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Original Article

Dentistry Section

Comparative Evaluation of Marginal Gap and Flexural Strength of CAD/CAM Milled, 3D Printed and Conventional Chairside Interim 3-unit Fixed Dental Prosthesis: An In-vitro Study

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ABSTRACT

Introduction: Interim prosthesis play an important role in maintaining integrity of abutment tooth till final prosthesis is fabricated. Thus, using different fabrication techniques which can affect the mechanical properties of material can be useful to determine longevity of prosthesis.

Aim: To evaluate the marginal gap and Flexural Strength (FS) of Computer-aided Designing/Computer-aided Milling (CAD/CAM) milled, 3D printed and conventional chairside interim 3-unit Fixed Dental Prosthesis (FDP).

Materials and Methods: The present in-vitro study conducted in the Department of Prosthodontics, Bharati Vidyapeeth Dental College and Hospital, Sangli, Maharashtra, India, for duration of one year and six months between May 2022 to November 2023, 45 dies were fabricated by 3D printing technique. A total of 45 3-unit fixed dental prosthesis were fabricated over these dies by various techniques i.e., CAD/CAM Milled, 3D Printed and Conventional i.e., 15 sample per group I and J. All samples were cemented on dies under 20 N force and were evaluated for marginal gap with stereomicroscope under 40X magnification and assessed in millimetre (mm). Mean of marginal gap at premolar and molar for each sample was evaluated. Thermocycling was carried out for 5,000 cycles in distilled water (5°C and 55°C) in a digitally controlled water-bath chamber. Universal testing machine was used to evaluate FS using "three-point bend test". One-way ANOVA and Post-hoc Tukey's Honest Significant Difference (HSD) test were used for statistical analysis.

Results: On evaluation of marginal gap, a significant difference was noted between the three groups with p-value=0.0006 with 3D printed group showing the most marginal gap. On evaluation of FS, a significant difference was noted between the three groups with p-value=0.0001. On pair-wise comparison, highly statistically significant difference was seen between all groups where CAD/CAM Milled showed greater FS followed by conventional and 3D printed.

Conclusion: The CAD/CAM Milled showed better marginal adaptation and greater FS followed by conventional and 3D printed group.

Keywords: Abutment, Computer-aided designing/Computer-aided milling, Molar, Premolar, Techniques, Temperature

INTRODUCTION

"Necessity is the mother of invention," as Plato appropriately stated, driving digital advancements in a conventional world. This is evident in fixed prosthodontics, where interim restorations withstand oral temperature fluctuations, humidity and masticatory forces until a fixed restoration is fabricated [1,2]. An ideal interim prosthesis should limit movement of abutment, maintain health of the gingiva, protect from heat injury to pulp, be stable under masticatory forces, chemically resistant, biocompatible, aesthetically pleasing, easy to fabricate, offer good marginal adaptation and resist degradation [1,3]. An interim prosthesis is defined as- a "fixed or removable dental prosthesis designed to improve aesthetics, stabilisation and function for a specified period, after which it must be replaced by a permanent prosthesis" given by Glossary of Prosthodontic Terms (GPT) [4].

Despite evolution of fixed prosthesis, interim prosthesis remain inevitable part in clinical situations such as implant loading, orthodontic therapy, endodontic therapy and full mouth rehabilitation, where prolonged use is required [5,6]. An ideal interim material should possess properties like good marginal fit, abrasion resistance, strength, durability, low shrinkage and good polishability [7]. Various materials, including Polymethyl Methacrylate (PMMA), bis-acryl composite resin, Polyethyl Methacrylate (PEMA), polyvinyl methacrylate and visible light-cured Urethane Dimethacrylate (UDMA) are used with PMMA being the most popular [8-10].

Interim prosthesis can be fabricated using various techniques, such as conventional (direct and indirect), CAD/CAM milling and 3D printing. Marginal accuracy and FS are important properties that affect the integrity of interim restorations under functional stresses [11]. Interim crowns must have marginal fit similar to definitive restorations to avoid dentinal sensitivity, gingival irritation and inflammation of pulpal tissue [12,13]. As the oral cavity is subjected to temperature fluctuation, interim prosthesis has to sustain without changing its properties. Thermocycling, which simulates oral temperature variations from 5°C to 55°C, helps predict the longevity of prosthesis by demonstrating the effect of these fluctuations on interim restorative materials [1,11,14].

Fracture is the most common cause of failure in interim fixed partial dentures, facilitating the importance of FS for durability of material [12,15]. FS is particularly important for long-span interim restorations that must withstand bending forces. Various studies suggest that different fabrication techniques affect the properties of prosthesis [1-3,11,14], but there has been limited research on the marginal gap and FS of interim three-unit fixed dental prosthesis fabricated by different techniques [12,15]. The aim of the present study was to evaluate the marginal gap and FS of interim three-unit fixed dental prosthesis fabricated using conventional methods, 3D printing and CAD/CAM milling.

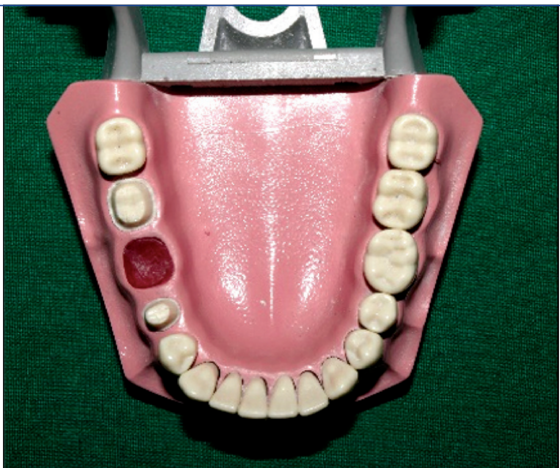
MATERIALS AND METHODS

The present in-vitro study was conducted at Department of Prosthodontics, Crown and Bridge and Implantology; Bharati Vidyapeeth (Deemed to be University) Dental College and Hospital, Sangli, Maharashtra, India for duration of one year and six months between May 2022 to November 2023 with IEC NO-{BV(DU)MC&H/Sangli/Dissertation2021-22/D-66}.

Sample size: A total of 45 samples were fabricated, which were divided into three groups randomly- with 15 samples per group.

Study Procedure

Mandibular first molar was removed from the typodont. Abutments second premolar and second molar were prepared with 1 mm shoulder using flat end tapered fissure diamond bur and the internal line angle was rounded for an idealised 3-unit fixed dental prosthesis. The occlusal reduction was 1.5 mm with 6 degrees of convergence which was achieved with the help of milling machine. (Paraskop M-Bego). As standard reference points for the measurement of samples, points were engraved above the facial and lingual finish line of the prepared 2nd premolar and 2nd molar using a round diamond bur. The socket of mandibular 1st molar was filled with modelling wax (Deepti Dental Products) [Table/Fig-1].



[Table/Fig-1]: Typodont-tooth preparation.

Prepared premolar and molar were scanned (Irific NH-100) and the master die was fabricated by using a CAD software and 3D printing. (Anycubic-Standard Resin) A total of 45 dies were fabricated. Over these 45 dies; 45 3-unit fixed dental prosthesis were fabricated by various techniques i.e., CAD/CAM Milled, 3D Printed and Conventional i.e., 15 sample per group [Table/Fig-2].

[Table/Fig-2]: Cemented interim prosthesis on master model -3D printed FPD, CAD/CAM milled FPD and conventional FPD.

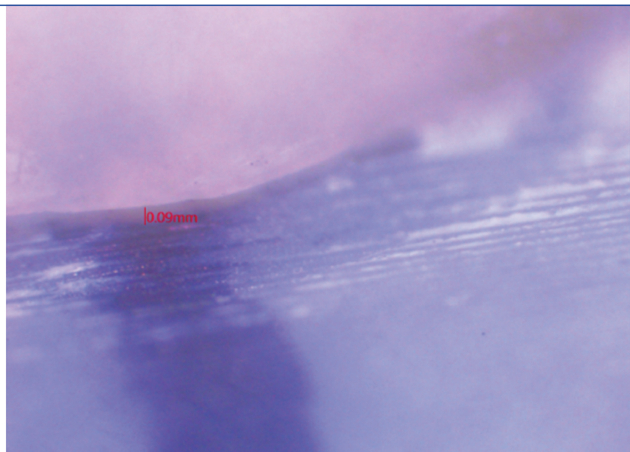
Interim fixed dental prosthesis made from CAD/ CAM (Ruthinium-PMMA milled) and 3D Printing (Jamg HE-C & B-3D Printed resin) was digitally designed. The connector cross-sectional area was designed for Buccolingual (BL) and Mesiodistal (MD) aspects of pontic region.

The connector cross-sectional area for 2nd premolar and 1st molar was 10 mm^2 and for 1st molar and 2nd molar was 12 mm^2. A modified saddle pontic was made. The Standard Tessellation Language (STL) file was generated which was used for designing of interim prosthesis. Scanned data was imported into a CAD/CAM program and milled Fixed Dental Prosthesis (FDPs) were fabricated from CAD-Temp PMMA blocks. A 3D Digital Light Processing (DLP) Printer was used to fabricate specimens from resin material.

Conventional prosthesis were made from Putty index of already fabricated prosthesis with putty and light body (Avue- Dental Avenue). The interim restorative material (Protemp 4 TM -bisacrylic composite) was injected into putty index and allowed to set completely according to manufacturer's instructions. Finishing and polishing was done using handpiece with rotary rubber cups at a speed of 2000-5000 rpm and then checked around for any defect.

Cementation of the interim fixed dental prosthesis to master die was done with non eugenol temporary cement (RelyXTM TEMP NE- 3M ESPE). Cement was mixed according to manufacturer's instructions and held with finger pressure followed by a static load of 20N for 60 seconds using universal testing machine. (Fine Spavy Associate & Engineers Pvt., Ltd.,). Excess cement was mechanically removed from the margins with the help of dental probe or an explorer and floss.

The marginal gap was evaluated at buccal and lingual locations. The reference points were extended with a marker at the finish line and to the inferior edge of the dies of the interim FDPs and with the help of stereomicroscope (Lawrence & Mayo) under 40X magnification marginal gap was measured in millimetre (mm) [Table/Fig-3].



[Table/Fig-3]: Marginal gap analysis under 40X magnification.

All specimens were thermocycled for 5,000 cycles in distilled water (5°C and 55°C, with 10 seconds transfer time and 60 seconds dwell time) in a digitally controlled water-bath chamber (Bio-Technics India) to represent six months of oral environment.

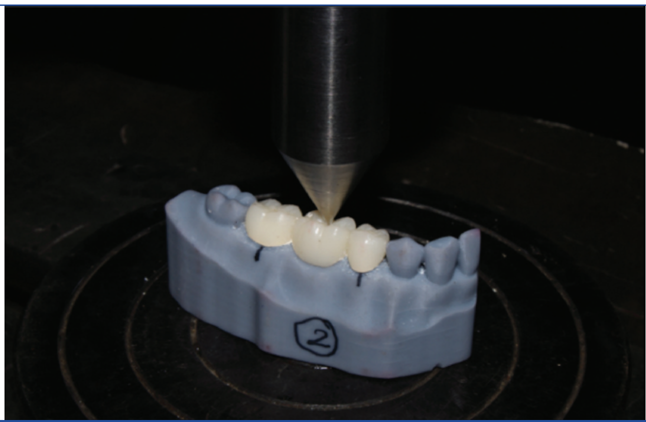
The FS was evaluated by applying vertical load at the center of the specimens with a crosshead speed of 1 mm/min with the help of universal testing machine (Fine Spavy Associate & Engineers Pvt., Ltd.,). Until the specimen got fractured, load was applied [Table/Fig-4]. The maximum load at which the specimen fracture was noted and using the formula FS (s) was calculated in megapascals (MPa)-

Flexural Strength (FS) formula:

$s=3Fd/2wh^2$

where, F (N)=maximum load at fracture;

d (mm)=distance between vertical support spans;



[Table/Fig-4]: Flexural Strength (FS) analysis by universal testing machine.

w (mm)=width measured at the center of the specimen;

h (mm)=height measured at the center of the specimen [11,12].

STATISTICAL ANALYSIS

Microsoft office excel sheet was used to compile data and statistical analysis was done by Statistical Package for Social Sciences Software (SPSS v 26.0, IBM). The depiction of mean and Standard Deviation (SD) for numerical data has been done for descriptive statistics. Shapiro-Wilk test was used to check Normality of numerical data. Parametric tests were been used for comparisons as data followed normal curve. Intergroup comparison (i.e., >2 groups) was done using One-way ANOVA followed by pair-wise comparison using Tukey's post-hoc test. The power to the study was given as 80%, as p<0.05 was considered to be statistically significant, keeping 'α' error at 5% and 'β' error at 20% for all statistical tests.

RESULTS

On marginal gap analysis, cumulative mean and standard deviation for CAD/CAM milled was 0.0667±0.0519, for 3D printed it showed 0.1095±0.0527 and for conventional group it was 0.0715±0.0256, a statistically significant difference was noted between the three groups with p-value=0.0006 [Table/Fig-5].

Group	Mean (mm)	Std. Dev.	Std. Err.	95% CI for mean		F-value	p-value
				Lower	Upper		
CAD/CAM	0.0667	0.0519	0.0095	0.0473	0.0860	8.0927	0.0006*
3D printed	0.1095	0.0527	0.0096	0.0898	0.1292		
Conventional	0.0715	0.0256	0.0047	0.0619	0.0811		

[Table/Fig-5]: Cumulative mean and standard deviation of marginal gap (mm) for three groups and comparison of three groups by one-way ANOVA.

Pair-wise comparison using Post-hoc Tukey's HSD test, between 3D printed and CAD/CAM and 3D printed and conventional showed more marginal gap followed by conventional and CAD/CAM Milled group with p=0.0010* and 0.0050*, respectively [Table/Fig-6].

(I) Group	(J) Group	Mean difference (I-J)	Std. Error	p-value	95% Confidence interval	
					Lower bound	Upper bound
3D printed	CAD/CAM	0.0428	0.0117	0.0010*	0.0150	0.0706
	Conventional	0.0380	0.0117	0.0050*	0.0102	0.0658
CAD/CAM	Conventional	-0.0048	0.0117	0.9100	-0.0326	0.0230

[Table/Fig-6]: Pair-wise comparison of marginal gap (mm) for three groups using Tukey Post-Hoc test.
*p<0.05

On FS analysis, Cumulative mean and standard deviation for CAD/CAM Milled was 49.92±1.42, for 3D printed it showed 22.45±1.88 and for conventional group it was 26.47±1.53, a statistically significant difference was noted between the three groups with p-value=0.0001* [Table/Fig-7].

Group	Means	Std. Dev.	Std. Err.	95% CI for mean		F-value	p-value
				Lower	Upper		
CAD/CAM	49.92	1.42	0.37	49.13	50.70	1257.2656	0.0001*
3D printed	22.45	1.88	0.48	21.41	23.49		
Conventional	26.47	1.53	0.40	25.62	27.32		

[Table/Fig-7]: Cumulative mean and standard deviation for Flexural Strength (FS) (MPa) and comparison of three groups by One-way ANOVA.

On pair-wise comparison using Post-hoc Tukey's HSD test, highly statistically significant difference was seen between all groups where CAD/CAM milled showed greater FS then followed by conventional and 3D printed [Table/Fig-8].

(I) Group	(J) Group	Mean difference (I-J)	Std. Error	p-value	95% Confidence interval	
					Lower bound	Upper bound
3D printed	CAD/CAM	-27.4627	0.5916	0.0001*	-28.9000	-26.0253
	Conventional	-4.0140	0.5916	0.0001*	-5.4513	-2.5767
CAD/CAM	Conventional	23.4487	0.5916	0.0001*	22.0113	24.8860

[Table/Fig-8]: Pair-wise comparisons of three groups for Flexural Strength (FS) (MPa) using Tukey Post-Hoc test.
*p<0.05

DISCUSSION

In the present study, for marginal gap evaluation, CAD/CAM milled FDPs showed the least marginal discrepancy, followed by conventionally fabricated and then 3D printed FDPs. CAD/CAM utilises subtractive manufacturing to mill pre-polymerised resin blocks, while 3D printing uses an additive layer-by-layer technique with liquid resins [16]. The superior fit of CAD/CAM may be attributed to the dense pre-polymerised resin blocks and their stability for long-term use. Studies done by Yao J et al., Abdullah AO et al., and Cheng CW et al., also showed that interim crowns fabricated by CAD/CAM are more superior in internal and marginal fit than Conventional fabricated crown [15,17,18].

On comparative evaluation of marginal gap between 3D printed and conventional, values were statistically significant and Conventional group showed least marginal discrepancy. This can be attributed to fact that efficiency of 3D printed materials is influenced by printer type, thickness of layer, number of layers, Ultraviolet (UV) intensity, printer wavelength, total thickness, die-spacer thickness, post-processing method, build angle and total number of placement of supporting structure [18,19]. Studies done by Mohajeri M et al., and Wu J et al., also showed that 3D printed provisional crowns displayed the greatest marginal discrepancy [20,21].

Contradict to this study Elfar M et al., concluded that the heightened accuracy of 3D printing could be attributed to the incremental layering approach i.e., additive technique during fabrication which ensures the precise reproduction of intricate details, effective compensation for polymerisation shrinkage and a superior marginal fit compared to the milling technique, which can be due to different bur used during milling [22].

On marginal gap evaluation between CAD/CAM Milled and conventional, values were statistically non significant but on mean analysis CAD/CAM milled showed least marginal discrepancy. Marginal gap seen for conventional interim FPD's can be due to high polymerisation shrinkage, more susceptible to dimensional distortion by oral fluids, improper mixing, incorporation of voids by overfilling of impression, replication of designed prosthesis can produce error while duplication, defects with silicone impression, manual trimming and the number of the measuring points [12,23].

In the present study, samples were thermocycled for 5,000 cycles (5°C-55°C), it simulates oral environment and mimics temperature fluctuation. Thermocycling affects the mechanical properties of interim restoration as it may deteriorate in the oral environment, leading to unreacted monomers release, softening of matrixes of resin, breakdown of products and filler ions leaching all of which can lead to reduction of mechanical strength [15].

In the present study, samples were subjected to force till the specimen fractures under Universal testing machine. FS was evaluated by formula and expressed in MPa. On comparative evaluation for FS between CAD/CAM Milled and 3D printed, values were highly statistically significant where CAD/CAM Milled showed greater FS which can be due to the fact that CAD/CAM PMMA blocks are more uniform and have lower chances of porosities and voids during their manufacturing process, which may lead to reduce water absorption and higher overall FS [14].

showed greater FS. Bis-acryl composite resins (protemp-4) are difunctional and can cross-link different monomer chains. The cross-linkage gives strength and longevity to the material which could have been the reason for increased FS [12].

Studies done by Nejatidanesh F et al., and Ireland MF et al., concluded that provisional materials like bisacrylic surpass the FS of methacrylate resins [8,28]. Lang R et al., evaluated 2 PMMA and four composite interim materials in an artificial oral environment [29]. The results showed that the composite-based group had the highest strength values and the lowest fracture rate [12]. This is in support with the present study. Similar studies from the literature have been compared in [Table/Fig-9] [11,12].

S. No.	Author's name and year of study	Place of study	Sample size	Material compared	Parameters assessed	Conclusion
1.	Dureja I et al., [12] 2018	Department of Prosthodontics, Faculty of Dental Sciences, SGT University, Gurgaon, Haryana, India	80 Sample divided into 2 group- 40 sample in each group	Group I was subdivided as Group IA-bis-acrylic composite-based autopolymerising resin material (Protemp™ 4) blocks and Group IB i.e., CAD/CAM provisional material blocks. Similarly, Group II was subdivided as Group IIA, i.e., bis-acrylic composite-based autopolymerising resin material (Protemp™ 4) and Group IIB, i.e., interim CAD/CAM crowns	Vertical marginal fit and Flexural Strength (FS) of provisional crowns prepared using Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) temporary material versus those fabricated using bis-acrylic composite-based autopolymerising resin material.	Protemp™ 4 and CAD/CAM provisional materials have comparable Flexural Strength (FS). However, the marginal fit of temporary crowns fabricated by CAD/CAM was found to be superior to the ones fabricated using bis-acrylic composite-based autopolymerising resin material (Protemp™ 4).
2.	Taşın S et al., [11] 2022	Department of Prosthodontics, Faculty of Dentistry, University of Kyrenia, Mersin, Turkey	Rectangular specimens (n=30 for each material) which was divided into 3 groups n=10	Autopolymerised Polymethyl Methacrylate (PMMA), bis-acryl resin (Bis-acryl), CAD/CAM Polymethyl Methacrylate-based polymer (CAD/CAM/Milled) and 3D printed composite resin (3D Printed)	Effect of different thermocycling periods on the Flexural Strength (FS), Resilience (R) and Toughness (T) of conventionally polymerised, CAD/CAM milled and 3D printed interim materials.	The results suggested that digitally fabricated interim materials had better mechanical properties than conventionally polymerised materials and greatest stability was seen with milled material with absorbtion of initial energy.
3.	Present study	Department of Prosthodontics, Bharati Vidyapeeth Dental College and Hospital, Sangli	45 total 3-unit fixed dental prosthesis i.e., CAD/CAM Milled, 3D printed and Conventional i.e., 15 sample per group	CAD/CAM Milled,3D printed and Conventional Chairside Interim 3 unit fixed dental prosthesis	Marginal gap and FS of CAD/CAM milled, 3D printed and Conventional chairside interim 3 unit fixed dental prosthesis.	Result of this study showed that CAD/CAM Milled showed better marginal adaptation and greater FS followed by Conventional and 3D printed group.

[Table/Fig-9]: Similar studies from the literature [11,12].

In accordance to the present study, Prpic V et al., conducted a study where FS was tested of material kept in a water bath for 50 hours between 3D printed and milled PMMA interim materials and was concluded that FS was higher for milled resins [24]. In contrast, Suralik KM et al., also compared the FS of milled PMMA and 3 Dimensionally printed 3-unit interim fixed prosthesis, concluding that 3D printed specimens had a higher FS than milled ones [25]. This could be attributed to differences in fabrication factors, testing procedure used for evaluation of properties type of printer, layer thickness, build angle, chemical composition, specimen design and intensity of polymerising light [11,23,25].

On comparative evaluation for FS between CAD/CAM Milled and Conventional, values were highly statistically significant where CAD/CAM Milled showed greater FS. Studies done by Digholkar S et al., reported that milled PMMA and conventional heat-cured PMMA resins had significantly higher FS compared to 3D printed micro-hybrid filled composite resin, which is in accordance to our present study [26]. Yao J et al., done study, where they were able to conclude that CAD/CAM interim materials were able to withstanding hot, cold and moist conditions; were not only stable but also exhibits higher initial marginal accuracy [15]. The reason for increase FS may be due to the fact that CAD/CAM block contains pre-polymerised resin and prior to utilisation, blocks are kept under air for post polymerisation which helps in releasing excess monomer from blocks [9,27].

On comparative evaluation for FS between conventional and 3D printed, values were highly statistically significant where conventional

Thus, CAD/CAM showed better mechanical properties of marginal adaptation and FS followed by conventional and lastly 3D printed resins.

Limitation(s)

It is an in-vitro study done under ideal conditions. Only one material was compared for each fabrication technique. Other properties which might be affected like surface roughness, microhardness, elastic modulus etc., were not checked.

CONCLUSION(S)

On comparative evaluation for marginal gap using various fabrication techniques, 3D printed group showed more marginal gap followed by conventional group and least with CAD/CAM milled group. On comparative evaluation for FS using various fabrication techniques, there was highly statistically significant difference with CAD/CAM being the highest followed by conventional group and least with 3D printed group. Thus, it can be concluded that CAD/CAM milled showed better marginal adaptation and greater FS followed by conventional and 3D printed group. Similar in-vivo studies can be conducted with evaluation of other mechanical properties.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Jul 01, 2024
- Manual Googling: Oct 30, 2024
- iThenticate Software: Nov 02, 2024 (9%)

ETYMOLOGY: Author Origin

EMENDATIONS: 8

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? No
- For any images presented appropriate consent has been obtained from the subjects. NA

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