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An *In vitro* Comparative Evaluation of Marginal Integrity and Axial Wall Adaptation of Provisional Restorations Fabricated by CAD/CAM with those Fabricated Manually

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Abstract: ***Aim: The aim of this study was to evaluate and compare marginal integrity and axial wall adaptation of provisional restorations fabricated by CAD/CAM with those fabricated manually. Materials and Methods: Thirty provisional crowns were prepared from CAD/CAM, light cure and self cure temporization material. They were sectioned mid bucco-lingually. Marginal integrity and axial wall adaption was evaluated at three different points on a 40x stereomicroscope. Results: Statistical difference was found between the marginal integrity and axial wall adaptation of CAD/CAM crowns when compared to other manually fabricated provisional restorations (P<0.001). Lowest Marginal discrepancy and better axial wall adaptation was found with CAD/CAM followed by Light cure and then self cure. Conclusion: Within the limitations of this study, it can be concluded that CAD/CAM provisional crowns showed better marginal integrity and axial wall adaptation than manually fabricated provisional restorations and thus, can be thought for long term purposes.***

Keywords: Provisional restoration, CAD/CAM, marginal integrity, axial wall adaptation

1. Introduction

Fixed Prosthodontics is the branch of Prosthodontics concerned with the replacement and/or restoration of teeth by artificial substitutes that cannot be removed from the mouth by the patient.[1] Fixed Prosthodontic treatment, whether involving complete or partial coverage and natural tooth or dental implant abutments, commonly relies on indirect fabrication of definitive prostheses within the dental laboratory. Historically, the necessity for the provisional treatment has been primarily derived from this methodological process.[2] Provisional or interim restorations are the essential components of Fixed Prosthodontic treatment. According to Glossary of Prosthodontic Terms, provisional restoration can be defined as "a fixed prosthesis, designed to enhance aesthetics, stabilization and/or function for a limited period of time, after which it is to be replaced by a definitive prosthesis."[3]

Provisional restorations are thus necessary to protect dental surfaces from biological, mechanical, and physical effects until the definitive restoration can be cemented. These prostheses may be for short-term or long-term purposes.[4]Long-term provisional restorations are necessary for oral implantation treatment or in situations involving comprehensive occlusal reconstruction, where the restorations could face extended functional loading.[5]

Polymethylmethacrylate (PMMA) resins and composite-based resins (CBR) are the most commonly used materials to fabricate provisional restorations.[6] PMMA resins have showed several deficiencies. Previous studies have reported polymerization shrinkage and marginal discrepancies with these materials. The danger of pulpal damage because of exothermic reaction of polymerization has been equally documented as has sensitivity of the periodontium to the contour and fit of provisional restorations. However, these problems are associated primarily with direct methods of fabrication. It is beneficial to fabricate provisional restorations indirectly on casts made from impressions of prepared teeth.[7]

Bis-acryl, based on multifunctional methacrylicacid esters, has similar properties to those of conventional materials and is also used in the direct technique.[4]In comparison, bis-acryl-based provisional restorative materials are easier to manipulate thanks to their cartridge-based dispensing system, which enables a more accurate and consistent mixture, while also offering low polymerization shrinkage, a less exothermic reaction and minimal pulpal irritation.[8]

Using computer-aided design/computer-aided manufacturing (CAD/CAM) to fabricate these provisional prostheses is of interest because CAD/CAM provisional treatments eliminate patient discomfort. Moreover, CAD/CAM provisional materials are prefabricated from industrially polymerized

blocks, which prevents the heat of polymerization and shrinkage of the material.[9]

During the interim between the preparation and the placement of the final prosthesis, treatment or temporary restorations must promote soft tissue healing. Gingival overgrowth and inflammation are minimized by well-contoured treatment restorations with good marginal integrity.[10]Thus marginal fit of an interim crown should be as precise as the definitive restoration to prevent irritation or inflammation of the periodontal/pulpal tissues and to ensure an aesthetically satisfactory outcome.[4] However, there is little information available in the dental literature concerning the marginal integrity and axial wall adaptation of CAD/CAM provisional restorations. Hence study was planned to evaluate and compare marginal integrity and axial wall adaptation of provisional restorations fabricated by CAD/CAM with those fabricated manually.

2. Materials and methods

Ethical committee approval and study design:
This study was carried out in the Department of Prosthodontics, SMBT Dental College and Hospital, Sangamner Maharashtra, India, in 2018-2019. Ethics was granted by the Institutional Ethical Committee and research board approval. The study design is *in vitro* experimental type of study.

Preparation of master model
A mandible first molar was prepared to receive a ceramic fixed restoration with a 1.5-mm occlusal reduction, 1-mm round finish line, and 6-degree convergence angle. The prepared tooth was embedded in an epoxy resin base (Tri-Epoxy; Keystone Industries, Germany). An addition silicone impression (Aquasil; Zhermack, Italy) was made of the whole assembly and poured to fabricate epoxy resin dies (Tri-Epoxy dies, Keystone Industries, Germany). Thirty such dies were made, ten for each group.

Procedure
One of the die was scanned (S 50 Zenotec CAD; Wieland Dental, Germany) to produce a CAD model for a complete mandibular molar. Two silicone indices were made of the produced CAD model with polyvinyl siloxane (Hydrorise putty; Zhermack, Italy). These indices were used as templates for the other groups.

GROUP A: In the autopolymerizing temporary resin group, cocoa butter was applied to the dies to prevent the interim material from adhering. According to the manufacturer's instructions, acrylic resin (Alike; GC Europe) powder and liquid were and loaded into the index and placed on the dies until completely set. The crowns were then removed, finished, and polished using rotary rubber cups (Komet Dental Gebr Brasseler GmbH, Germany).

GROUP B: In the light cure temporary resin group, the die was lubricated with cocoa butter. The light cure material was adapted onto the die over which the index was kept and light cured. The interim crowns were allowed to set completely finished and polished as previously described.

GROUP C: In the CAD/CAM group molars were milled from a CAD/CAM PMMA block (Telio CAD; DeguDent GmbH, Germany).

Zinc oxide-based interim cement (RelyX Temp NE; 3M ESPE, Germany) was mixed on a waxed paper pad, and a plastic filling instrument was used to fill each interim restoration, which was seated in its corresponding epoxy die. Excess cement was removed with a cotton pellet after 10 minutes under a 17.8 N load to simulate the force generated when constant finger pressure is applied on an interim crown intraorally.

Thermo cycling (Willytec Thermcycler) was carried out for 100 cycles between 5_C and 55_C (±2_C) with a 30-second dwell time to simulate a clinically relevant 10-week intraoral duration. After thermo cycling, the dies were placed in 0.5% acid fuschin for 24 hours to evaluate micro leakage. The dies were then sectioned from mid buccal to mid ligual. The marginal discrepancy was measured at 3 points, A- 3mm from the bucco-occlusal margin, B- mid bucco-lingually, C- 3mm from the lingua-occlusal margin to standardize all samples. The cut sections were examined under stereo microscope of 40x to evaluate the die penetration and results were obtained.

3. Results

Table 1: Descriptive statistics for Mean Marginal Integrity (Average) among three groups

	(I) Group	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
MI Avg	Group A Cool Temp	10	.143000	.0191775	.0060645	.1200	.1750
	Group B Revotek LC	10	.128500	.0363662	.0115000	.1050	.2300
	Group C Telio CAD temp	10	.046000	.0242441	.0076667	.0200	.0600
	Total	30	.105833	.0509409	.0093005	.0200	.2300

Table 2: Comparison of Adaptation (Average) among three groups by ANOVA (Analysis of variance)

	ANOVA					
		Sum of Squares	df	Mean Square	F	Sig.
MI Avg	Between Groups	.055	2	.027	36.052	<0.001*
	Within Groups	.021	27	.001		
	Total	.075	29			

*Statistically significant

Table 3: Pair wise comparison of Marginal Integrity (Average) among three groups by Tukey's Post hoc Test.

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig p Value	95 % Confidence Interval	
					Lower Bound	Upper Bound
Group A Cool Temp	Group B Revotek LC	.0145000	.0123236	.477	-.016055	.045055
Group A Cool Temp	Group C Telio CAD temp	.0970000*	.0123236	<0.001*	.066445	.127555
Group B Revotek LC	Group C Telio CAD temp	.0825000*	.0123236	<0.001*	.051945	.113055

*Statistically significant

A sample size of 30 crowns (n=10) was statistically calculated from the data obtained from the previous studies making it 10 samples for each group. Previous in vitro studies of interim crowns comparing marginal integrity and axial wall adaptation found statistically significant differences among various types of crowns. After obtaining stereomicroscope results, the data was statistically evaluated and a statistically significant difference was found between the CAD/CAM provisional crowns and the conventionally made crowns for marginal integrity and axial wall adaptation with p value <0.001.

A statistically significant difference was found among the 3 types of crowns when the marginal discrepancy was measured (F [36.052]; P<.001 1-way ANOVA) (Table. 2). Mean difference of CAD/CAM provisional crowns was 0.046 which is far more less than Cool temp with 0.143 and Revotec LC with 0.128 clearly stating that the marginal adaptation of CAD/CAM was better followed by Light cure followed by self cure material . Furthermore, Inter group pair wise comparison was done between the three groups by Tukeys Post Hoc test .(Table no.3) No statistical difference was found between group A and group B with a p value more than 0.5 Although a statistical difference was found between Group A & Group C and Group B & Group C .

Table 4: Descriptive statistics for Adaptation (Average) among three groups

Avg	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Cool Temp	10	2.0480000	.37296013	.11794035	1.50667	2.66667
Revotek LC	10	1.9496667	.28661261	.09063487	1.59333	2.51000
Telio CAD temp	10	.0486667	.02515139	.00795357	.01667	.08000
Total	30	1.3487778	.97201512	.1146487	.01667	2.66667

Table 5: Comparison of Adaptation (Average) among three groups by ANOVA (Analysis of variance)

ANOVA					
Avg	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	25.403	2	12.701	171.734	<0.001*
Within Groups	1.997	27	.074		
Total	27.400	29			

*Statistically significant

Table 6: Pair wise Comparison of Adaptation (Average) among three groups by Tukey's Post hoc Test.

Multiple Comparisons'						
Dependent Variable: Adaptatiom Tukey HSD						
(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig p Value	95 % Confidence Interval	
					Lower Bound	Upper Bound
Cool Temp	Revotek LC	.09833333	.12162199	.701	-.2032184	.3998851
Cool Temp	Telio CAD temp	1.99933333*	.12162199	<0.001*	1.6977816	2.3008851
Revotek LC	Telio CAD temp	1.90100000*	.12162199	<0.001*	1.5994483	2.2025517
*The mean difference is significant at the 0.05 level.						
a. Point = Point C						

A statistically significant difference was found among the 3 types of interim crowns for the axial wall adaptation (F [171.7]; P<.001; 1-way ANOVA) (Table 4). Mean difference of CAD/CAM provisional crowns for axial adaptation was 0.048 which is far less than Cool temp with 2.048 and Revotec LC with 1.949 clearly stating that the axial wall adaptation of CAD/CAM provisional crowns was better followed by light cure followed by self cure material.

Furthermore, Inter group pair wise comparison was done between the three groups by Tukeys Post Hoc test. No statistical difference was found between group A and group B with a p value more than 0.5. Although crowns made up of self cure acrylising group showed high marginal and axial wall gap as compared to light cure. A statistical difference was found between Group A and Group C and Group B and Group C.

4. Discussion

The hypothesis tested was whether there is a difference between marginal integrity and axial wall adaptation of CAD/CAM-fabricated provisional restorations with those of manually fabricated provisional crowns. Results of the study indicated that there is a difference between marginal

integrity and axial wall adaptation of CAD/CAM-fabricated provisional restorations with those fabricated manually.

Temporary crown and bridge restorations are meant to provide interim protection, mastication, aesthetics, and positional stability while the definitive restoration is being fabricated. "Temporary" and "provisional" are terms used synonymously in dentistry.[11] the most important role that a provisional restoration plays are to stabilize and protect the existing tooth structure after tooth preparation. With the advancements in aesthetic restorative materials, such as composites and ceramics, the provisional materials have also shown marked improvement in terms of strength, aesthetics, and biocompatibility. At present, numerous temporary materials are available in the market for the effective restoration of prepared teeth which fall into two basic types, based on their chemistry with each category having distinct advantages and disadvantages.[12]

Polymethylmethacrylate (PMMA) resins and composite-based resins (CBR) are the most common materials used to fabricate provisional restorations. In this study, Group A and Group B are composite based whereas Group C is PMMA based. PMMA resin possesses satisfactory overall physical properties, including marginal finish and the potential to impart and maintain polish.[13] However, polymerization shrinkage, exothermic setting reaction, and the irritation associated with monomer are among the material's disadvantages and relatively lower levels of finish and fine marginal adaptation have been reported.[14-16] Composite resins have gained popularity because of its ease of manipulation. They have also been reported with low polymerization shrinkage and lack of exothermic reaction. However, the material appears to suffer from inherent brittleness, which makes finishing and polishing difficult.[7]

The disadvantages of chair side fabrication of provisional restorations using Composite or PMMA materials affects the mechanical strength as well as its surface texture and fit, for example, mixing procedures and filling the over impression might lead to incorporation of voids, compromising the mechanical strength.[17-18] CAD/CAM technologies used to fabricate temporaries may solve some of these issues.

The introduction of CAD/CAM has revolutionized modern dentistry. It has led to the evolution of "tooth in a day" restoration. Restorations fabricated by means of CAD/CAM technology are known to be more accurate and stronger with easier manipulation. Similarly, CAD/CAM provisional restorations are predicted to have good mechanical properties, so they may present a solution for long-term/long-span interim restorations where strength and colour stability are required.[19-20] CAD/CAM PMMA block materials are industrially polymerized under optimum manufacturing conditions. Such conditions offer those provisional restoration better mechanical properties than those that are manually fabricated. The good mechanical properties of these materials represent a solution for long-term interim restorations where strength and colour stability are required. Moreover, the improved fit of the milled CAD/CAM products lowers the risk of bacterial contamination of the tooth and prevent damage to the pulp from excessive temperature changes.[21-22]

One of the inherent problems of provisional restorations made directly in the mouth is the marginal discrepancies that may be due to polymerization shrinkage of the material. This problem is significantly more with PMMA provisional materials and is comparatively less with bis-acryl composite resin materials but still poses a problem which was highlighted by Nivedita and Prithviraj in their research.[23] When a satisfactory marginal and internal fit has been achieved following fabrication crowns, it can be considered as a successful process, particularly, if the material can withstand the masticatory forces in oral environment. The marginal adaptation is a crucial aspect, which should be considered carefully. Poor marginal adaptation leads to damage of the surrounding tooth tissues, a situation that deteriorates the complete restoration seriously, causing exposed margins and poor aesthetics.

In the present study, the marginal fit was observed on three surfaces (occlusal, buccal, and lingual). The mean value obtained for the marginal discrepancy of CoolTemp and RevotecLC crowns showed significantly higher marginal discrepancy than those fabricated from TelioCAD provisional blocks ($P < 0.001$). This result was consistent with a study done by Yao *et al*. in which it was found that the CAD/CAM provisional crowns had lower marginal gaps compared to direct provisional crowns.[19]

In the study by Adil Othman Abdullah comparing the internal fit of the provisional crowns showed similar results with CAD/CAM provisional restorations having superior fit and compared to conventionally fabricated provisionals.[4]

One of the limitations of this study is only the vertical component of marginal discrepancy was measured and not the horizontal component. Further clinical studies are required regarding the marginal fit and axial wall adaptation of the provisional materials which may add to a conclusive decision of the present study.

5. Conclusion

Within the limitations of the present in vitro study, the conclusion is in accordance with the expected objectives or hypotheses. It can be concluded that CAD/CAM provisional crowns showed better marginal integrity and axial wall adaptation compared to manually fabricated provisional crowns and can be considered for long term purposes .

6. Financial support and sponsorship

Nil

7. Conflicts of interest

There are no conflicts of interests.

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