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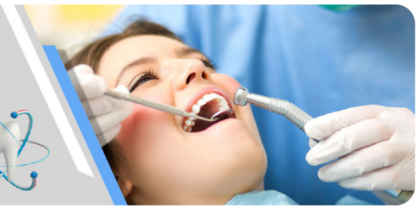

Comparative Evaluation of the Marginal and internal adaptation of Metal Copings Fabricated using Conventional Casting, Computer aided Design/ Computer aided Milling and direct Metal Laser Sintering techniques: An invitro study

Taranjit Singh Walia[1*], Ravudai singh Jabbal[2], Fatinderjeet Singh[3], Sumanjit[4], ARV Gayathrinath[5], Lovejeet Ahuja[6]

Abstract

Aim: To comparatively evaluate the vertical marginal gap and internal fit of metal copings obtained from the four techniques and to determine the technique that will provide the best marginal accuracy and internal fit for better clinical results.

Material and Method: Forty metal copings will be fabricated using the custom-made metal master die and divided into four groups of ten samples each according to the different fabrication techniques used. The copings from each group will be luted on the metal die using a light viscosity silicone material. Then heavy viscosity silicone material will then be injected on the internal surface and external surface of the light viscosity silicone and sectioned bucco-lingually and observed under a stereomicroscope. Post Hoc Tukey HSD and One-way ANOVA were applied to analysis data.

Results: The mean MG was highest for Group I followed by Group III, Group II and Group IV. The mean internal gap at MAW was highest for Group I followed by Group II, I and III. At AOLA the mean gap was highest for Group III followed by Group I, II and IV. While for the MIS the mean gap was greatest for Group III followed by Group II, IV and I.

Conclusion: Within the limitations of the study, it was concluded that Copings made by using stainless steel ring with DMLS technique had the least marginal gap then other techniques.

Keywords: Conventional casting; CAD/CAM; DMLS; Marginal adaptation; Internal adaptation

Introduction

The aim of fixed dental restorations is to restore the lost function and esthetics of intraoral structures without causing harm to the oral or systemic health of the patient. The construction of metal substructures to function as copings and crowns with an accurate marginal seal has for long been a crucial factor for long term success of restorations [1]. One of the major factors in determining success of the restoration is the accuracy in fit of cast metal restoration. A good-fitting restoration needs to be accurate both along its edges and inner surface [2].

Excessive marginal discrepancy for crowns increases cement dissolution and micro leakage [3]. The luting space between the internal surface of the crown and the prepared abutment tooth needs to be uniform to facilitate placement without compromising retention and resistance [4].

Affiliation:

[1]Department of Prosthodontics, Teerthanker Mahaveer University, Uttar Pradesh, India

[2]Department of Prosthodontics, Genesis Institute of Dental Sciences and Research, Punjab, India

[3]Department of Endodontics, Teerthanker Mahaveer University, Uttar Pradesh, India

[4]Department of Prosthodontics, Rayat Bahra Dental College and Hospital, Punjab, India

[5]Department of Prosthodontics, Genesis Institute of Dental Sciences and Research, Punjab, India

[6]Department of Pedodontics, Dashmesh Dental College and Research Institute, Punjab, India

***Corresponding author:**
Taranjit Singh Walia, Department of Prosthodontics, Teerthanker Mahaveer University, Uttar Pradesh, India

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The term 'marginal gap' was defined in many ways. Eden et al. [5] have evaluated fit as a percentage oversize or undersize of castings, whereas Christensen GJ [6] have used rating scales and Kay et al. [7] have eliminated the laboratory phase of fit evaluation with the use of a computer simulation study to analyze the effects of preparation design, die relief, and cementation factors.

The basic solution to this problem was given by Holmes et al. [8], who established several definitions according to contour differences between the crown and tooth margin. According to their classification, an acceptable definition for the minimum gap width is, "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." The actual maximum gap width called the absolute marginal discrepancy was defined as "the angular combination of marginal gap and constant error." However, in practice it is almost impossible to explain a certain gap by only single definition due to morphologic aberrations, rounded margins or defects. This is one of the main reasons for the large amount of variation commonly reported among investigators [9].

The fabrication of dental cast restorations with the base metal alloys by conventional lost wax technique involves impression procedure, preparation of the die, fabrication of pattern, and investing and casting. Difficulties like wax distortion, foreign body inclusion, complex and time consuming procedures encountered during casting of base metal dental alloys may result in unforced errors and inaccurate castings [2].

To overcome the limitations of the Conventional Casting (TC) procedure, Computer Aided Design/Computer-Aided Milling (CAD/CAM) and Direct Metal Laser Sintering (DMLS) manufacturing systems have been introduced for fabricating metal frameworks for metal ceramic crowns. In the CAD/CAM milling system, a digital production pre shape is generated via computer; then a reconstruction is manufactured in the CAM section by using CAD data. During the milling procedure, the virtual pre-shape serves as a pattern for milling a reconstruction from a solid Cobalt-Chrome (Co-Cr) blank.

DMLS which is an additive metal fabrication technology uses a high-temperature laser beam to carefully heat a substructure metal powder based on the CAD data with the framework design. A fine layer of the beamed area becomes fused, and the metal framework is completed by laminating these fine layers [4].

According to ADA specification no. 8, the marginal adaptation of cemented castings should be in the 25 µm range [10]. Karatasli O et al. [11] and Tan PL et al. [12] et al have estimated maximal marginal gap (MG) values in vitro in which MG values between 100-150µm are considered 100µm and there are still those who argue, that the acceptable value should range between 20-75µm.

Several investigators have compared the marginal adaptation and internal fit of restorations fabricated using CAD/CAM and DMLS systems with Conventional Casting techniques with conflicting results. Rai et al [2] and Colaco et al [1] reported that the copings fabricated using the direct metal laser sintering technique exhibited a mean marginal misfit value of 30 to 99.02 µm which is less compared to Conventional Casting method (110 to 169 µm). Whereas Park et al [15] and Ullattuthodi et al [16] reported that crowns fabricated by conventional casting procedure had less marginal and internal gap within range of 36.96 to 105µm compared to other techniques whose mean value was 70 to 110 µm. Tamac et al [4] and Ucar et al [3] reported no significant difference among Conventional Casting, CAD/CAM and DMLS techniques, so the correct vertical marginal gap and internal fit are still not verified.

Therefore, the purpose of this study will be to compare the marginal and internal adaptation of metal copings obtained from Conventional Casting procedure using Nickel-Chrome (Ni-Cr) alloy and Co-Cr copings obtained from Conventional Casting, CAD/CAM, and Direct Metal Laser Sintering (DMLS) procedure.

Method

Ni-Cr (Star loy N, Dentsply, Germany) and Co-Cr (Mega-bond CP, Dentsply, Germany) alloy copings were fabricated using Conventional Casting machine (Fornex T, BEGO, Germany). Coping were also fabricated using Co-Cr milling blocks (Kera-disc, Woerth, Germany) CAD/CAM milling machine (D3, 3shape, Denmark) and Co-Cr laser sintered blocks (Osprey, Sandvik, UK) using DMLS machine (M 100, EOS, Germany).

Methodology:

This study was conducted on 40 specimens, divided into four groups with ten specimens in each group based on fabrication technique used as follows:

A. Preparation of Master Die Assembly

A stainless steel die [Figure 1a] was milled to simulate preparation for a maxillary first premolar with a uniform shoulder margin of 1.2 mm width. The axial height of the master die was 7mm with 6.5mm diameter at the top and 8mm at the bottom. A bevel was placed at one side of occlusoaxial line angle to serve as seating guide for the copings. A counter die made of stainless steel was constructed to make wax pattern with uniform thickness of 0.5mm.

B. Wax Pattern Fabrication [Figure 1b]

On stainless steel die, die spacer was applied 1mm short

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of the margin. The die was lubricated with a die lubricant. The stainless steel former was filled with molten inlay wax and was pressed on the stainless steel die. The stainless steel die and former assembly were held together for one minute with finger pressure. The die was then separated from the former and the wax pattern was obtained.

C. Casting and seating

Forty Copings fabricated using different casting techniques and divided into 4 groups of ten samples each.

Group I: Ten Ni-Cr Copings were fabricated with Conventional Casting procedure. [Figure 2a]

Group II: Ten Co-Cr Copings were fabricated with Conventional Casting procedure. [Figure 2b]

Group III: Ten Co-Cr Copings were fabricated with CAD/CAM procedure. [Figure 2c]

Group IV: Ten Co-Cr Copings were fabricated with Direct Metal Laser Sintering procedure. [Figure 2d]

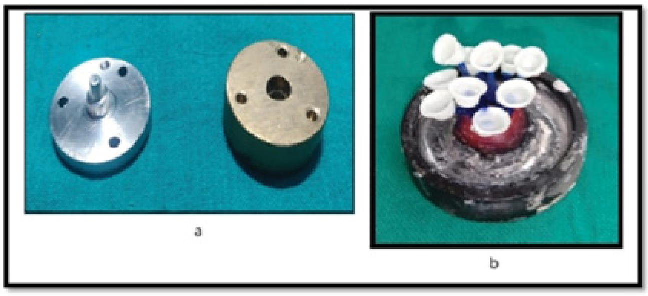

Figure 1: (a) Stainless Steel Metal Die and Mould; (b) Wax Pattern.

D. Impression making

The copings from each group were luted on the metal die using a light viscosity silicone material (Aquasil, Dentsply, Germany) under application of finger pressure. After setting the copings were retrieved along with the silicone material. Heavy viscosity silicone material (Aquasil, Dentsply, Germany) having contrasting color than light viscosity silicone was then injected on the internal surface of the copings. After setting, the two layers of silicone material were retrieved from the metal copings and heavy viscosity silicone material was applied to the external surface of the light viscosity silicone. The silicone material obtained from each coping was sectioned bucco-lingually using a surgical blade into two halves [Figure 3a].

II. Stereo microscope analysis

All the 40 sectioned specimens were observed to measure the marginal and internal gaps at seven different predetermined points:- Buccal margin, lingual margin, mid axial wall (buccal), mid axial wall (lingual), axio-occusal line angle (buccal), axio-occusal line angle (lingual), mid occlusal surface under a stereomicroscope (SMZ 745T, Nikon, Japan) [Figure 3b]:-

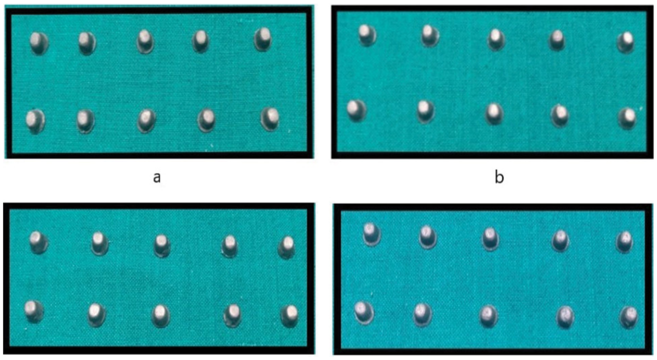

Figure 2: (a) Ni-Cr copings fabricated using conventional casting technique (Group I); (b) Co-Cr Casting fabricated using conventional casting technique (group II); (c) Co-Cr copings fabricated using CAD/CAM milling technique (Group III); (d) Co-Cr copings fabricated using DMLS technique (Group IV).

The results of the four groups were compared using One-way ANOVA and Post Hoc Tukey HSD was used to make individual comparisons for the study groups.

Results

Mean marginal gap and internal (MG) values in µm and other descriptive statistical measures such as standard deviation (SD), standard error of mean (SEm) were computed for all groups and are presented in table 1.

The mean marginal gap was highest for Group I (206.48µm) followed by Group III (169.03µm), Group II (160.96µm) and Group IV (130.54µm) [Table 1].

The mean internal gap at mid-axial wall (MAW) was highest for Group I (181.02µm) followed by Group II (131.81µm), Group IV (103.02µm) and Group III (96.45µm). At axio-occlusal line angle (AOLA) the mean gap was highest for Group III (257.02µm) followed by Group I (210.18µm), Group II (197.01µm) and Group IV (167.29µm). While for the mid-occlusal surface (MOS) the mean gap was greatest for Group III (325.24µm) followed by Group II (238.92µm), Group IV (238.52µm) and Group I (151.41µm) [Figure 4-Table 1]. One way ANOVA revealed highly significant difference between all study groups [Table 2].

Post Hoc Tukey HSD was used to make individual comparisons for the study groups. The intergroup comparison

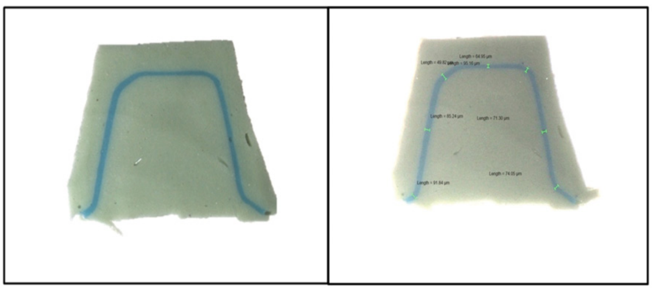

Figure 3: (a) Silicone specimen obtained from copings; (b) Measurements at seven predetermined points.

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Table 1: Descriptive analysis of all study groups.

						95% Confidence Interval for Mean	
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound
MG	Group I	10	206.486	14.48511	4.58059	196.124	216.848
	Group II	10	160.964	12.11157	3.83002	152.2999	169.6281
	Group III	10	169.03	6.66838	2.10873	164.2597	173.8003
	Group IV	10	130.5435	6.9546	2.19924	125.5685	135.5185
	Total	40	166.7559	29.23356	4.62223	157.4065	176.1052
MAW	Group I	10	181.0265	10.31749	3.26268	173.6458	188.4072
	Group II	10	131.813	10.05575	3.17991	124.6196	139.0064
	Group III	10	96.4515	11.21305	3.54588	88.4302	104.4728
	Group IV	10	103.027	6.01526	1.90219	98.7239	107.3301
	Total	40	128.0795	35.00116	5.53417	116.8856	139.2734
AOLA	Group I	10	210.189	20.26607	6.4087	195.6915	224.6865
	Group II	10	197.014	21.2781	6.72873	181.7926	212.2354
	Group III	10	257.025	9.51303	3.00828	250.2198	263.8302
	Group IV	10	167.291	8.2183	2.59885	161.412	173.17
	Total	40	207.8798	36.18137	5.72078	196.3084	219.4511
MOS	Group I	10	151.416	19.52248	6.17355	137.4505	165.3815
	Group II	10	238.928	21.31169	6.73935	223.6825	254.1735
	Group III	10	325.247	27.74585	8.77401	305.3988	345.0952
	Group IV	10	238.525	25.08701	7.93321	220.5788	256.4712
	Total	40	238.529	66.25495	10.47583	217.3396	259.7184

Table 2: One-way ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
MG	Between Groups	29285.364	3	9761.788	86.898	0
	Within Groups	4044.08	36	112.336		
	Total	33329.444	39			
MAW	Between Groups	44452.82	3	14817.607	160.414	0
	Within Groups	3325.361	36	92.371		
	Total	47778.18	39			
AOLA	Between Groups	41860.994	3	13953.665	54.639	0
	Within Groups	9193.586	36	255.377		
	Total	51054.58	39			
MOS	Between Groups	151088.455	3	50362.818	90.155	0
	Within Groups	20110.549	36	558.626		
	Total	171199.004	39			

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Table 3: Intergroup comparisons of groups at MG using Post Hoc Tukey HSD

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
MG	Group I	Group II	45.52200*	4.73995	0	32.7562	58.2878
		Group III	37.45600*	4.73995	0	24.6902	50.2218
		Group IV	75.94250*	4.73995	0	63.1767	88.7083
	Group II	Group I	-45.52200*	4.73995	0	-58.2878	-32.7562
		Group III	-8.066	4.73995	0.338	-20.8318	4.6998
		Group IV	30.42050*	4.73995	0	17.6547	43.1863
	Group III	Group I	-37.45600*	4.73995	0	-50.2218	-24.6902
		Group II	8.066	4.73995	0.338	-4.6998	20.8318
		Group IV	38.48650*	4.73995	0	25.7207	51.2523
	Group IV	Group I	-75.94250*	4.73995	0	-88.7083	-63.1767
		Group II	-30.42050*	4.73995	0	-43.1863	-17.6547
		Group III	-38.48650*	4.73995	0	-51.2523	-25.7207

*The mean difference is significant at the 0.05 level.

Table 4: Intergroup comparisons of groups at MAW using Post Hoc Tukey HSD

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
MAW	Group I	Group II	49.21350*	4.29817	0	37.6376	60.7894
		Group III	84.57500*	4.29817	0	72.9991	96.1509
		Group IV	77.99950*	4.29817	0	66.4236	89.5754
	Group II	Group I	-49.21350*	4.29817	0	-60.7894	-37.6376
		Group III	35.36150*	4.29817	0	23.7856	46.9374
		Group IV	28.78600*	4.29817	0	17.2101	40.3619
	Group III	Group I	-84.57500*	4.29817	0	-96.1509	-72.9991
		Group II	-35.36150*	4.29817	0	-46.9374	-23.7856
		Group IV	-6.5755	4.29817	0.431	-18.1514	5.0004
	Group IV	Group I	-77.99950*	4.29817	0	-89.5754	-66.4236
		Group II	-28.78600*	4.29817	0	-40.3619	-17.2101
		Group III	6.5755	4.29817	0.431	-5.0004	18.1514

* The mean difference is significant at the 0.05 level.

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Table 5: Intergroup comparisons of groups at AOLA using Post Hoc Tukey HSD

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
AOLA	Group I	Group II	13.175	7.14671	0.27	-6.0727	32.4227
		Group III	-46.83600*	7.14671	0	-66.0837	-27.5883
		Group IV	42.89800*	7.14671	0	23.6503	62.1457
	Group II	Group I	-13.175	7.14671	0.27	-32.4227	6.0727
		Group III	-60.01100*	7.14671	0	-79.2587	-40.7633
		Group IV	29.72300*	7.14671	0.001	10.4753	48.9707
	Group III	Group I	46.83600*	7.14671	0	27.5883	66.0837
		Group II	60.01100*	7.14671	0	40.7633	79.2587
		Group IV	89.73400*	7.14671	0	70.4863	108.9817
	Group IV	Group I	-42.89800*	7.14671	0	-62.1457	-23.6503
		Group II	-29.72300*	7.14671	0.001	-48.9707	-10.4753
		Group III	-89.73400*	7.14671	0	-108.9817	-70.4863

* The mean difference is significant at the 0.05 level.

Table 6: Intergroup comparisons of groups at MOS using Post Hoc Tukey HSD

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
MOS	Group I	Group II	-87.51200*	10.57002	0	-115.9795	-59.0445
		Group III	-173.83100*	10.57002	0	-202.2985	-145.3635
		Group IV	-87.10900*	10.57002	0	-115.5765	-58.6415
	Group II	Group I	87.51200*	10.57002	0	59.0445	115.9795
		Group III	-86.31900*	10.57002	0	-114.7865	-57.8515
		Group IV	0.403	10.57002	1	-28.0645	28.8705
	Group III	Group I	173.83100*	10.57002	0	145.3635	202.2985
		Group II	86.31900*	10.57002	0	57.8515	114.7865
		Group IV	86.72200*	10.57002	0	58.2545	115.1895
	Group IV	Group I	87.10900*	10.57002	0	58.6415	115.5765
		Group II	-0.403	10.57002	1	-28.8705	28.0645
		Group III	-86.72200*	10.57002	0	-115.1895	-58.2545

*. The mean difference is significant at the 0.05 level.

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for marginal gap revealed highly significant difference (p<0.001) between all study groups except Group II and Group III [Table 3]. The intergroup comparison for internal gap at MAW revealed highly significant difference (p<0.001) between all study groups with the exception of Group III and Group IV [Table 4]. The comparison at AOLA revealed highly significant difference between all study groups except Group I and Group II [Table 5]. The intergroup Post Hoc comparison at MOS revealed highly significant difference between all study groups with the exception of Group II and Group IV [Table 6].

Discussion

The aim of this study was to comparatively evaluate the vertical marginal gap and internal fit of Ni-Cr and Co-Cr metal copings obtained from the techniques:- Conventional Casting, CAD/CAM milling and DMLS and to determine the technique that will provide the best marginal accuracy and internal fit for better clinical results. Results from the marginal fit as well as internal fit data support rejection of the null hypothesis.

There are many clinical and laboratory factors responsible for the marginal and internal adaptation of dental cast restorations. Technical errors such as damage to the margins during die trimming, excessive thickness of die spacer, inaccurate wax adaptation, incorrect investment and casting failures may occur. In order to minimize marginal and internal fit inaccuracies several methods and technique have been advocated by various authors [17]. These include over-waxing the margin of wax pattern, removing wax from internal surface of wax pattern, die relief with application of die spacer, internal relief of cast restoration by sandblasting, mechanical milling, acid etching and electrochemical milling and occlusal venting for escape of luting agent [13].

Main causes for casting inaccuracies are the disadvantageous properties of material used to fabricate pattern. Waxes which have been used over many decades have shrinkage and stress relaxation properties and resins have polymerization shrinkage [18].

Recently introduced computer aided design/computer aided manufacturing like three dimensional printing and Polyjet have been used to fabricate patterns using wax and resins accurately, but final fit of restoration is determined by the technique sensitive casting procedures employed to cast these patterns. In DMLS technique, Co-Cr powdered alloy is used in composition. The Molybdenum content material inside the alloy powder utilized in DMLS is comparatively much less than the alloy that's used for traditional casting. This new technique produces high accuracy, detailed resolution, good surface quality, and excellent mechanical properties [17].

Co-Cr alloys were primarily used for RPD frameworks and currently also used more commonly than Ni-Cr alloys for fixed prosthesis. Co-Cr alloys contain predominantly cobalt and sometimes tungsten in small amounts and possess high rigidity and hardness. Nickel based alloy also have greater restoration sensitization potential, whereas with Co-Cr alloy allergies are rare. Electrochemical studies show that Co-Cr alloys are greater resistant to corrosion than Ni-Cr alloys.

Several studies have been done to improve the fit of the cast restoration and multiple protocols to minimize errors and yield best internal and marginal fit of the cast restoration have also been suggested. However, very few studies have reported on the marginal accuracy of metal copings fabricated directly using CAD/ CAM technique using Co–Cr alloys. Also, few studies can be found in literature comparing accuracy of copings fabricated using DMLS with other fabricating techniques [19].

A phosphate bonded investment material (Wirovest) using combination of Begosol and distilled water was used in this study with a recommended powder-liquid ratio of 80g: 12ml was used. These investments are stronger, more refractory and can be manipulated for a greater degree of mould expansion [20]. Phosphate bonded investments are more suited for accelerated/rapid wax elimination technique. They attain sufficient strength to sustain thermal shock when maximum exothermic setting reaction is achieved [21].

No preferred protocol is to be had for comparing the adaptation of dental restorations. This may lead to misinterpretation and limits the comparison of results from different studies.

Marginal and internal gaps are generally measured directly under a microscope after sectioning the embedded specimens into acrylic resin or epoxy resin [22]. However, this technique is destructive and therefore cannot be used to evaluate the clinical adaptation of dental restorations [23]. The silicone replica technique allows in vivo measurement of the adaptation of indirect restorations just before luting and has been validated as an appropriate method of measuring the adaptation of indirect restorations [24]. The applied seating force on the crown lined with light viscosity silicone material cannot be standardized in clinical conditions. However, differences in seating force did not significantly affect the thickness of silicone layer [14].

A wide range of clinically acceptable marginal gap has been reported in literature ranging from a gap of 75.92-96.23μm suggested by Tamac et al [4] to a gap of 36.38-122.55μm and 200 μm suggested by Radhika et al [2] and Gulker [25] respectively. According to them, a marginal gap <80 μ was difficult to detect clinically. McLean et al [26] reported a maximum allowable marginal gap of 120 μ.

The marginal gap values for all the groups in this study ranged from 130.54-206.48μm and thus were within the clinically acceptable range

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The marginal gap values were found to be statistically significant between all the study groups. The values reported in this study were higher than those of Tamac et al [4] who reported a mean marginal gap of 75.92µm for TC, 86.64µm for CAD/CAM and 96.23µm for DMLS technique respectively. Radhika et al [2] also reported a mean marginal gap of 122.55µm for TC, 72.68µm for CAD/CAM and 36.38µm for DMLS. This difference in results may be due to difference in the materials, fabrication equipment, testing techniques and testing conditions.

The internal gap values for all the groups in this study ranged from 151.41-325.24µm and thus were within the clinical acceptable range.

The mean values for the internal gap for Group II, Group III and Group IV were found to be greatest at MOS (238.93µm, 325.25µm, 238.53µm) followed by AOLA (197.01µm, 257.03µm, 167.3µm) and MAW (131.81µm, 96.45µm, 103.03µm).

Similar findings have been reported by Tamac et al [4] in which metal ceramic crowns fabricated with CAD/CAM milling, DMLS, and conventional casting (TC) using Co-Cr alloy exhibited similar adaptation at the mid axial wall (117.5µm, 139.01µm, 121.38µm), whereas higher measurement values were observed at the axio-occlusal angle (142.1µm, 188.12µm, 140.63µm) and occlusal surface (265.73µm, 290.39µm, 201.09µm) except metal ceramic crowns fabricated with TC using Ni-Cr alloy. This can be due to the fact a scanner using the laser technique has a tendency to round sharp edges. Another possible explanations for this could be the optical properties of the optical scanner used in this study

Similar findings have also been reported by Radhika et al. [2] however the values were comparatively less in axial and occlusal surfaces of crowns fabricated with TC, CAD/CAM milling and DMLS.

The present study has a few limitations. The study doesn't take into account the distortion of wax pattern during conventional casting procedure which is the most common cause for inaccurate castings. Marginal discrepancy was measured without permanent cementation which can potentially affect marginal adaptation. The effect of subsequent porcelain firing on metal copings has not been accounted for. Also, the in vitro testing conditions cannot exactly replicate the clinical situation.

Within the conditions of this study, copings fabricated with conventional casting technique exhibited the highest marginal gap but least internal gap. The marginal gap and internal gap with DMLS technique was reported to be within the clinically acceptable range and may be used as a time saving option to fabricate precision castings.

Conclusion

Within the limitations of the study, it was concluded that

1. The mean marginal gap of the copings for Group I, Group II, Group III and Group IV was 181.02µm, 160.96µm, 169.03µm and 206.48µm respectively and the difference between any two group mean was found to be statistically significant. Copings made by using stainless steel ring with DMLS technique (Group IV) had the least marginal gap while copings made by using TC technique (Group I) had the highest marginal gap.
2. Metal ceramic crowns manufactured using DMLS, CAD/CAM, and TC systems exhibited similar clinical marginal adaptation within an acceptable range.
3. The mean internal gap of the copings at MAW, AOLA and MOS for Group I, Group II, Group III and Group IV was (181.03µm, 210.18µm, 151.41µm), (131.81µm, 238.92µm, 197.01µm), (96.45 µm, 257.02µm, 325.24µm) and (103.03 µm, 167.29µm, 238.52µm) respectively. With the exception of Group I, the mean internal gap values increased from the MAW towards the MOS. Thus the occlusal region was found to have the highest cement film thickness in all study groups.
4. Clinically acceptable crowns can be fabricated by all the techniques however; copings fabricated using DMLS technique yielded the most desirable results within clinically acceptable range.

Conflicting interest: No

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