthodontics which includes dental crowns and fixed partial dentures (FPDs) is essential because it provides long-lasting treatments that restore both function and appearance.

With increasing awareness of biocompatibility and aesthetics, these restorations enhance chewing efficiency, appearance, and self-confidence while remaining comfortable and easy to maintain. Whether replacing single or multiple teeth, fixed prostheses provide reliable, long-term outcomes.

Fixed partial dentures are a widely accepted treatment for missing teeth, improving patient comfort, appearance, function, and self-esteem. The restorative dentist's primary objective is to meet these functional and aesthetic demands without compromising oral or general health.¹ A number of variables affect the clinical success of fixed restorations, including abutment integrity, bone support, material choice, and most importantly, marginal integrity. Clinical results and prosthesis longevity are enhanced by smaller marginal gaps, which lessen cement washout and gingival irritation.²

Marginal adaptation refers to how closely a restoration's edge conforms to the tooth contour. While perfect sealing is ideal, a gap of 100–120 µm is generally accepted to allow for cement thickness. Good marginal fit minimizes plaque buildup, recurrent caries, and periodontal disease. Several factors influence fit, including preparation type, cementation pressure, fabrication technique, and cement viscosity.³ Poorly fitting restorations, including those with over- or under-contoured margins, may foster bacterial accumulation, causing periodontal disease, gingival inflammation, or secondary caries⁴. Micro leakage can lead to pulpitis and reduce prosthesis strength due to internal stress concentrations.³ Conversely, a well-fitting prosthesis reduces such risks and ensures predictable results.

Metal-ceramic restorations remain a popular choice due to their strength and aesthetics. However, the fit accuracy of cast metal restorations and the choice of dental alloy are vital to their success.⁵ Nickel-chromium alloys are not as desirable as cobalt-chromium (Co-Cr) alloys due to their

biocompatibility and lower allergenic potential. Co-Cr alloys offer excellent mechanical properties, corrosion resistance, and cost-effectiveness.⁶

Traditional lost-wax casting, introduced by W.H. Taggart, remains common but is technique-sensitive and time-consuming. Several fabrication steps—from impression to casting—can introduce marginal discrepancies.⁷

Modern alternatives like Direct Metal Laser Sintering (DMLS) and CAD/CAM are designed to overcome these issues. CAD/CAM reduces manual error and speeds up production,⁸ while DMLS uses laser energy to fuse metal layers precisely, reducing material waste and improving fit. Despite clinical acceptance, limited studies compare marginal fits across these three fabrication methods. Hence, this study assesses the slight variations in Co-Cr copings produced by DMLS, CAD/CAM, and conventional casting. There is no discernible difference between these approaches, according to the null hypothesis.

MATERIAL AND METHODOLOGY

A. Study Design

This in-vitro experimental investigation was conducted to assess and contrast the marginal discrepancies of Co-Cr metal copings made using three techniques: conventional casting, CAD/CAM, and Direct Metal Laser Sintering (DMLS).

B. Sample Size Determination

Using G*Power software (Version 3.0.1, Franz Faul, Universität Kiel, Germany), a sample size of 30 was determined. These were divided equally and separated into three groups: Groups A and B were conventional casting (n = 10), CAD/CAM (n = 10), and group C was DMLS (n = 10).

C. Tooth Preparation

Standardized tooth preparation was carried out on the mandibular right first molar of typodont models. Occlusal reduction (1.5–2 mm) was done using a round-end tapered diamond bur, followed by shoulder and chamfer finish lines on buccal and lingual walls, respectively. All line angles were rounded and functional cusp bevels provided. The same technique was repeated for all 30 samples.

D. Final Impression and Cast Fabrication

Final impressions were made using vinyl polyether silicone in specially made trays made of acrylic resin that auto-polymerizes.

The Type IV die stone was used to pour the imprints, and the base was made of Type III dental stone. These casts were used to fabricate copings.

E. Coping Fabrication

Conventional Casting: Wax patterns were fabricated on the die with 1 mm die spacer from the margin. Patterns were invested, burnout performed, and Co-Cr alloy was cast using an induction casting machine. Copings were retrieved, completed, and refined. **(Figure 1)**



Figure 1: Metal copings fabricated by casting (n=10)

CAD/CAM: Casts then scanned, and coping designs were created using hyperDENT® software. Wax patterns were milled from wax blocks, cast in Co-Cr, and then finished and polished. **(Figure 2)**

DMLS: Digital scans were used to create 3D models. Copings were fabricated directly by laser sintering Co-Cr powder, followed by heat treatment and surface finishing. **(Figure 3)**



Figure 2: Metal copings fabricated by CAD/CAM (n=10)



Figure 3: Metal Copings fabricated by DMLS (n=10)

F. Marginal Gap Measurement

All copings were assessed under a stereomicroscope. Pre-marked buccal and lingual

reference points on the die were used to measure gaps with an image analyzer. Copings were not cemented to ensure standardization. **(Figure 4, 5)**



Figure 4: Stereomicroscope attached to image analyzer (Leica S9i Wetzlar, Germany)

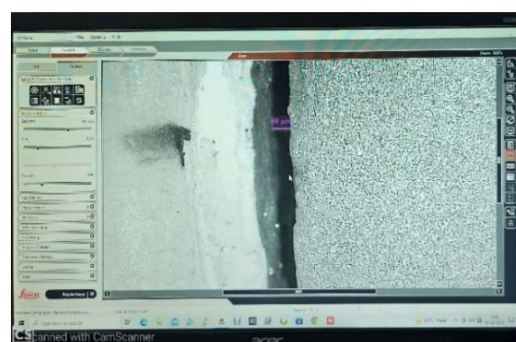


Figure 5: Evaluation of margin discrepancy under stereomicroscope

G. Statistical Analysis

Microsoft Excel was used to enter the data, while SPSS v21 was used for analysis. We computed the mean and standard deviation. Shapiro–Wilk test assessed normality. For intergroup comparison, a one-way ANOVA was employed, followed by Tukey's post hoc test.

RESULTS

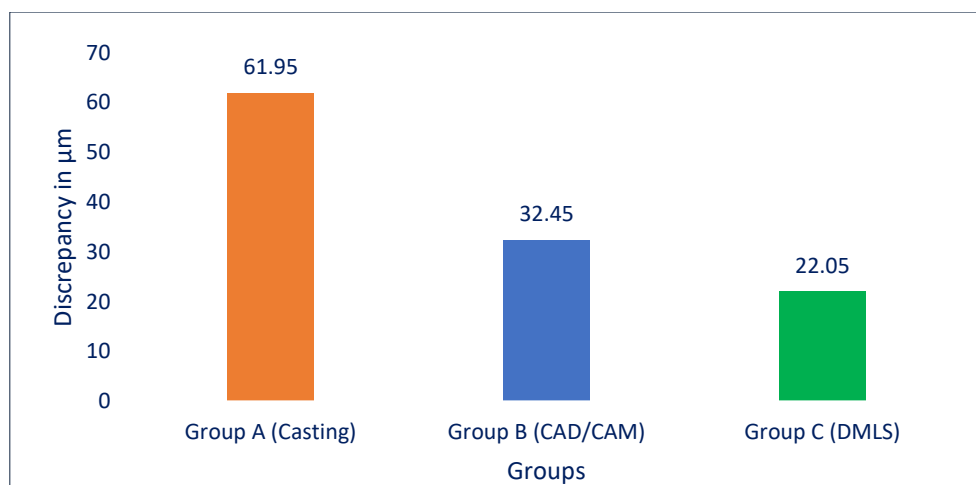
This in vitro investigation contrasted the marginal fit of 30 Co-Cr copings made using CAD/CAM, conventional casting, and DMLS. Each coping was evaluated at buccal and lingual sites using a stereomicroscope, and average marginal discrepancies were recorded.

The outcomes revealed that the highest mean marginal discrepancy was observed in Group A (conventional casting), with an average value of $61.95 \pm 4.70 \mu\text{m}$. Group B (CAD/CAM) showed a mean discrepancy of $32.45 \pm 5.38 \mu\text{m}$, while Group C (DMLS) demonstrated the least discrepancy, with a mean value of $22.05 \pm 7.36 \mu\text{m}$. (**Table 1, Graph 1**) Buccal sites consistently exhibited higher marginal gaps compared to lingual sites across all groups. Specifically, the highest buccal discrepancy was recorded in Group A ($65.2 \mu\text{m}$), followed by Group B ($40.2 \mu\text{m}$) and Group C ($25.4 \mu\text{m}$). Lingual discrepancies were generally lower, with values of $58.7 \mu\text{m}$, $24.7 \mu\text{m}$, and $18.7 \mu\text{m}$ for each of Group A, B, and C.

Table 1: The standard deviation and mean marginal discrepancy value for each of the three groups (A, B, and C).

GROUPS	MEAN	SD
Group A (Casting)	61.95	7.36
Group B (CAD/CAM)	32.45	5.38
Group C (DMLS)	22.05	4.70

Graph 1: Value of the mean marginal discrepancy for each of the three groups (A, B, and C).



Statistical analysis using one-way ANOVA showed a notable difference in marginal adaptation between the three groups ($p < 0.001$) (**Table 2**). Tukey's post hoc analysis verified that the variations between Group A and Group B (mean difference = 29.5 μm)

and between Group A and Group C (mean difference = 39.9 μm) were statistically significant ($p < 0.001$) (**Table 3**). However, the comparison between Group B and Group C showed no statistically significant difference (mean difference = 10.4 μm , $p > 0.05$).

Table 2: Overall comparison of standard deviation and mean marginal discrepancy value for each of the three groups (Groups A, B, and C) using One-way Anova F-test

SOURCE	SUM OF SQUARES	DEGREE OF FREEDOM	MEAN SQUARE	F	SIGNIFICANCE
BETWEEN GROUPS	8568.067	2	4284.033	121.927	$p < 0.001^{**}$
WITHIN GROUPS	948.675	27	35.136		
TOTAL	9516.742	29			

Table 3: Pairwise comparison of Mean Marginal Discrepancy value and standard deviation for all three groups (Group A, B and C) using Tukey's post hoc test.

GROUP	MEAN	SD	MEAN DIFFERENCE (SE)	P VALUE
Group A (Casting)	61.95	7.36	29.5 (2.65)	$p < 0.001^{**}$
Group B (CAD/CAM)	32.45	5.38		
Group A (Casting)	61.95	7.36	39.9 (2.65)	$p < 0.001^{**}$
Group C (DMLS)	22.05	4.70		
Group B (CAD/CAM)	32.45	5.38	10.4 (2.65)	$p = 0.002^*$
Group C (DMLS)	22.05	4.70		

Overall, the copings fabricated using DMLS showed the best marginal adaptation, followed by those fabricated using CAD/CAM. Conventional casting, though still widely used, resulted in the highest marginal discrepancies, which may compromise the longevity and clinical performance of the prosthesis. The results highlight the superior precision and consistency offered by digital fabrication methods, particularly DMLS, in producing metal copings with optimal marginal integrity.

DISCUSSION

In order to restore both function and appearance, crowns and fixed partial dentures (FPDs) are essential. Defined by GPT 10 as the branch concerned with non-removable artificial tooth replacements, it is a technique-sensitive field requiring high clinical and laboratory precision due to its irreversible nature. For restorations to be successful over the long run, marginal fit is essential. The marginal gap is defined as "the perpendicular measurement from the internal surface of the casting

to the axial wall of the preparation at the margin" by Holmes et al. (1989).⁹ Poor marginal adaptation can cause caries, periodontal disease, restoration failure, and reduced prosthesis longevity.¹⁰

The purpose of this study was to compare the little variations in metal copings made by three different methods: conventional casting (Group A), Computer- Aided Design / Computer- Aided Manufacturing (Group B), and DMLS (Group C). All groups were evaluated using a stereomicroscope, a non-destructive and accurate method widely supported in literature.¹¹ The findings revealed average marginal differences of 61.95 μm (Group A), 32.45 μm (Group B), and 22.05 μm (Group C), all within clinically acceptable limits (<120 μm).⁹

Conventional casting showed the highest marginal discrepancy, likely due to factors like wax distortion, material shrinkage, casting errors, and oxide formation. CAD/CAM and DMLS demonstrated superior fits due to reduced manual intervention, controlled fabrication, and advanced software-guided design.¹² DMLS, in particular, achieved the lowest discrepancy due to its precise, layer-by-layer sintering process of Co-Cr alloy, resulting in high-density restorations with minimal voids.⁴

Supporting studies include Gunsoy and Ulusoy (2016), who reported lowest marginal gaps with DMLS, followed by CAD/CAM and casting. Sharma et al. (2017) also found DMLS (27.9 μm) to outperform casting (40.4 μm). Harish et al. (2014) observed lower marginal gaps in laser-sintered copings (102.15 μm) than cast copings (176.57 μm). Similarly, Bhaskaran et al. (2013) reported the least marginal gap in DMLS (10.52 μm) over 3D printing and casting.¹³

However, contrasting results were observed in some studies. Park et al. (2015) found lower gaps in casting (36.96 μm) than CAD/CAM (63.01 μm) and DMLS (70.98 μm), while Vojdani et al. (2013) also reported superior fit with conventional casting.^{6,7} Variability in scanner accuracy, software algorithms, and fabrication hardware could explain these discrepancies.

Though ADA suggests an ideal marginal gap under 25 μm , clinical studies accept a range between 50–120 μm depending on location and method.^{3,9} The present study's findings affirm that while all methods produced clinically acceptable results, DMLS offered the most accurate marginal fit, followed by traditional casting and CAD/CAM.

CONCLUSION

The following conclusions were reached within the parameters of this investigation:

1. All three fabrication techniques—DMLS, CAD/CAM, and conventional casting—produced Co-Cr copings with marginal discrepancies between 100 and 120 μm , which is the clinically acceptable range.
2. Significant disparities were found between traditional casting and both Computer- Aided Design / Computer- Aided Manufacturing (29.5 μm) and DMLS (39.9 μm), while the difference between CAD/CAM and DMLS (10.4 μm) was minimal.
3. DMLS showed the least marginal discrepancy (22.05 μm), followed by CAD/CAM (32.45 μm), with conventional casting showing the highest (61.95 μm).
4. DMLS offers superior accuracy and reduced human error, making it the most effective method for fabricating well-fitting Co-Cr copings.

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