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Comparative Evaluation of Marginal Fit of Copings Fabricated By Two Different Techniques with Two Different Finish Lines- An Invitro Study

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Abstract:
Background: *Marginal fit plays an important role in the long-term success of restorations. Inadequate marginal adaptation of the crown to abutment leads to vertical or horizontal discrepancies which are detrimental to tooth and cause failure of the prosthesis. Traditionally, metal copings were fabricated by lost wax technique. Advancements in dental technology led to development of sophisticated methods like direct metal laser sintering (DMLS) for casting metal crowns. There is limited data on marginal fit of fixed prosthesis fabricated by direct metal laser sintering technology. We aimed to evaluate and compare the marginal fit of metal copings fabricated by conventional and DMLS techniques with two different finish lines.*
Materials and Methods: *In this in-vitro study, two cobalt chromium alloy models of mandibular first molars with chamfer and radial shoulder finish lines were fabricated by CAD/CAM. Elastomeric impressions of these models were made in a custom tray, and poured in Type IV Gypsum. Twenty metal copings each were fabricated using conventional lost-wax method and DMLS; half of them were given chamfer and the other half radial shoulder finish lines. Thus, four groups with 10 copings each were obtained. The metal copings were seated onto their respective gypsum models and stabilized using a custom-made device. The marginal gap of the copings was measured at predetermined points (mid buccal, mid mesial, mid lingual, mid distal) using a stereomicroscope.*
Results: *Copings fabricated by DMLS technique showed a lesser marginal gap compared to copings fabricated by the conventional technique ($p < .001$ for both chamfer and radial shoulder finish lines). Copings with chamfer and radial shoulder finish lines fabricated by same technique had no statistically significant difference ($p = .143$ for conventional and $p = .959$ for DMLS techniques).*
Conclusion: *Though results obtained fell within the clinically acceptable range, the DMLS copings exhibited minimal marginal gap. This is important because the drawbacks of conventional casting procedures are eliminated in DMLS apart from yielding promising results.*
***Key Words**: CAD/CAM, DMLS, Stereomicroscope, Marginal gap, co-cr copings, Chamfer, Radial shoulder.*

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I. Introduction

Cast metal restorations have been used to replace missing tooth structure for more than a century now. Accuracy of marginal fit regulates their longevity[1], failing which, microleakage and cement breakdown induce periodontal problems around the restored teeth [2]. Of the several clinical and laboratory determinants, finish line geometry and casting technique are two major factors that influence the marginal integrity greatly [3,4].

Finish lines must be distinct, smooth, and follow the alveolar bone form. Chamfer and radial shoulder are commonly used in metal-ceramic preparations, with a good biomechanical performance[5], marginal fit[6], and produce lesser distortion of restoration margins[7].

To avoid the problem of wax pattern distortion with conventional casting, computer-aided-design/computer-aided-manufacturing (CAD/CAM) was introduced, which fabricate restorations by additive or subtractive methods[8]. Direct Metal Laser Sintering (DMLS) is a newer procedure of fabrication of alloy copings, through an automated scanning process. The CAD software helps in gaining control over the coping thickness, margin placement, and margin design, all of which contribute to its superiority over other techniques- Stereolithography (SL), Selective Laser Sintering (SLS), and Polyjet- used to produce copings for bridges.

Study results comparing DMLS against conventional casting techniques are mixed, with comparable findings in some[9], and a better marginal fit for DMLS in others[10,11,12]. On the contrary, Sujana Ullattuthodi et al[13] found a better internal fit for conventional copings. Hence, additional research would help in a better understanding. We aimed to compare the two techniques for vertical marginal adaptation of Cobalt-Chromium (Co-Cr) copings. Our objectives were to

i. To evaluate the marginal fit of the copings fabricated by conventional technique with chamfer and radial shoulder finish lines

ii. To evaluate the marginal fit of the copings fabricated by Direct metal laser sintering with chamfer and radial shoulder finish lines

iii. To compare the marginal fit of copings from the above two techniques and the two finish lines.

II. Material And Methods

This was an in-vitro study conducted in the department of Prosthodontics at Panineeya Mahavidyalaya Institute of Dental Sciences and Research Centre. Twenty Co-Cr copings each were fabricated using conventional casting and DMLS techniques. These were in turn divided into two groups of ten each, based on the type of finish line, thus giving four groups as follows:

Group 1: Conventionally cast Co-Cr copings with chamfer finish line (n=10)

Group 2: Conventionally cast Co-Cr copings with radial shoulder finish line (n=10)

Group 3: Co-Cr copings obtained from Direct Metal Laser Sintering (DMLS) and with chamfer finish line (n=10)

Group 4: Co-Cr copings obtained from Direct Metal Laser Sintering (DMLS) and with Radial shoulder finish line (n=10)

Materials and equipment used for the study

1. Two Co-Cr master models with chamfer and Radial shoulder finish lines
2. Custom trays and Polyether Medium body (3M ESPE, US) impression material
3. Type IV die stone, die spacer, and lubricant (YETI, Germany)
4. Inlay casting wax (Kerr, US) and Sprue wax (Bego, Germany)
5. Siliring
6. Phosphate bonded investment (Bellasun, Bego, Germany)
7. Colloidal silica (Begosol, Bego, Germany)
8. Co-Cr alloy (Denchrome-C, CE Germany)
9. PKT instruments
10. Shining 3d scanner, China
11. Direct Metal Laser Sintering machine (EOSINT M 270)
12. Vacuum powder mixer (Whipmix, Kentucky USA)
13. Burnout furnace (Technico, Ind products, Chennai)
14. Induction casting machine (Fornax Bego, Germany)
15. Stereomicroscope (Lynx- Mumbai, India)

III. Methodology

Cobalt chromium master models with Chamfer and Radial shoulder finish lines were prepared using a CAM Machine. The shape and dimensions of tooth preparation resembled that of mandibular first molar and as per guidelines by C.J Goldacre[14]. Elastomeric impressions of these models were made in a custom tray, and poured in Type IV Gypsum.

Fig 1: Master model with chamfer finish line

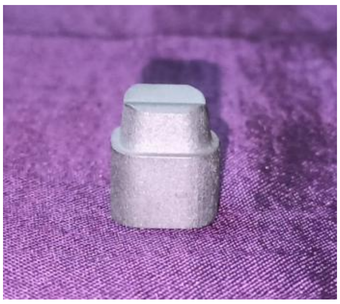

Fig 2: Master model with radial shoulder finish line

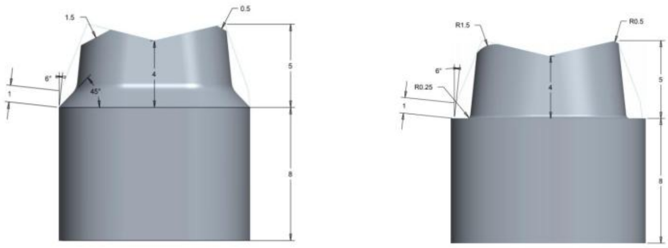

Fig 3 and 4: Measurements for the master model with chamfer and radial shoulder finish line

The casting technique for fabricating twenty copings followed regular steps of wax pattern preparation, sprue former attachment, investing procedure, burn out, casting, divesting, and finishing of cast copings.

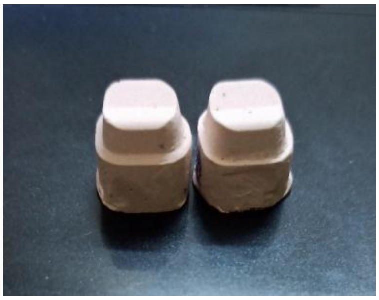

Fig 5: Master dies (Chamfer and Radial shoulder finish lines- type IV Diestone)

Fig 6: Completed wax patterns

For the Direct Metal Laser Sintering, master dies were scanned using a Shining 3d scanner after which algorithms were used to reconstruct the scanned data to a triangular solid model. After this, the STL data was forwarded to a CAM bridge, and then to a building chamber, where an infrared laser beam fused the Co-Cr powder layer-by-layer, to obtain a final coping. Twenty such copings were prepared and sandblasted with 110μm Aluminium oxide powder. 10 copings were given a chamfer finish line and the other 10 copings radial shoulder finish line in both the techniques.

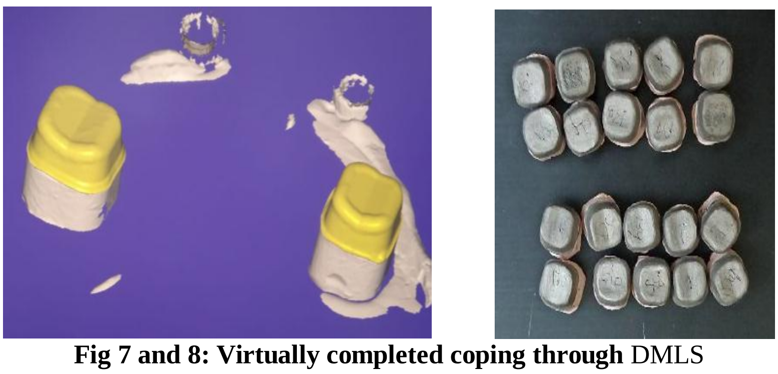

Fig 7 and 8: Virtually completed coping through DMLS

The vertical marginal gap of the 40 copings was evaluated using Stereomicroscope and ImageJ software. Stereomicroscopy overlaps macro photography for examining solid samples with complex surface topography, where a three-dimensional view is needed for analyzing the detail. Measurements were rounded to the nearest micron on each cast coping seated on each die at four predetermined reference areas-mid-mesial, mid-buccal, mid-distal, and mid-lingual, and an average for each coping was obtained. The overall mean vertical marginal gap for the four groups was calculated.

Fig 9: Stereomicroscope (Lawrence and Mayo, India)

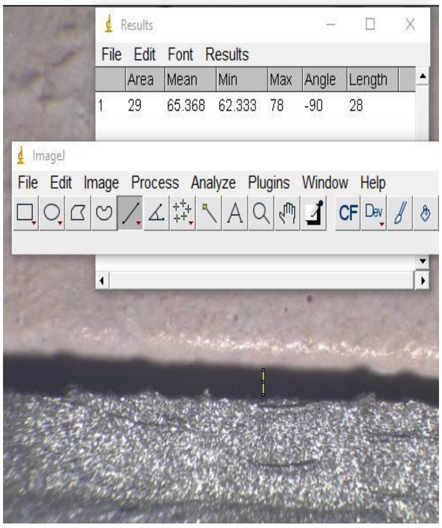

Fig 10: IMAGEJ Software

The collected data were entered into an excel sheet and analyzed using IBM SPSS Version 21.0. Armonk, NY: IBM Corp. ANOVA followed by post hoc was used to compare the four groups. A p-value of less than 0.05 was considered statistically significant.

IV. Results

The vertical marginal gap of Co-Cr copings fabricated using two techniques and with two finish lines were compared. A significant difference was detected in the marginal gaps of the copings from the four groups. Post hoc analysis revealed that the significant difference was between the two techniques, i.e., copings from the DMLS had a lesser gap than conventionally cast copings. The two finish lines within the same technique did not show any remarkable difference. However, copings with radial shoulder finish line had a greater gap when compared to chamfer for both procedures. Comparing the copings with the same finish line but manufactured from two different procedures also showed a lesser gap for DMLS copings.

Table 1: ANOVA to compare the mean vertical marginal gap (in microns) for the 40 copings belonging to the four groups.

	Vertical marginal gap (in microns) of the ten copings in each group			
S no	Conventional chamfer	Conventional radial shoulder	DMLS chamfer	DMLS radial shoulder
	Group 1	Group 2	Group 3	Group 4
1.	59	68	20.1	19.75
2.	61	60	14.4	19.8
3.	55	55	19.8	23.2
4.	54	65	18	18.2
5.	52	66	22.5	23
6.	65	60	19.75	23.7
7.	64	71	21.5	20.2

8.	64	65	20.25	18.5
9.	69	61	20	19.75
10.	55	66	19.75	18.75
Mean marginal gap	59.8	63.7	19.60	20.48
F statistic (p-value)	30.092* (0.000)			

* Highly significant at p<0.01

Table 2: Post-hoc pairwise comparison between each of the individual groups

Groups compared	Mean difference	95% CI		P-value
		Lower	**Upper**	
Group1 Vs group 2	-3.90	-8.6761	.8761	.143
Group1 Vs group 3	40.19*	35.41	44.97	.000
Group1 Vs group 4	39.31*	34.53	44.09	.000
Group2 Vs group 3	44.09*	39.31	48.87	.000
Group2 Vs group 4	43.21*	38.43	47.99	.000
Group3 Vs group 4	-.88	-3.8961	5.65	.95

* Highly significant at p<0.01

V. Discussion

A group of clinical (type of finish line, degree of taper, and nature of impression material) and laboratory (investment material, casting procedure) factors play a crucial role in the success of cast metal crowns. The marginal inaccuracies in crowns fabricated from conventional casting can be minimized by methods like over waxing the margin of wax pattern, die relief, sandblasting, and mechanical milling[3,15,16]. Additionally, margins with an inclined vertical configuration have been recommended[7,17,18]. Though there is debate about the best position, most of them favor a supragingival placement[19]. The present study was done to simulate a supragingival margin where the vertical gap which exposes cement to the oral environment was measured. We selected Co-Cr alloys because of their high rigidity, better electrochemical resistance than Ni-Cr alloys, and rare allergies [9, 20, 21].

Lost wax casting technique for fabricating cast copings is highly technique sensitive[4]. The newer 3D printing technologies like stereolithography apparatus, and direct metal laser sintering (DMLS) are additive processes characterized by a layer-by-layer building of the final product[8,22].

The two finish lines in our study- radial shoulder and chamfer, exhibited comparable marginal accuracy, thus demonstrating that either of these finish lines can be used to fabricate metal-ceramic restorations. Instead of prepared natural teeth, we used standardized dies with a volumetric size similar to teeth and thereby could reduce variation within each group of finish line preparations. For the same reason, accurate control on other details of preparation viz., degree of axial wall taper, and the finish line dimensions was enabled.

The impressions of the master model were taken with polyether impression material using a custom tray and master dies were made using Type IV die stone. Polyether is hydrophilic, thereby flowing well around the crown margins. Its rigidity is higher than PVS, producing an accurate replica with better dimensional stability[23 24].

Ideal cementation of fixed prosthesis leads to a perfect marginal seal but this procedure sometimes causes incomplete seating and marginal opening. Providing an adequate relief space compensates for the cement film thickness, and produces an optimum fit, along with preventing roughness due to the tooth and casting surfaces. The die spacer thickness of 26 μm in our study matches with the ADA specification no. 8 which suggests a film thickness of 25 μm to 40 μm for luting agents [25,26,27]. While two coats of the die spacer were applied in the conventional technique, it is controlled by computer software in the DMLS technique.

The copings obtained using the DMLS technique showed a lesser vertical marginal gap than those from the conventional technique attributed to the total elimination of casting and manual errors in DMLS[10,11]. The marginal discrepancy in the conventionally casted copings could also be caused by the high-temperature heating of the alloy beyond its melting point, which affects its viscosity and flow. On the other hand, selective laser sintering and rapid solidification of cobalt chrome powder in small sections minimize the chances of alloy shrinkage for laser sintered metal copings.[28,29] The high density of laser-sintered crowns when small-sized particles (3–14 μm) are combined with a very fine point laser of 0.1 mm, contributes to a stronger and void-free coping, and the resulting restorations are accurate[9].

In both the techniques chamfer finish line had a lesser marginal gap than the radial shoulder finish line. This is because, the curve design of the chamfer finish line, causes a better spread of the load throughout, whereas the right-angled margin gives sharp endings to the radial shoulder finish line[5, 30]. Our study findings are in line with that of Priya L Vaswani et al who also found that shoulder and deep chamfer did not exhibit a significant statistical difference in terms of marginal accuracy and concluded that either of them can be used to fabricate metal-ceramic restorations[6]. Eshwaran et al found a clinically acceptable range of marginal fit, for both conventional casting and DMLS techniques, but they opined that the difficulties encountered during conventional casting procedures are eliminated in DMLS technique[10].

Marginal fit of cast restoration is one of the most researched subjects in fixed prosthodontics. A marginal gap of 52-71 μm was found for copings from conventional technique, in our study. Mc Lean et al found that after casting, the marginal gap ranged from 40-61.5μm and suggested that a marginal gap of 120μm is the maximum clinical acceptable gap.[31] Hung et al also reported a practical range of 50 to 75μm for clinical acceptability.[32]

Our study had a few limitations, the first of which is its in-vitro design, which cannot simulate oral conditions. Further, the marginal discrepancy was measured without permanent cementation of the cast copings, and it could potentially affect the marginal adaptation. Previous studies have demonstrated that the marginal discrepancy had been increased significantly after cementation[33]. Groten et al[34] reported that approximately fifty measurements were needed for clinically relevant information about the gap size. This should be followed regardless of the gap definition or cementation condition. In this study, four predetermined reference areas were used to measure the marginal gap. More number of readings could yield better results. The sample size was small and horizontal discrepancies were not estimated, which require sectioning of copings along with the standard models. Future studies with larger sample sizes and that evaluate horizontal discrepancies are recommended.

VI. Conclusion

Within the above limitations, our study results suggest that marginal fit of Co-Cr copings with either of the two techniques and either of the two finish lines were within the clinically acceptable range, in line with the previous literature. But the marginal gap was less for the DMLS copings. Further studies on DMLS would help obtain a confirmative and consistent estimate of the marginal and internal discrepancy, thereby improving their acceptability.

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