TO EVALUATE THE MARGINAL FIT OF METAL COPINGS FABRICATED BY CONVENTIONAL CASTING PROCEDURE AND DIRECT METAL LASER SINTERING TECHNOLOGY – AN IN VITRO STUDY

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ABSTRACT

Purpose: The purpose of this in vitro study was to evaluate marginal fit of cobalt-chromium (Co-Cr) copings fabricated by direct metal laser sintering system (DMLS) and conventional lost-wax technique (LW). **Materials and method:** Forty tooth preparations were carried out over extracted mandibular molars. They were divided into two groups A and B of 20 each. For group A Co-Cr copings were fabricated by direct metal laser sintering (DMLS) and for group B by lost wax technique (LW). Glass-ionomer cement (GIC) was used to tack the copings over their preparations. Marginal fit was then evaluated directly under the stereomicroscope. **Results:** The mean marginal gap of group A was $27.9 \pm 2.4 \mu\text{m}$ and group B was $40.4 \mu\text{m}$. Statistical analysis using t-test showed highly significant difference ($P > .05$) between the marginal mean of the DMLS (group A) compared to LW (group B). **Conclusion:** The DMLS copings demonstrated superior marginal fit compared to that of conventional Co-Cr casted copings.

Keywords: Cobalt Chromium, Direct metal laser sintering, Porcelain fused metal crowns

INTRODUCTION

Metal fused to ceramic prosthesis is still the most widely used restoration material for fabricating complete coverage crowns and partial fixed dental prostheses.¹ A porcelain fused to metal prosthesis is made by sintering layers of porcelain over metal coping. An essential factor for the success of a metal-ceramic fixed dental prosthesis is marginal fit of the metal coping.^{2,3} Excessive marginal discrepancy for crowns increases cement dissolution and microleakage and can cause inflammation of the vital pulp.⁴ Poor marginal adaptation of crowns increases plaque retention,^{5,6} changes the composition of the subgingival microflora,⁷ and can result in the onset of periodontal disease.

Casting of metal copings has traditionally been carried out by lost wax (LW) technique given by Taggart in 1907. Initially noble alloys were used for fabricating metal copings because of their ease of use and biocompatibility.⁸ However with time manufacturers shifted to less costly alternatives like the base metal alloys. Casting of all base metal alloys is more technique sensitive compared to casting of noble alloys because of their high melting range and oxidation of base metal alloys during casting.⁸⁻¹¹ In addition, due to their high hardness, grinding of base metals especially Co-Cr alloys, to finish castings is comparatively time consuming for dental laboratories.¹² Such limitations of casting procedures has led to introduction

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of direct metal laser-sintering (DMLS) system to dentistry.

The newly developed direct metal laser-sintering (DMLS) system is a rapid prototyping method for fabricating metal products directly from computer-aided design (CAD) data. Automated fabrication is accomplished layer-by-layer by selectively fusing together metal powders with the help of a laser beam. Advantages of the DMLS system include ease of fabrication, use of fully automated system, and comparatively shorter working time.³ Also, metal copings fabricated with DMLS have been reported to have satisfactory mechanical and chemical properties.¹³⁻¹⁶

While an essential condition for a successful dental prosthesis is good marginal fit, there is little data on the marginal fit of fixed dental prostheses (FDPs) fabricated by the DMLS system.^{3,8,17-21}

The purpose of this *in vitro* study was to evaluate and compare the marginal fit of Co-Cr copings, fabricated by direct metal laser-sintering technology and conventional lost wax technique. The hypothesis for the study was that marginal fit of copings fabricated with both the techniques i.e. DMLS and lost wax technique would be same.

MATERIAL AND METHOD

Forty caries-free natural mandibular molars, extracted for reasons other than the study, were selected. They were cleaned and stored in 0.1% thymol solution (Amrit chemicals Ltd, India) at room temperature throughout the course of the study, to prevent them from drying and becoming brittle. Each tooth was mounted over self-cure acrylic resin mount (Self cure, DPI, India).

Tooth preparation and Die Fabrication

The tooth preparation of all the forty specimens was done following standard preparation protocol,²² using a high-speed angled handpiece and diamond rotary cutting instruments under water cooling. A 1.2 mm wide, smooth, continuous, shoulder

finish line was prepared, 2 mm above cemento-enamel junction and an occlusal reduction of 1.5 mm was done (Figure 1). The convergence angle of the preparation

Figure 1: Prepared teeth

corresponded to the convergence angle of diamond rotary cutting instrument. New diamond bur was used for every tooth preparation. To control the amount of tooth reduction while doing tooth preparation silicone putty index (Putty, 3M EPSE, Germany) was used and a periodontal probe was used to gauge the tooth reduction. Impressions were made for each sample in custom tray fabricated with self cure resin (DPI) using medium-body polyvinyl siloxane impression material (Aquasil Monophase, Dentsply, USA). Dies were poured in type IV die-stone (Kalrock, Kalabhai, India) (Figure 2). Specimens were then divided into two

Figure 2: Stone Dies

groups (A&B) of twenty sample each over which copings with direct metal laser sintering and conventional casting were fabricated.

Fabrication of copings

GROUP A consisted of copings fabricated by DMLS technology. All 20 dies (A1-A20) were first scanned by an optical scanner (Lava Scan ST scanner, 3M ESPE Lava, Germany). The scanner software program converted the data points into 3D CAD data to form a digitalised die. In the CAD process (Figure 3), coping

Figure 3: Formation of wax pattern using CAD on digitalized die of group A

thickness was set at 0.5mm, cement thickness 30 μ m, starting at 0.5 mm above the margin. The 3D CAD data was then sent to a fabrication center where, 20 Co-Cr alloy (SP2 powder - Co: 61.8-65.8, Cr: 23.7-25.7, W: 4.9-5.9, Mo: 4.6-5.6, Si: 0.8-1.2, Fe: max 0.5, Mn: max 0.1) copings were completed using the DMLS equipment (EOSINT M270). Each coping was subsequently sandblasted with 125 μ m aluminum oxide at a pressure of 3 bar.

GROUP B consisted of conventional Cobalt-Chromium (Co: 64, Cr:28, W: 5.3, Mo: 5.1 Si: max 1.0, Fe: max 1.0, Ce: max 1.0 ; Wirobond C+; Bego Dental) copings fabricated by lost wax technique. All 20 dies (B1-B20) were treated with a die hardener (Han Dae Chemical Co.LTD, Korea) applied in 2 steps without creating a visible surface layer. After drying, 3 coats of die spacer (Han Dae Chemical Co.LTD, Korea) were applied within 0.5 mm of the margin. The wax pattern

was fabricated with a dip-wax technique (Blue inlay wax, Bego, Germany) and a subsequent readaptation of the margin with the sealing wax. **Iwanson's wax thickness measuring gauge** was used to confirm the thickness of each coping to be 0.5 mm.

Each wax pattern was directly connected with a wax sprue (Bego, Germany) 3-mm in diameter and 6 mm in length to the base of the sprue former. Wax patterns were invested in a phosphate bonded investment (Bellasum, Bego, Germany) in metal casting rings lined with cellulose acetate ring liner, following the powder/liquid ratio as recommended by manufacturer. After a setting time of 60 minutes casting ring was kept in preheated furnace at 250°C for 30-60 min and then heated up to final temperature of 900°C maintaining for 30- 60min. The casting of Co-Cr alloy (Co: 64, Cr:28, W: 5.3, Mo: 5.1 Si: max 1.0, Fe: max 1.0, Ce: max 1.0 ; Wirobond C+; Bego Dental) was carried out in induction casting machine. They were then bench cooled, divested and air-abraded with 50 μ m aluminum oxide particles and separated from the sprues using a carborundum disc. Airborne particle abrasion was repeated externally and internally with 150- μ m aluminum oxide and at 3-bar pressure.

Marginal Fit Measurements

The marginal fit was measured as the gap between the external edge of metal coping and the tooth preparation limit. Before measuring, each coping was luted on its respective tooth preparation (Figure 4) with

Figure 4: Copings luted over respective prepared tooth

minimum amount of GIC (Glass Ionomer, GC Corporation, Japan) applied over the occlusal surface of the prepared tooth and secured with finger pressure for 3 min.²³ The marginal gap was then examined using stereomicroscope $\times 40$ (Magnus, Olympus, Tokyo, Japan), and digital images were captured at each of the four surfaces mesial, distal, buccal and lingual. The flat base of the specimens along each surface prevented the specimens from moving and kept each surface perpendicular to the objective lens. Using image analysing software, five measurements were made at each of the four positions (Figure 5, 6) for a total of 20 measurements per coping.

Figure 5: Marginal gap measurement for Group A using stereomicroscope

Figure 6: Marginal gap measurement for Group B using stereomicroscope

RESULTS

In total 800 marginal gap measurements were made for all the samples. The mean marginal gap values for each specimen of group A and group B are given in the table I and table II. The over all mean marginal gap of group A was $27.9 \pm 2.4 \mu\text{m}$ and group B was $40.4 \pm 6 \mu\text{m}$ (Table-III & Graph-I). Statistical analysis using t - test showed (Table VI) highly significant difference between the overall mean marginal gap of group A compared to group B.

Table 1: Results for Group A

GROUP A (DMLS)	MEAN MARGINAL GAP	STANDARD DEVIATION	MAXIMUM	MINIMUM	MEDIAN
A1	25.3605	5.23	35.18	16.15	25.155
A2	29.732	6.906	39.96	19.42	31.09
A3	27.663	6.852	40.1	17.63	29.24
A4	24.602	4.637	34.71	15.67	23
A5	25.898	6.157	36.83	17.49	24.33
A6	26.814	5.838	35.99	17.11	27.64
A7	24.48	4.652	34.56	17.68	23.2
A8	24.62	4.2173	34.23	16.11	24.195
A9	29.551	6.141	38.96	19.56	30.83
A10	30.518	5.130	39.75	23.17	29.06
A11	27.17	4.37	37.89	20.87	26.17
A12	27.12	5.186	37.66	19.34	26.045
A13	27.53	4.460	37.84	21.56	27.085
A14	28.423	4.893	38.91	21.31	28.825
A15	30.861	5.239	39.88	21.34	31.995
A16	33.455	5.756	42.88	21.56	32.77
A17	28.997	5.758	38.91	18.91	29.155
A18	26.889	4.243	36.67	19.47	26.28
A19	29.492	4.811	39.65	19.23	28.96
A20	29.414	6.022	41.67	21.56	29.165

Table II: Results for Group B

GROUP B (LW)	MEAN MARGINAL GAP	STANDARD DEVIATION	MAXIMUM	MINIMUM	MEDIAN
B1	51.168	10.066	68.12	34.56	49.17
B2	53.818	12.25	78.56	32.87	53.215
B3	48.842	13.662	76.87	30.11	49.15
B4	42.165	17.334	77.85	19.78	38.42
B5	41.164	9.395	56.78	25.56	38.775
B6	34.128	5.457	39.76	22.34	35.83
B7	40.17	12.291	67.14	23.45	37.235
B8	45.155	9.231	67.45	32.11	42.99
B9	36.218	6.723	47.28	25.11	36.55
B10	42.84	8.105	58.34	30.17	40.31
B11	42.242	14.513	68.45	22.11	39.225
B12	35.257	5.999	49.43	23.11	36.455
B13	31.651	7.139	40.43	20.11	32.785
B14	32.892	5.095	43.99	21.99	32.32
B15	39.173	14.085	78.87	20.9	36.27
B16	36.273	6.952	48.97	23.11	37.715
B17	35.109	10.781	55.78	18.99	33.46
B18	38.678	7.308	48.56	24.76	38.17
B19	44.717	10.599	66.89	29.57	41.705
B20	37.756	10.068	67.45	25.77	37.56

Table III: Overall mean marginal gap of Group A and Group B

	GROUP	N	Mean	Std. Deviation	Std. Error Mean
MARIGNAL GAP	A	20	27.93	2.36438	0.529
	B	20	40.47	6.04445	1.351

Table IV: Comparison of mean marginal gap of Group A with Group B using independent t-test

Independent Samples Test						
t-test for Equality of Means						
T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
-8.6	24.681	<.001**	-12.54	1.451	-15.53	-9.55

Graph I: Bar graph depicting mean marginal gap of Group A and Group B

DISCUSSION

Precise marginal fit is one of the most important criteria for the long term success of FPD's.⁸ The marginal discrepancy of metal copings may depend on several factors, such as, margin design configuration, type of alloy used, casting procedures, and subsequently cementation. Among these, casting is highly technique-sensitive, requiring qualified technicians, control of the wax pattern fabrication and investing procedure, and careful attention during the casting process.²⁴ Many procedures are required to

execute this process, which increases the possibility of mistakes affecting the accuracy and fit of copings made. To overcome these flaws, a new additive technique for forming the metal substructures has been introduced. Direct Metal Laser Sintering (DMLS) is a promising new technology that may avoid the distortions inherent to casting procedures.²⁵ The CAD process of producing copings by DMLS technique using automated scanning process and powerful CAD software offers many advantages such as complete control over the framework and coping designing, margin placement and cement space maintenance. To date, very few studies have been published on the marginal fit of FPD's made by DMLS. Therefore, this study was carried out to assess the marginal fit of metal copings made by new DMLS technique compared with conventional casting procedure.

Co-Cr was used to fabricate the metal copings in the study, because currently they are used more commonly than Ni-Cr alloys for fixed prosthesis. Electrochemical studies show that Co-Cr alloys are more resistant to corrosion than Ni-Cr alloys. Nickel based alloys have a greater sensitization potential than cobalt-chromium alloys, whereas Co-Cr alloy allergies are rare.^{12,24}

The clinical objective is to have the lowest marginal gap that still allows proper seating of the coping. All marginal fit values obtained for both the techniques in this study were within clinical permissible limits, that is, $120\mu\text{m}$ ²⁸. The marginal fit of 20 samples of DMLS technique varied between 24-33.5 μm as compared to conventional casting whose marginal fit varied from 34-54 μm . This shows that consistent and better marginal fit values can be obtained with the DMLS technique. The comparison of overall mean marginal fit of copings made by DMLS technique was significantly superior to that of LW group ($p>0.001$). This is in accordance to the findings of Ortop *et al*, Huang *et al*. and Xu *et al*.²¹ who recorded lower discrepancies for laser sintered Co-Cr than for cast Co-Cr.^{11,18} Li *et al* observed 220 metal crowns for 24 months in order to evaluate the clinical effect of laser sintered

Co-Cr and cast Co-Cr metal crowns and found that laser sintered Co-Cr metal crowns resulted in better marginal fit than cast Co-Cr metal crowns.²⁹

DMLS technique has its further advantages like less time in fabrication and a uniform thickness of metal coping. Reducing the technicians work in adjusting the coping to desired thickness and a uniform thickness of ceramic layer can be added.

DMLS is a relatively new method compared to conventional casting procedure. The use of CAD/CAM prosthetic frameworks may rely on the precision of the scanner that reads the abutments, on the ways in which the software can transform the scanning data into a 3D model on the computer, and on the accuracy of the machine that uses CAM to produce objects from the CAD data.⁸ The use of the DMLS technology may result in the most predictable fabrication method under the tested experimental conditions. However, clinical implementation of the DMLS system seems to require further investigation, because studies of restoration longevity are scarce.

LIMITATIONS OF THE STUDY

The tooth preparations for all the 40 specimens were carried out manually to simulate the oral environment which may have incorporated operator errors, but the preparations closely simulated the clinical conditions.

CONCLUSION

Within the limitations of this *in vitro* investigation, the following conclusions were drawn:

1. Both the casting techniques exhibited different results, disproving the null hypothesis.
2. Copings fabricated with DMLS technique had better marginal fit when compared to copings fabricated from conventional lost wax technique.

The reference drawn from this study strongly suggests use of DMLS technique in place of conventional lost wax technique to fabricate copings for FPD in routine dental practice.

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