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Comparison and Evaluation of Marginal Adaptation of Interim Restorations Fabricated with Polymethylmethaacrylate Resin, Bisphenol A-Glycidçyl Methacrylate Resin and Photopolymer Resin- An In-Vitro Study

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KEYWORDS

Evaluation of Marginal Adaptation, Interim Restorations Fabricated, Polymethyl methaacrylate Resin

ABSTRACT:

Aim

The aim of the study is to compare and evaluate marginal adaptation of interim restorations fabricated with polymethylmethaacrylate resin, bisphenol A-glycidyl methacrylate resin and photopolymer resin.

Materials and Method:

The present study included 24 samples, divided into three groups of eight each. Group 1: Interim restorations with polymethylmethacrylate resin; Group 2: restorations with bisphenol A-glycidyl methacrylate resin; Group 3: restorations with photopolymer resin. A putty index of an unprepared mandibular molar was obtained, and a master model was prepared to fabricate 24 interim crowns. The mandibular first molar on a typodont was prepared for an all-ceramic crown with 1.5 mm occlusal reduction and 1 mm chamfer margin. An initial impression was recorded and poured with Type IV dental stone to obtain dies for interim restorations. Group 1 interim crowns were fabricated using polymethylmethacrylate resin. Impressions were made with polyvinyl siloxane putty and poured in Type IV gypsum. The cast was scanned, and 3D printed casts were obtained. Interim crowns were designed using stereolithography (ProJet 6000, 3D Systems) with light-cure biocompatible resin (VisiJet SL Clear). Printing parameters included 50 µm layer thickness, 405 nm wavelength, and 2.40 s curing per layer. Post-printing, crowns were cleaned in 99% isopropyl alcohol, dried with compressed air, and UV-cured for 90 s. Eight interim restorations were fabricated for each group.

Results

Group 1(PMMA) had the highest mean value (53.66 ± 13.18 µm) while Group 2 (Bis-GMA) showed 44.45 ± 8.67 µm. Group 3 (3D-printed resin) showed the least discrepancy (28.93 ± 3.35

μm).

Minimal overlap in confidence intervals indicated significant differences.

Overall, Group 1 showed the greatest marginal gap. Group 3 demonstrated the best marginal fit among all groups. 3D-

printed restorations showed better adaptation than PMMA.

The SMD was 24.73 (95% CI: 12.61–36.84) in favor of 3D-printed resins. Comparison with Bis-GMA also showed significance (SMD –15.52; $p < 0.05$).

Conclusion : Within the limitation of the study, the following conclusions drawn were that the marginal adaptation of digitally fabricated interim crown is superior when compared to manually fabricated interim crown and the interim crowns fabricated from 3D-printed resins have better adaptation when compared to polymethylmethaacrylate resin, bisphenol A-glycidyl methacrylate resins. Hence, they can be used as a reliable alternative to other resins.

Introduction

Provisional crowns and fixed dental prostheses (FDPs) are an integral part of fixed prosthodontics. They serve important functions in aesthetics, pulp protection, gingival tissue management, maintaining tooth position, and facilitating diagnosis and treatment planning. Provisional crowns protect vital tissues of prepared teeth and the surrounding periodontium.[1]

Besides meeting biologic and biomechanical requirements, provisional restorations provide valuable diagnostic information. They act as a functional and esthetic try-in, serving as a prototype for the definitive prosthesis.[2] According to Shillingburg, an ideal provisional restoration should protect pulp and periodontium, prevent tooth movement, maintain harmonious occlusion, and allow for hygienic maintenance.[3]

They should also be esthetically pleasing, biocompatible, and capable of maintaining gingival health and emergence profile without inducing pathosis. Essential requirements include proper marginal adaptation, low thermal conductivity, and adequate mechanical properties such as strength, fracture resistance, and wear resistance.[4]

When selecting a material, clinicians must consider physical properties (flexural strength, hardness, wear resistance, dimensional stability, shrinkage, color stability), handling properties (mixing and setting time, ease of trimming and repair), patient acceptance (smell, taste), and cost.[5]

Over time, various techniques for provisional restoration fabrication have evolved—from conventional resin-based methods to digital CAD/CAM workflows.[6] Conventional methods utilize PMMA, PEMA, bis-acrylic, and dimethacrylate resins, applied either directly chairside or indirectly in the laboratory.[7–8]

PMMA resins are inexpensive and widely used but show disadvantages such as high polymerization shrinkage, poor stain resistance, and heat generation during curing. These shortcomings are reduced in bis-acrylic resins, introduced in the late 1990s.[9] Bis-acryl composite resins contain divinyl methacrylate monomers and fillers, offering reduced shrinkage, less exothermic reaction, and improved color stability compared to PMMA.

They are often supplied in automix syringes, allowing easy handling and reducing air entrapment, though at higher cost. They are suitable for most interim restorations and demonstrate superior abrasion resistance, esthetics, lower marginal misfit, reduced monomer elution, and better repair potential.[10]

The accuracy of FDPs depends on impression-making, master cast fabrication, and prosthesis manufacturing. The final impression is crucial for a well-fitting restoration.[11] Optical impressions have been shown to be more time-efficient, operator-friendly, and capable of producing restorations with marginal gaps under 120 μm for single units and short FDPs.

Although digital technology is advancing, physical models remain necessary for contouring, finishing, and evaluating occlusion and proximal contacts, especially in complex or esthetic cases. Thus, analog, digital, and hybrid workflows continue to rely on working models.[12]

Accurate working models reduce framework misfit, improving prosthesis longevity. Traditionally, stone models poured from conventional impressions were considered the gold standard, but these workflows are time-consuming, labor-intensive, and prone to errors from multiple steps.[13]

CAD/CAM introduced alternative methods such as milling and 3D printing. Milling creates precise shapes by grinding resin blocks based on CAD designs, but it generates material waste, depends on bur size, and causes bur wear during large-scale fabrication.

To overcome these limitations, 3D printing has gained popularity as an additive technique. It allows fabrication of accurate, standardized prostheses and models with minimal waste and greater efficiency.[14]

Among available technologies, stereolithography (SLA) is the earliest and most widely used. It uses UV laser scanning to cure photopolymer resin layers sequentially, producing accurate and reproducible dental models. The advantages of 3D printing include reduced fabrication time, improved standardization, and cost-effectiveness.[15]

Therefore, the present study aims to compare and evaluate the marginal adaptation of interim restorations fabricated using polymethylmethacrylate resin, bisphenol A-glycidyl methacrylate resin, and photopolymer resin.

Materials & Methods

Methodology

The study was conducted in the Department of Prosthodontics and Crown & Bridge, I.T.S Dental College, Ghaziabad, with prior ethical approval. The aim was to compare marginal adaptation of interim restorations fabricated with PMMA resin, bis-GMA resin, and photopolymer resin.

Sample Size

Sample size was calculated as 24 using power analysis ($\alpha = 0.05$, power = 95%). Expected SDs were 0.016 ± 0.007 (Group 1) and 0.004 ± 0.006 (Group 2). Final distribution: 8 samples per group. Statistical analysis used one-way ANOVA with Tukey's post hoc test.

Tooth Preparation and Indexing

A mandibular first molar typodont tooth was prepared for an all-ceramic crown with 1.5 mm occlusal reduction and 1 mm chamfer finish line. A putty index of the unprepared tooth was made as a reference guide. Master models were fabricated in Type IV gypsum to prepare stone dies.

Grouping

- Group 1 (PMMA): Impressions were made with PVS putty and poured in Type IV gypsum. Casts were scanned, and 3D printed models obtained. Interim crowns were fabricated using PMMA resin.
- Group 2 (Bis-GMA): Impressions made and poured in gypsum; 3D printed casts obtained. Material dispensed into preformed putty index and seated on stone model. Vertical reference lines ensured accurate seating. Excess trimmed; finishing and polishing done with acrylic kit.
- Group 3 (Photopolymer Resin): Similar protocol followed; provisional crowns fabricated using SLA 3D printer with photocurable resin. Printing parameters: 50 µm layer thickness, 405 nm wavelength, 2.40 s exposure per layer, orientation at zero. Post-processing involved isopropyl alcohol bath (60 s), air-drying, and UV curing (90 s).

Marginal Adaptation Assessment

Adaptation was assessed under a stereomicroscope in micrometers (µm). Marginal gaps were evaluated at buccal, mesial, distal, and lingual sites between crown margins and CEJ. Each sample was stabilized in a mold for standardized imaging.

Scanning parameters: 130 kV X-ray energy, 60 µA source current, 300 ms exposure, 0.25 mm brass filter, 0.2° rotation step over 360°, frame averaging = 4. Average scan time = 1.5 h.

3D reconstruction used slice thickness 14 µm with 10,890 slices. Image enhancement included artifact reduction (6%), hardening correction (25%), and Gaussian smoothing (level 2). Images saved in 16-bit TIFF format.

Digital analysis was carried out with Geomagic software, using zoom/rotation for landmark visualization. Measurements were taken between prepared tooth surfaces and inner crown surfaces.

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Statistical Analysis

The data were analyzed using SPSS version 23. Absolute errors were computed as the difference between measured and reference values. Normality of data distribution was assessed using the Kolmogorov–Smirnov test and normality plots. Descriptive statistics including mean and standard deviation (SD) were calculated, where the arithmetic mean was obtained as $\Sigma x/N$ and SD as $\sqrt{(\Sigma(x - \bar{x})^2 / N)}$. To compare differences among groups, a one-way ANOVA was performed with the null hypothesis (H0) stating equal population means ($\mu 1 = \mu 2 = \ldots \mu m$) against the alternative (H1) of at least one differing mean. The grand mean (xGM) was calculated, followed by determination of total sum of squares (TSS), partitioned into between-group (SSB) and within-group (SSW) components. These were divided by respective degrees of freedom to obtain mean squares (MS), and the F-statistic (MSB/MSW) was used to test significance at a 5% level. Upon finding significant differences, Tukey's post hoc test was applied, where the honest significant difference (HSD) based on the studentized range (q) was used to evaluate pairwise mean differences.

Figure 1: Typodont model

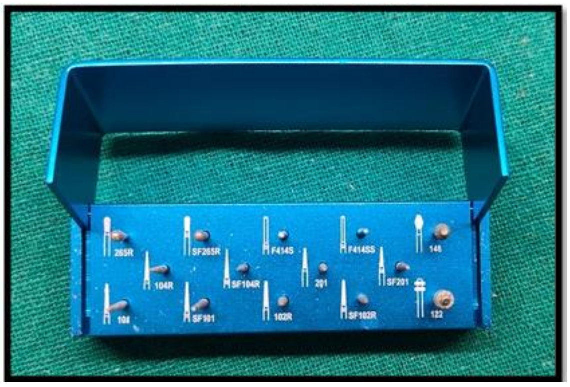

Figure 2 Crown preparation kit

Figure 3 Desktop scanner

Figure 4 3D printer

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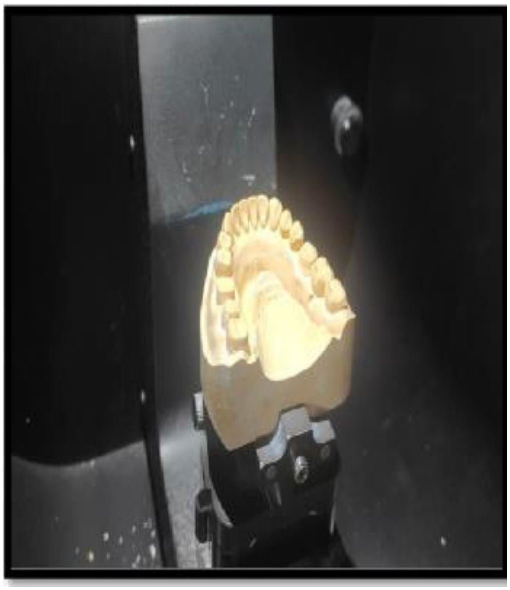

Fig5 Scanning of cast with desktop scanner

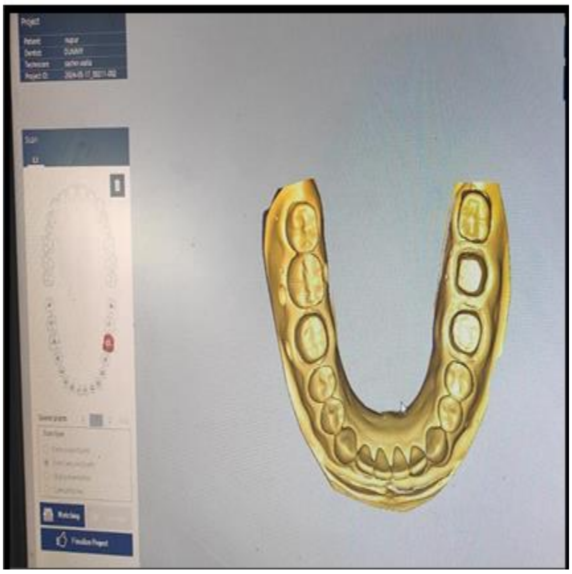

Figure 6 Designing of prepared tooth

Figure 7 Printing of the cast

Figure 8 Stereomicroscope

Results

The current in vitro study to compare and evaluate marginal adaptation of interim restorations fabricated with polymethylmethaacrylate resin, bisphenol A-glycidyl methacrylate resin and photopolymer resin. Data was analyzed using SPSS software version 23. Level of significance was set at 5%. Data was assessed for normality testing using Shapiro Wilks test. Results showed that the data was following the normal distribution. One-way analysis of variance (ANOVA) was used to assess mean among the groups followed by post hoc pairwise comparison test.

Table1: Comparison of mean of marginal adaptation among groups (Buccal Side)

	N	lea n	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimu m	
					Lower Bound	Upper Bound		ximu m
Group 1	8	54.9 62	15.4047	5.4464	42.084	67.841	32.3	71.8
Group 2	8	48.5 00	12.5176	4.4257	38.035	58.965	30.6	67.6
Group 3	8	29.6 00	3.6233	1.2810	26.571	32.629	25.2	35.2

Table 1 compares the mean of marginal adaptation among the three groups. The mean was highest in Group 1 and least in Group 3. The overall difference in the mean was significant.

Table 2 Intergroup comparison of marginal adaptation among all groups using post hoc test

(I) Group	(J) Group	Difference (I-J)	Std. Error	P value	95% Confidence Interval	
					Lower Bound	Upper Bound
Group 1	Group 2	6.4625	5.8247	.839	-8.690	21.615
	Group 3	25.3625*	5.8247	.001	10.210	40.515
Group 2	Group 1	-6.4625	5.8247	.839	-21.615	8.690
	Group 3	18.9000*	5.8247	.012	3.748	34.052
Group 3	Group 1	-25.3625*	5.8247	.001	-40.515	-10.210
	Group 2	-18.9000*	5.8247	.012	-34.052	-3.748
*. The mean difference is significant at the 0.05 level.						

Post hoc Tukey test;*indicatesasignificantdifferenceatp≤0.05

In Table 2, a pairwise comparison of means of marginal adaptation showed that the mean difference in Group 3 was significantly greater than Group 2 and Group 1 and Group 3 there was highly significant difference between groups.

Table3: Comparison of mean of marginal adaptation among groups (Lingual Side)

					dence Interval for Mean			
					Lower Bound	Upper Bound		

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	N	Mean	Std. Deviation	Std. Error			Minimum	Maximum
Group 1	8	50.425	14.7899	5.2290	38.060	62.790	34.3	75.6
Group 2	8	48.075	12.4712	4.4092	37.649	58.501	34.3	68.9
Group 3	8	31.612	5.4347	1.9214	27.069	36.156	25.3	39.5

Table 3 compares the mean of marginal adaptation among the three groups. The mean was highest in Group 1 and least in Group 3. The overall difference in the mean was significant.

Table 4 Intergroup comparison of marginal adaptation among all groups using post hoc test

(I) Group	(J) Group	Difference (I-J)	Std. Error	P value	95% Confidence Interval	
					Lower Bound	Upper Bound
Group 1	Group 2	2.3500	5.8009	1.000	-12.740	17.440
	Group 3	18.8125*	5.8009	.012	3.722	33.903
Group 2	Group 1	-2.3500	5.8009	1.000	-17.440	12.740
	Group 3	16.4625*	5.8009	.030	1.372	31.553
Group 3	Group 1	-18.8125*	5.8009	.012	-33.903	-3.722
	Group 2	-16.4625*	5.8009	.030	-31.553	-1.372
*. The mean difference is significant at the 0.05 level.						

Post hoc Tukey test;*indicatesasignificantdifferenceatp≤0.05

In Table 4, a pair wise comparison of means of marginal adaptation showed that the mean difference in Group 3 was significantly greater than Group 2 and Group 1 and comparable of Group 1 and Group 2.

Table 5: Comparison of mean of marginal adaptation among groups (Mesial Side)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Group 1	8	49.388	11.1483	3.9415	40.067	58.708	33.5	65.7
Group 2	8	37.775	7.1994	2.5454	31.756	43.794	29.7	50.2
Group 3	8	21.450	1.9198	.6788	19.845	23.055	18.7	24.3

Table 5 compares the mean of marginal adaptation among the three groups. The mean was highest in Group 1 and least in Group 3. The overall difference in the mean was significant.

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Table 6 Intergroup comparison of marginal adaptation among all groups using post hoc test

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval	
					Lower Bound	Upper Bound
Group 1	Group 2	11.6125*	3.8708	.020	1.543	21.682
	Group 3	27.9375*	3.8708	.000	17.868	38.007
Group 2	Group 1	-11.6125*	3.8708	.020	-21.682	-1.543
	Group 3	16.3250*	3.8708	.001	6.256	26.394
Group 3	Group 1	-27.9375*	3.8708	.000	-38.007	-17.868
	Group 2	-16.3250*	3.8708	.001	-26.394	-6.256
	*. The mean difference is significant at the 0.05 level.					

Post hoc Tukey test;*indicates asignificantdifferenceatp≤0.05

In Table 6, a pairwise comparison of means of marginal adaptation showed that the mean difference in Group 3 was significantly greater than Group 2 and Group 1 and Group 3 there was highly significant difference between groups.

Table7: Comparison of mean of marginal adaptation among groups (Distal Side)

Group	N	Mean	Std. Deviation	Std. Error	dence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Group 1	8	59.875	13.0069	4.5986	49.001	70.749	38.9	72.8
Group 2	8	43.475	4.6036	1.6276	39.626	47.324	37.3	49.7
Group 3	8	33.062	3.8213	1.3510	29.868	36.257	28.3	38.9

Table 7 compares the mean of marginal adaptation among the three groups on the distal side. The mean was highest in Group 1 and least in Group 3. The overall difference in the mean was significant.

Table 8 Intergroup comparison of marginal adaptation among all groups using post hoc test

(I) Group	(J) Group	Difference (I-J)	Std. Error	P value	95% Confidence Interval	
					Lower Bound	Upper Bound
Group 1	Group 2	16.4000*	4.1330	.002	5.649	27.151
	Group 3	26.8125*	4.1330	.000	16.061	37.564
Group 2	Group 1	-16.4000*	4.1330	.002	-27.151	-5.649

	Group 3	10.4125	4.1330	.060	-.339	21.164
Group 3	Group 1	-26.8125*	4.1330	.000	-37.564	-16.061
	Group 2	-10.4125	4.1330	.060	-21.164	.339
*. The mean difference is significant at the 0.05 level.						

Post hoc Tukey test;*indicates asignificantdifferenceatp≤0.05

In Table 8, a pairwise comparison of means of marginal adaptation showed that the mean difference in Group 3 was significantly greater than Group 2 and Group 1 and Group 3 there was highly significant difference between groups.

Table 9: Comparison of mean of marginal adaptation among groups

Group	N	Mean	Std. Deviation	Std. Error	dence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Group 1	8	53.6625	13.18122	4.66026	42.6427	64.6823	34.75	71.48
Group 2	8	44.4562	8.67763	3.06800	37.2016	51.7109	33.25	57.38
Group 3	8	28.9313	3.35090	1.18472	26.1298	31.7327	24.78	34.22

Table 9 compares overall mean of marginal adaptation among three groups. The mean was highest in Group 1 and least in Group 3. The overall difference in the mean was significant.

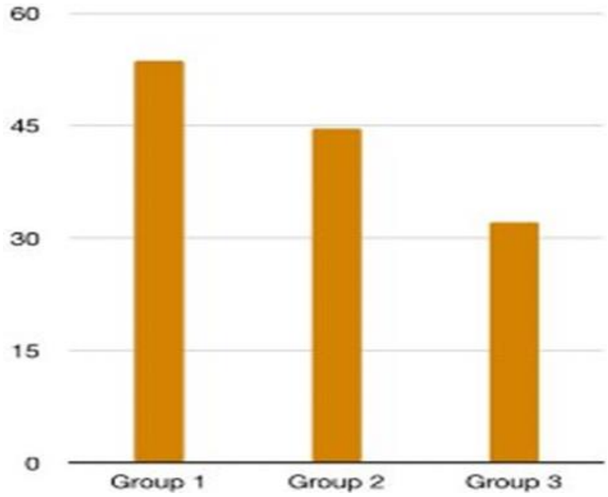
Table 10 Intergroup comparison of marginal adaptation among all groups using post hoc test

(I) Group	(J) Group	Difference (I-J)	Std. Error	P value	95% Confidence Interval	
					Lower Bound	Upper Bound
Group 1	Group 2	9.20625	4.65720	.184	-2.9088	21.3213
	Group 3	24.73125*	4.65720	.000	12.6162	36.8463
Group 2	Group 1	-9.20625	4.65720	.184	-21.3213	2.9088
	Group 3	15.52500*	4.65720	.009	3.4100	27.6400
Group 3	Group 1	-24.73125*	4.65720	.000	-36.8463	-12.6162
	Group 2	-15.52500*	4.65720	.009	-27.6400	-3.4100
*. The mean difference is significant at the 0.05 level.						

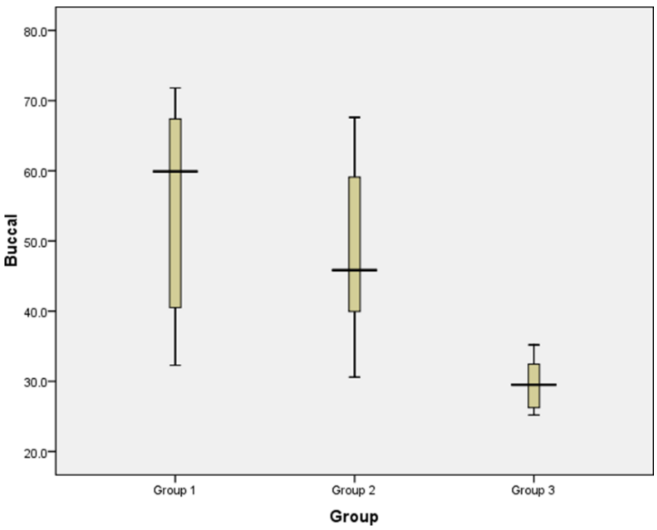
Post hoc Tukey test;*indicates a significant difference at p≤0.05

InTable10,a pairwise comparison of means of marginal adaptation showed that the mean difference in Group 3 was significantly greater than Group 2 and Group 1 and Group 3 there was highly significant difference between groups.

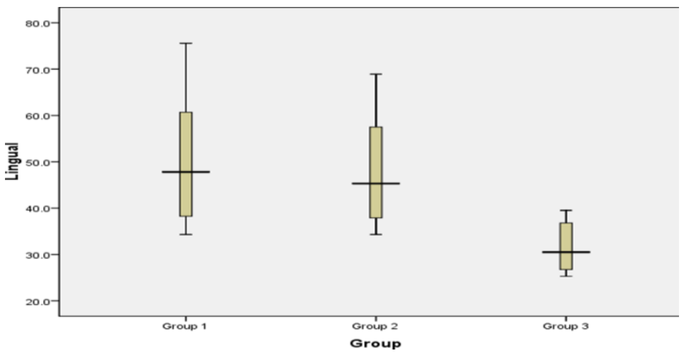
Graph 1 Comparison of marginal adaptation among the groups



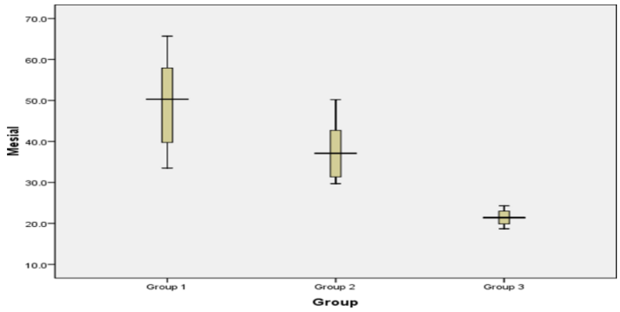
Graph 2 Comparison of marginal adaptation of the 3 groups from buccal aspect



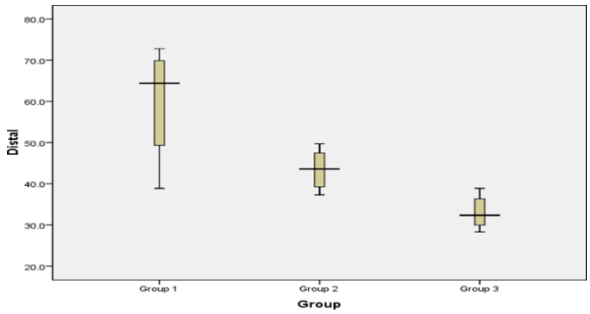
Graph 3 Comparison of marginal adaptation of the 3 groups from lingual aspect



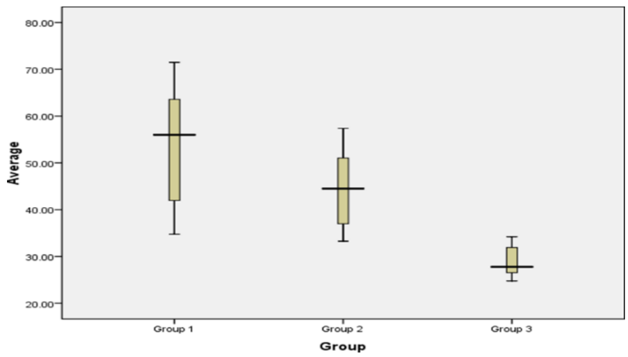
Graph 4 Comparison of marginal adaptation of the 3 groups from mesial aspect



Graph 5 Comparison of marginal adaptation of the 3 groups from distal aspect



Graph 6 Comparison of marginal adaptation of the 3 groups



Discussion

Digital fabrication techniques have gained popularity recently and have efficiently substituted for conventional ones. These techniques allow for the fabrication of restorations with virtual models and dies using the CAD software without the need for a working model, along with digital manufacturing (CAM), whether subtractive (milling) or additive (3D printing) techniques. However, in some cases, a working model is still essential during the digital workflow. In the present study, the marginal adaptation of interim crowns

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fabricated with three-dimensional (3D) printed, polymethylmethaacrylate resin, bisphenol A-glycidyl methacrylate resin were compared. Numerous studies have been performed on the marginal adaptation of interim crowns fabricated with three-dimensional (3D) printed, polymethylmethaacrylate resin, bisphenol A-glycidyl methacrylate resin but data regarding their comparison is lacking. A well-fabricated provisional prosthesis should have a precise marginal fit in order to minimize the microleakage, protecting the pulp of the prepared tooth and minimizing bacterial accumulation at the margins of the restoration, thus preventing the inflammation of the soft tissues around the tooth and the implant-supported restorations. The provisional restoration is employed in-between from the time of tooth preparation till final cementation is done. To ensure a successful final restoration, a suitable fabricated provisional restoration is important, which becomes even more crucial in cases of full mouth rehabilitations.[30] The marginal adaptation of 3D-printed provisional restoration was higher when compared with polymethylmethacrylate resin provisional restoration. The overall SMD was 24.73 (12.61to 36.84) in favor of 3D-printed provisional resins. Similarly lower marginal discrepancies were reported for Group 3wherein 3D-printed provisional restoration when compared to Group 2 bis-acrylic provisional resins. The pooled SMD was -15.52 (−27.64 to −3.41) in favor of 3D-printed methacrylate oligomers and was statistically significant ($p < 0.05$).Similar findings were reported in the study conducted by Peng et al [31] which explored how fabrication methods affect adaptation. This is likely due to shrinkage during manual fabrication. The high marginal discrepancy for the chamfer finish line could be due to the topography of the chamfer finish line having a curved axiogingival line angle, which can increase the chances of stair stepping errors during the incremental layer pattern of buildup in 3D printing. Alharbi et al reported that the fabrication method of provisional restoration has more effect on the marginal fit as compared to the type of finish line. Karasan et al.[32] compared two different brands of 3D-printed methacrylate oligomers and reported lower marginal discrepancies when compared to conventional bis-acrylic provisional resins. However, Sampaio et al.[33] reported higher marginal discrepancies for provisional crowns fabricated with 3D printed resins when compared to those fabricated using conventional PMMA and bis-acrylic provisional resins. The marginal discrepancies were highest in provisional restorations fabricated using conventional 50 techniques and materials. Even though there were differences in marginal discrepancies in provisional restorations fabricated using different materials and techniques, they were within the clinically acceptable limit of less than 120 µm for most of the studies.[2,5] Contradicting results were reported by Savencu et al.[35] They found that the best vertical marginal gap values were obtained for the milled metal copings, followed by the 3D printed ones. They declared that the decreased accuracy of the 3D printed copings is due to the accumulation of errors at different stages of fabrication, the design segmentation by the printing software, processing, and during the printing process itself. The shrinkage during building and post-curing led to a more considerable marginal discrepancy. Conventional provisional resins exhibit high volumetric polymerization shrinkage (higher with PMMA as compared to acrylic-based composite resins). They also involve manual trimming of excess material and removal during the setting time, leading to distortion and, thus, exhibiting poor marginal and internal adaptation when compared to 3D-printed provisional crowns.[9] In 3D printing, there is an incremental layering process, which reproduces details accurately and compensates for polymerization shrinkage. Sidhom et al[36] compared fabrication methods and revealed that 3D-printed provisional most accurate fit along the edges. Studies have reported that the process of placement and cementation of the prosthesis can lead to variations and may cause bias in the outcome. Some additive techniques may cause certain problems, such as the staircase effect on the finished product due to the layer by-layer technique, the nonhomogenous shrinkage, and the extensive postprocessing of the porous structures. Finally, in spite of improving the speed and precision of fabrication, many additive methods fail to provide the accuracy and reproducibility necessary for some dental restorations.[37] Evidence has shown that increasing accuracy would slow the production speed. The accuracy of fabricated products has also been reported to be influenced by the thickness of the print layer and the printer model. The limitations of this study include failing to reproduce clinical situations fully, namely saliva, patient

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movement, and anatomical features (tongue, lips, and cheeks) during scanning and designing. In addition, the scanner used during the digitalization of the tested models was not an industrial "reference scanner". The present study was limited to analyzing the fit of single provisional crown. Moreover, the present study investigated the accuracy of SLA 3D printing technology only. Finally, the provisional restorations were not tested after aging and thermocycling. Therefore, further research should be conducted with simulated oral environmental and clinical factors. Additionally, investigating the fit of long-span FDPs and in oral rehabilitation cases is recommended. Finally, the upcoming studies should test 3D printing technologies other than the tested SLA technology. [51]

CONCLUSION

The present study was conducted to evaluate and compare the marginal adaptation of interim restorations fabricated with polymethylmethaacrylate resin, bisphenol A-glycidyl methacrylate resin and photopolymer resin. Within the limitation of the study, the following conclusions drawn were:

1. The marginal adaptation of digitally fabricated interim crown is superior when compared to manually fabricated interim crown.
2. Interim crowns fabricated from 3D-printed resins have better adaptation when compared to polymethylmethaacrylate resin, bisphenol A-glycidyl methacrylate resins. Hence, they can be used as a reliable alternative to other resins.

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