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"Marginal Fit and Flexural Strength of Cobalt Chromium Crowns Fabricated By CAD/CAM Method And Direct Metal Laser Sintering(DMLS) Method": In Vitro Comparative Study

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ABSTRACT

Background: Cobalt-Chromium (Co-Cr) alloy, known for its strength and corrosion resistance, is widely used in dental crowns due to its biocompatibility and low cost. Traditional crown-making methods are being replaced by advanced techniques like Computer Numerical Control Milling (CNCM) and Direct Metal Laser Sintering (DMLS). CNCM carves crowns from metal blocks, while DMLS builds them layer by layer. This study compares the marginal fit and flexural strength of Co-Cr crowns made by CNCM and DMLS, as these factors affect crown performance and clinical success.

Aim: Comparative evaluation of marginal fit and flexural strength of cobalt chromium crowns fabricated by CAD/CAM method and direct metal laser sintering (DMLS) method.

Materials and methods: Using a standardized in vitro model, we assessed: (1) marginal adaptation at four surfaces (mesial, buccal, distal, lingual) via microscopic measurement, and (2) mechanical performance through maximum load and flexural strength testing. Statistical analysis incorporated normality testing Shapiro-Wilk, independent t-tests ($\alpha=0.05$), and descriptive statistics, with non-parametric alternatives where appropriate ($n=10$/group).

Result: DLMS crowns outperformed CNCM crowns in all tested areas, showing significantly better marginal fit, higher flexural strength, and greater force resistance, all with strong statistical significance ($p=0.001$). This suggests DLMS crowns offer better adaptation, durability, and structural integrity.

Conclusion: The study strongly supports using DLMS over CNCM for dental crowns, showing better fit, strength, and durability. DLMS offers higher quality restorations, though further clinical research is advised.

I. INTRODUCTION

Cobalt-Chromium (Co-Cr) alloy, developed in the early 1900s, is known for its strength, heat resistance, corrosion resistance, and biocompatibility. Its high elasticity allows for strong yet lightweight structures. Widely used in dentistry, especially for crowns on damaged or treated teeth, Co-Cr's physical properties are key to the long-term success of dental restorations[1-3].

The traditional lost-wax technique for dental restorations has limitations in crown fit and strength, affecting long-term success. Poor marginal fit can lead to cement failure, decay, and gum issues[1-10]. Newer technologies like DMLS and CAD/CAM milling offer improved accuracy and strength, addressing the drawbacks of conventional casting methods[11].

Since the 1980s, CAD/CAM systems have advanced dental restoration by enabling two main techniques: milling (subtractive) and 3D printing (additive). Milling offers accuracy and uniformity but struggles with complex tooth shapes, requiring digital scanning. 3D printing is increasingly popular for producing high-quality crowns more quickly, cost-effectively, and with fewer remakes, making it a strong alternative to traditional methods[12-15].

DMLS (Direct Metal Laser Sintering) is a 3D printing process that uses a high-power laser to fuse metal powders, like chromium cobalt alloys, into complex components directly from CAD designs[16-18]. In dentistry, a tooth impression is scanned, a crown or bridge is digitally designed and then produced layer by layer using DMLS. Multiple prostheses can be made at once, with each crown taking about three minutes[19-23].

DMLS is a superior alternative to traditional casting, offering greater precision and consistency through scanning and CAD design. It ensures standardized coping, pontic, and cement thickness, while laser sintering delivers accurate, distortion-free frameworks with improved marginal fit[24-30].

II. MATERIALS AND METHOD

Materials and Equipments used in the study:

- Typodont with set of maxillary and mandibular teeth
- Tooth preparation bur
- Rim lock impression trays
- Heavy body and Light body Polyvinyl siloxane impression material
- Type IV die stone
- Laboratory scanner (Medit Scanner, Korea)
- Milling unit(cerec)
- Lab sintering unit (Densply sirona)
- Universal testing machine
- Marker

Study Sample and size: -

- Study sample: Mandibular first right molar on typodont
- Sample Size: 40
- 10 crowns fabricated by computer numerical control milling (CNCM).
- 10 crowns fabricated by direct metal laser sintering (DMLS).
- 10 bars fabricated by computer numerical control milling (CNCM).
- 10 bars fabricated by direct metal laser sintering (DMLS).

Figure 1 CNCM crowns and DMLS crowns

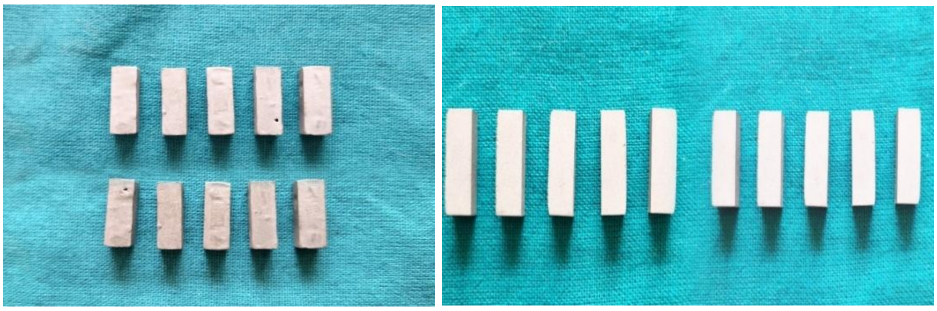

Figure 2 CNCM bar and DMLS bar

Eligibility Criteria:

Inclusion criteria

- Biomechanically prepared mandibular first right molar for Co-Cr crown.
- Polyvinylsiloxane impression of prepared mandibular 1st right molar.
- Die stone cast with no porosities or bubbles.
- Complete scans of Die Stone cast using laboratory scanner.
- Fabrication Standards: Specimens must meet exact dimensional tolerances (±0.1mm) verified by digital calliper. Only specimens milled using the standardized CAD/CAM protocol Crowns must demonstrate complete marginal continuity upon visual inspection (10× magnification)

• Quality Control: Specimens passing initial visual inspection for surface defects

• No visible cracks or porosity under 10× magnification

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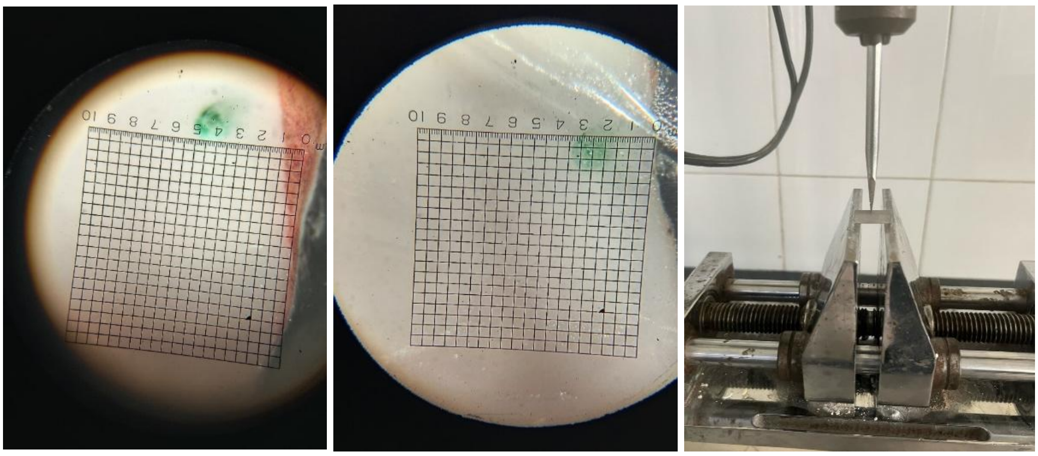

Figure 3 Measuring of marginal fit of CNCM crown and DMLS crown from stereomicroscope with grid lens and Universal testing machine

Exclusion Criteria: -

- Material Defects: Any specimens showing visible bubbles, inclusions, or inhomogeneities. Contaminated material blocks . Expired or improperly stored materials
- Fabrication Errors: Specimens with dimensional deviations >0.1mm from specifications. Milling artifacts affecting critical measurement surfaces o Improperly seated crowns with rocking motion >50µm
- Handling Damage: Specimens with post-fabrication surface damage . Contaminated or improperly stored test samples . Any specimen dropped or mishandled during processing

STATISTICAL ANALYSIS

Data was entered into Excel, summarized with tables and graphs, and analyzed using SPSS v21. The Shapiro-Wilk test confirmed normal distribution, allowing the use of inferential statistics. An independent t-test was used for intergroup comparisons, with significance set at $p < 0.05$

Table 1 Intergroup Comparison of Marginal Fit

Area	GROUP	N	Mean	Std. Deviation	Std. Error Mean	P VALUE
Mesial	DLMS CROWN	10	0.5865	0.24807	0.05547	0.001
	CNCM CROWN	10	1.0225	0.39818	0.08904	
Buccal	DLMS CROWN	10	0.0000	0.00000	0.00000	0.001
	CNCM CROWN	10	0.5500	0.25803	0.05770	
Distal	DLMS CROWN	10	0.7020	0.16741	0.03743	0.001
	CNCM CROWN	10	1.0450	0.23278	0.05205	
Lingual	DLMS CROWN	10	0.2525	0.13564	0.03033	0.001
	CNCM CROWN	10	0.5775	0.37679	0.08425	

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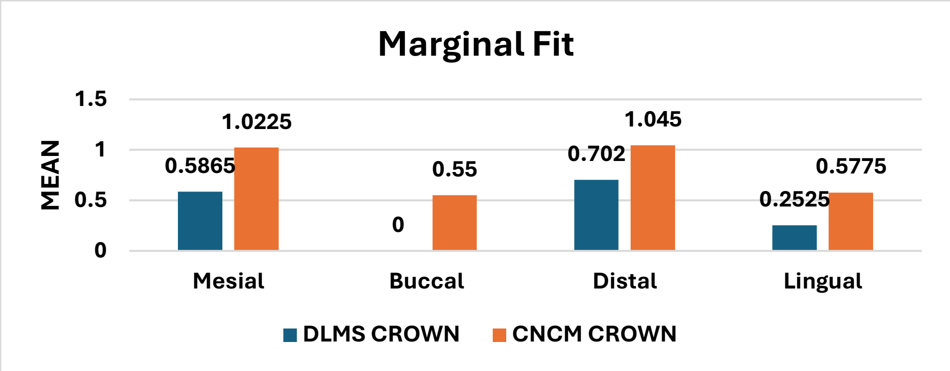
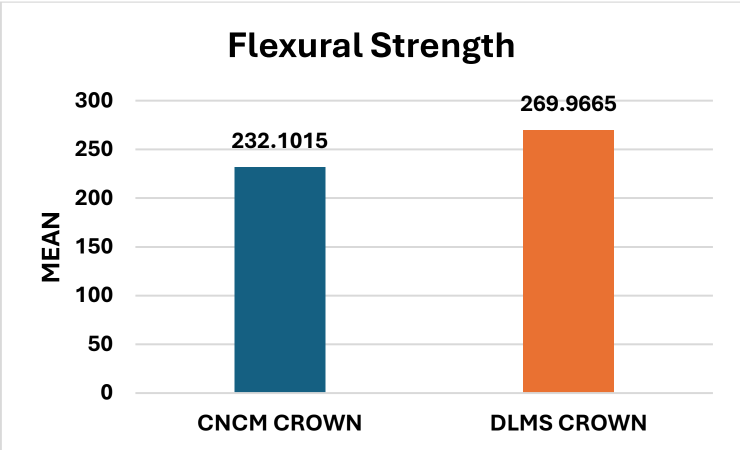


Graph 1 Marginal fit of CNCM crown vs DMLS crown

Table 2 Intergroup Comparison of Flexural Strength

GROUP	N	Mean	Std. Deviation	Std. Error Mean	P VALUE
CNCM CROWN	10	232.1015	10.04609	2.24637	0.001
DLMS CROWN	10	269.9665	10.12820	2.26474	



Graph 2 Flexural Strength of CNCM bar vs DMLS bar

III. RESULT

Intergroup Comparison of Marginal Fit

The comparison of marginal fit between DMLS and CNCM crowns showed significant differences across tooth surfaces. CNCM crowns had a higher (worse) mean marginal gap on the mesial side, while DMLS crowns had a perfect fit on the buccal side. DMLS crowns also showed better marginal fit on the distal and lingual sides. Overall, DMLS crowns demonstrated significantly better marginal adaptation than CNCM crowns in most areas.

Intergroup Comparison of Flexural Strength

When comparing the flexural strength between the two types of crowns, DLMS crowns demonstrated superior performance with a mean flexural strength of 269.9665 ± 10.12820 MPa compared to CNCM crowns, which had a mean of 232.1015 ± 10.04609 MPa. The p-value of 0.001 indicates a statistically significant difference, with DLMS crowns having greater flexural strength, suggesting they may be more durable under stress

IV. DISCUSSION

Cobalt-Chromium (Co-Cr) alloys, known for their strength, corrosion resistance, and biocompatibility, are widely used in dental restorations. Traditional lost-wax casting methods face limitations in precision and strength, which affect clinical outcomes. Advanced digital methods like CAD/CAM milling and Direct Metal Laser Sintering (DMLS) offer improved accuracy and performance.

This study compared the marginal fit and flexural strength of Co-Cr crowns fabricated using CNC milling (CNCM) and DMLS. Results showed that

DMLS crowns consistently outperformed CNCM crowns in most areas:

- **Marginal Fit:** DMLS showed significantly better fit on mesial, distal, and lingual surfaces. However, CNCM performed slightly better on the buccal side in this study, though DMLS still had excellent results overall.
- **Flexural Strength:** DMLS crowns had a significantly higher mean flexural strength (269.97 MPa) than CNCM crowns (232.10 MPa).
- **Force Resistance:** DMLS crowns withstood higher loads (2110.11 N) compared to CNCM (1812.78 N), indicating better durability under chewing forces.

DMLS's layer-by-layer additive process contributes to fewer internal flaws, better material homogeneity, and superior mechanical properties. While both methods are clinically viable, **DMLS offers clear advantages in strength, fit, and long-term performance**, making it a preferred choice for complex or high-stress restorations. Further clinical studies are recommended to evaluate long-term outcomes.

V. CONCLUSION

With the limitations of the current study, the following conclusions were drawn based on observation done during the course of the study:

1.The Direct Metal Laser Sintering (DMLS) technique exhibited higher flexural strength than the Computer Numerical Control Milled (CNCM) techniques

2. The Direct Metal Laser Sintering (DMLS) crowns generally demonstrated superior marginal fit on most surfaces, over CNCM crowns.

Thus, the crowns fabricated with DMLS technique overcomes casting failures has a promising approach for future high performance dental restorations.

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