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Original Research Article

Comparative evaluation of colour stability of Conventional, 3D printed and CAD CAM fabricated Provisional restorations- An in-vitro study

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ABSTRACT

Introduction: The temporization phase in fixed prosthodontics is vital for restoring function, esthetics, and protecting prepared teeth. Provisional restorations, traditionally made using PMMA, ensure interim comfort and are of diagnostic value. With advancements in digital technology, 3D printing and CAD/CAM milling have enhanced the precision and efficiency of temporary restorations. However, the effects of betel leaf, commonly chewed in Indian culture, on the color stability of these materials remain unexplored.

Aims and Objectives: This study evaluates and compares the color stability of conventional, 3D-printed, and CAD/CAM-fabricated provisional restorations when immersed in betel leaf solution

Materials and Methods: The provisional crowns measuring 2mm thickness made of PMMA (Polymethyl methacrylate) were evaluated for color stability with spectrophotometer using CIELAB values.

Results: The mean ΔE values were significantly higher for the conventional group, followed by 3D printed and CAD CAM groups.

Conclusions: The conventional Polymethyl methacrylate specimens changed color more and faster than the CAD CAM and 3D printed crowns. In addition, at 3 and 6 months, the color variations of conventional method at all time intervals were unacceptable when compared to their initial shade.

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1. Introduction

The temporization phase is crucial in fixed prosthesis particularly, since it plays a key role in restoring speech, aesthetics and has diagnostic significance, as they restore function.¹

Provisionalization is an important phase in providing a good treatment as it renders good outcomes in the definitive prosthesis. Provisionalization not only restores function, esthetics and comfort it also protects prepared teeth from sensitivity and any other trauma. There are various materials and techniques used in fabrication of temporary crowns the most economical and popular being

the polymethylmethacrylate (PMMA). However, with the advancement in technology and Material sciences there has been a huge leap in the prosthetic speciality which has created a new dimension in rehabilitation in a very short time interval and with added precision. Among the recent materials which work on the principle of digital technology are 3D printing and CAD CAM milling,² whose utilization has made the delivery of work at faster pace. However the properties of these temporary crown and bridges when incorporated on immersion in betel leaf solution is a topic of debatable interest.

As betel leaf is a common and most popular habit among the Indian population there is no study till date so as to analyze the changes in the color stability or mechanical properties of this technology-based provisionalization on

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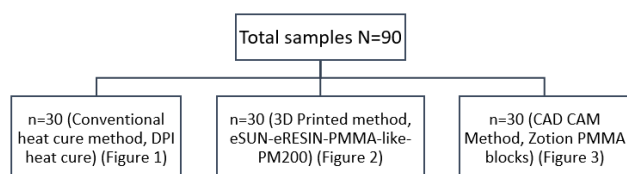
immersion in betel leaf solution, which exists as a most common scenario in the habit based culture in the Indian society. Hence this study was designed so as to evaluate and compare colour stability of conventional, 3D printed and CAD CAM fabricated provisional restorations.

2. Materials and Methods

The study design was conducted in Kamineni Institute of Dental Sciences, Narketpally with ethical clearance number EC/NEW/INST/2021/1767 from the Institute Ethical Committee, Kamineni Institute of Dental Sciences. The study comprised of 90 samples which were divided into three groups. In the present study, provisional crowns made of PMMA fabricated by conventional heat cure, 3D Printed and CAD CAM milled were compared for color stability after immersion in betel leaf solution at time intervals of 3 and 6 months.

2.1. Specimen fabrication

A typodont central incisor was prepared around 2mm to receive a PFM (Porcelain fused to metal crown (Figure 3). Elastomeric impression of the prepared tooth was made so as to process the fabrication of prosthesis 2mm thick as per the respective groups. A total of 90 specimens were divided into three groups, with each group comprising of 30 samples as follows.



In order to ensure proper anatomy, occlusion, and contacts, conventional crowns were manufactured using wax patterns. After the wax pattern was created, a boiling unit was used to dewax it. Following the manufacturer's directions, the heat-cure acrylic resin was combined, filled into the mould made in the flask, and allowed to cure. After cooling, the temporary crowns that had cured were taken out, trimmed, and polished.

Regarding the CAD CAM provisional crowns, the impression was scanned using a extra oral scanner (3 Shape D700 (TS) (3Shape, Copenhagen, Denmark). The prosthesis was designed using CAD software, after the digital impression was imported.^{3,4} The design tools within the software were used to create the provisional crown while accounting for the occlusal and proximal contacts and aesthetics. The toolpath for PMMA milling was generated by either the integrated CAM module in the CAD software. After milling was finished, the provisional crown was removed from the material block and the provisionals were polished and trimmed.^{5,6}

The following is how the 3D printed crowns were made. To scan the PVS impressions, an extra oral scanner was employed (3Shape D700 (TS) (3Shape, Copenhagen, Denmark). CAD software made especially for dental applications, such as 3Shape was used to design the crowns which were exported as an STL file, which is the common format used in 3D printing. The STL file was opened in a slicing programme (Formulas PreForm). 3D printer, (SLA printer) that uses PMMA. The sliced file was loaded into the 3D printer (SLA printer) using PMMA and the printing procedure was proceeded paying attention to the printer's directions. To finish the polymerization process, the cleaned crowns were placed in a curing unit in accordance with the instructions provided by the resin manufacturer.

To guarantee a comfortable fit and good aesthetics, the crown's edges and surfaces were smoothed and polished.

Diamond polishing paste was used to polish the specimens for 15 seconds using a polishing disc that was attached to an electric handpiece and was spun at 15,000 rpm. A visual inspection of each specimen's polished surface was conducted prior to the initial colour measurement to confirm that there was no porosity present. After that, the specimens were cleaned and put in distilled water for storage.¹

2.2. Implementation of protocol (Figure 7)

The specimens were artificially aged by thermocycling (each cycle= 30 sec in the -5 degree tray, 5sec of rest and 30 sec in the 55 degree tray. (Figure 5)

After each thermocycling step (2500,5000 cycles respectively, equivalent to 3,6 months) immersion in betel leaf solution was done to simulate the consumption of betel leaf over 3 and 6 months.⁷ (72 hrs of immersion being equivalent to 3 month of consumption, another 72 hrs being equivalent to 6 months of consumption).⁸ (Figure 6)

Color measurements were performed after each manipulation (thermocycling + immersion) using spectrophotometer.⁹

Prior to soaking, the specimens' original shade was evaluated, and the baseline colour values were noted at T₀ and at T₁ and T₂ at time intervals of 0 3 and 6 months respectively.¹⁰

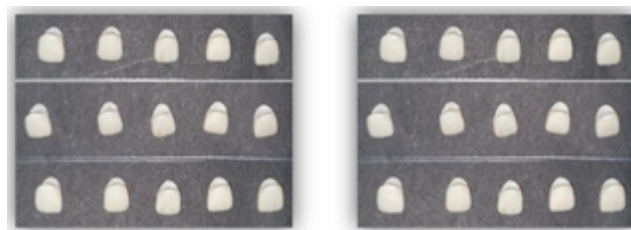


Figure 1: Conventional heat cure provisional crown



Figure 2: 3D printed crowns



Figure 3: CAD CAM milled crowns



Figure 4: Prepared typodont central incisor



Figure 5: Thermocycler



Figure 6: Immersion in betel leaf solution

2.3. Statistical analysis

Data was analysed using the statistical package SPSS 26.0 (SPSS Inc., Chicago, IL) and level of significance was set at $p < 0.05$. Descriptive statistics was performed to assess the mean and standard deviation of the respective groups. Normality of the data was assessed using Shapiro Wilkison test. Inferential statistics to find out the difference between the groups was done using ONE WAY ANOVA TEST and within group analysis by REPEATED MEASURES OF ANOVA followed by BONEFERRONI POSTHOC TEST.

3. Results

The L A B values were calculated. (Table 1).

3.1. Results within group

Shapiro wilkinson test for normality did not report significant difference ($p > 0.05$), Hence Parametric tests were used for the analysis. Regarding 'Delta E', Within group analysis by REPEATED MEASURES OF ANOVA Test reported statistically significant difference with respect to conventional and CAD CAM study groups ($P < 0.05$). Initial values for conventional group were 0.35 ± 0.08 , after first cycle 0.44 ± 0.10 and the values were 0.56 ± 0.09 after third cycle. For CAD CAM group, initial values were noted as 0.36 ± 0.09 and subsequent readings after second and third cycles were 0.39 ± 0.11 0.42 ± 0.11 respectively. The readings for 3D printed group were 0.33 ± 0.08 0.42 ± 0.12 , 0.48 ± 0.10 after each cycle respectively. After Boneferroni post hoc test, CONVENTIONAL and CAD CAM group reported significant difference between most of the pair groups ($p < 0.05$) except First cycle vs Second cycle of thermocycling(CONVENTIONAL) and CAD CAM group (Initial vs First cycle). (Graph 1) (Table 2).

3.2. Results between group

Shapiro wilkinson test for normality did not report significant difference ($p > 0.05$), Hence Parametric tests are used for the analysis. Regarding 'Delta E', between group analysis by ONE WAY ANOVA Test Reported Statistically

Significant Difference with Respect To CONVENTIONAL group only ($P < 0.05$). After Bonferroni post hoc test, most of the pair groups Shapiro reported significant difference ($P < 0.05$) except CAD CAM vs 3D PRINTED ($P > 0.05$). (Graph 2) (Table 3)

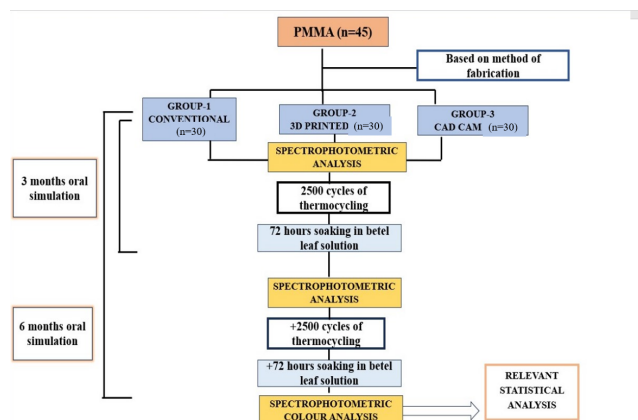
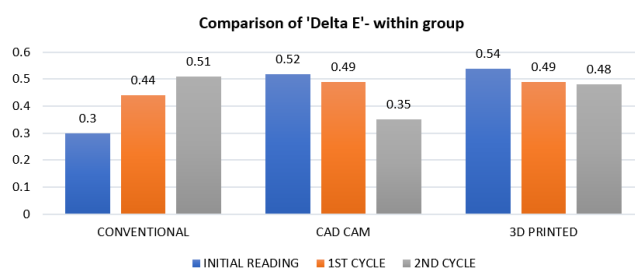
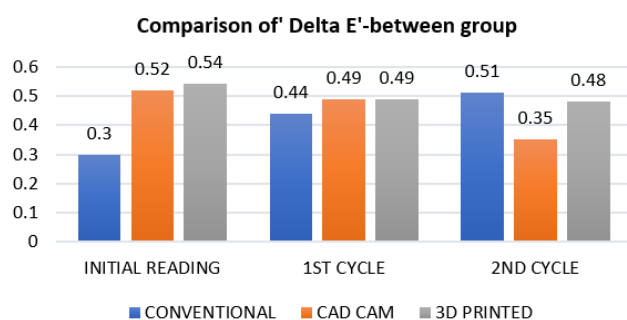


Figure 7: Implementation of protocol



Graph 1: Comparison of delta E within group



Graph 2: Comparison of delta group between group

4. Discussion

This study's primary aim was to compare the color stability of conventional, 3D printed, and CAD/CAM fabricated provisional restorations after exposure to thermal aging and immersion in betel leaf solution for durations equivalent

to 3 and 6 intraoral months. The findings revealed notable differences in color stability among the three groups.

According to a study conducted by Saurabh Jain et al.¹¹ indicated that the conventional provisional restorations exhibited the most significant and rapid color changes, followed by the 3D printed group,¹² and then the CAD/CAM group. This suggests that CAD/CAM fabricated restorations are more suitable for long-term aesthetic use,⁸ as they maintain color stability better than the other two groups.

Consistent with existing literature by Ahmed AlTarazi et al.^{13,14} our study reinforces the idea that minimal water sorption and solubility are crucial for the success of dental materials.¹¹ The 3D printed PMMA displayed higher water sorption and solubility compared to CAD/CAM milled PMMA. This is significant because higher water sorption can lead to dimensional changes, discoloration, and potential weakening of the material over time.¹⁵

Interestingly, our findings show that 3D printed PMMA had lower water sorption and solubility than conventional PMMA, which aligns with broader literature highlighting the limitations of conventional PMMA in terms of water-related properties.^{15,16} This supports the notion that while 3D printed PMMA offers improvements over conventional PMMA, it still falls short when compared to CAD/CAM milled PMMA, particularly in long-term applications.

The observed hierarchy of color stability—where CAD/CAM milled PMMA outperformed 3D printed PMMA, and both were superior to conventional PMMA—underscores the critical role of material composition and manufacturing process. In a study conducted by Prpić V, Schauerl et al.¹⁷ CAD/CAM milled PMMA's superior performance is attributed to its inclusion of MMA, a hydrophobic monomer, which contributes to its enhanced resistance to color changes. In contrast, 3D printed PMMA, which typically contains HDMA, a more hydrophilic component, exhibited poorer color stability. This hydrophilic nature likely leads to greater water uptake, which can facilitate more pronounced color changes.

Factors such as the presence of uncured or partially cured layers can introduce variability in color and impact long-term stability.¹⁷ Additionally, the lack of filler particles in 3D printed resins, compared to materials like CAD/CAM milled PMMA that often include fillers, further contributes to their inferior color stability. Fillers play a crucial role in enhancing the mechanical and aesthetic properties of dental materials by providing structural integrity and resistance to discoloration.

It is important to note that in the oral environment, in addition to betel leaf and temperature variations, restorative materials are exposed to a variety of other liquids and colouring substances, as well as functional and parafunctional load constraints and toothbrushing.

Table 1: Lab values for conventional, 3d printed and CAD cam groups

Heat cure after second thermocycling				CAD CAM after second thermocycling				3D printed after second Thermocycling			
L	a	b	E	L	a	b	E	L	A	b	E
69.35	1.6	12	0.51	62.14	-1.04	3.31	0.41	64.03	-1.4	5.66	0.82
69	1.38	12.07	0.76	61.74	-1.08	2.64	0.18	66.47	-1.38	6.22	0.27
63.77	2.17	11.42	0.28	61.84	-1.02	3.27	0.25	65.16	-1.36	5.28	0.37
66.45	2.38	12.18	0.59	61.8	-1.18	2.62	0.77	66.57	-1.16	6.54	0.64
65.41	2	11.37	0.37	61.33	-0.61	2.17	0.53	65.39	-1.45	6.21	0.36
69.36	1.8	12.01	0.52	62.12	-1.02	3.32	0.42	64.01	-1.2	5.62	0.8
69.01	1.36	12.09	0.77	61.72	-1.06	2.62	0.16	66.45	-1.36	6.2	0.26
63.78	2.19	11.44	0.26	61.82	-1.16	3.25	0.23	66.55	-1.14	5.26	0.35
69.34	2.39	12.2	0.57	61.81	-1.14	2.64	0.75	64.03	-1.12	6.52	0.62
63.79	2.01	11.36	0.36	61.32	-0.62	2.66	0.51	64.43	-1.42	5.21	0.34
66.48	1.4	12.02	0.51	62.14	0.05	2.61	0.27	64.05	-1.22	6.24	0.62
69.37	1.4	11.41	0.73	61.74	-1.18	3.26	0.14	66.49	-1.18	6.23	0.82
69.03	2.15	12.3	0.28	61.84	-1.01	3.37	0.14	65.54	-1.32	5.22	0.36
69.04	2.34	11.39	0.25	61.12	-1.03	3.25	0.24	66.52	-1.41	6.26	0.23
65.42	2.02	11.42	0.75	61.71	-1.07	2.61	0.22	66.51	-1.31	6.25	0.39

Table 2: Readings within the group

	Initial reading (A)	1 ST Cycle (B)	2 ND Cycle (C)	P Value(Repeated measures of anova)	Post HOC test	P Value
Conventional	0.30±0.11	0.44±0.10	0.51±0.19	0.0006*	A vs B	0.02*
					A vs C	0.0005*
					B vs C	0.36
CAD CAM	0.52±0.09	0.49±0.11	0.35±0.21	0.0001*	A vs B	0.84
					A vs C	0.007*
					B vs C	0.03*
3 D Printed	0.54±0.17	0.49±0.22	0.48±0.21	0.68	A vs B	0.77
					A vs C	0.69
					B vs C	0.98

*P<0.05 is statistically significant (Shapiro Wilkinson test, p>0.05)

Table 3: Readings between group

Conventional (A)		0.30±0.11	0.44±0.10	0.51±0.19
CAD CAM (B)		0.52±0.09	0.49±0.11	0.35±0.21
3 D Printed (C)		0.54±0.17	0.49±0.22	0.48±0.21
P Value (One way anova test)		0.0001*	0.58	0.09
P Value (Bonferroni) Posthoc test)	A vs B	0.0001*	0.63	0.09
	A vs C	0.0001*	0.63	0.91
	B vs C	0.90	0.99	0.21

*P<0.05 is statistically significant (Shapiro Wilkinson test, p>0.05)

Overall, this study highlights the importance of selecting appropriate materials for provisional restorations, especially when long-term aesthetics are a concern. CAD/CAM fabricated restorations, with their superior color stability and lower water sorption, emerge as the most reliable choice among the three groups studied.

Future research should explore the effect of different CAD/CAM materials, manufacturing technologies, and surface treatments on the clinical performance of

provisional restorations. This could include evaluating newer materials and technologies to further enhance the color stability and overall performance of provisional restorations. Additionally, investigating surface treatments that could improve the resistance of these materials to discoloration and wear would be beneficial.

Potential challenges we faced while conducting this research was ensuring the thermal aging and betel leaf immersion accurately mimic intraoral conditions, including

temperature fluctuations, pH variations, and interaction with saliva or other oral fluids. Controlling environmental factors like light exposure or humidity, which could independently impact color stability.

Finally, it would be interesting to investigate how many weeks this deterioration becomes perceptible and unacceptable in order to predict the patient's maximum period of acceptability of the provisional. An examination of the changes in the surface properties of the materials, particularly changes in their water sorption¹⁷ would provide additional insight into the dynamics and intensity of colour ageing of the materials stability was challenging.

5. Limitations

The study was an in vitro design and thermocycling method was used to simulate the physiological aging of the provisional restorations.

Further research must be conducted to evaluate the effect of different CAD-CAM materials, manufacturing technologies and surface treatments on clinical performance of the provisional restorations.

6. Conclusion

The findings revealed that the CAD/CAM group exhibited the least color change, followed by the 3D printed group, and finally, the conventional PMMA group.

7. Source of Funding

None.

8. Conflict of Interest

None.

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