

Color stability and flexural strength of poly (methyl methacrylate) and bis-acrylic composite based provisional crown and bridge auto-polymerizing resins exposed to beverages and food dye: An *in vitro* study

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ABSTRACT

Aim: To evaluate the color stability and flexural strength of poly (methyl methacrylate) (PMMA) and bis-acrylic composite based provisional crown and bridge auto-polymerizing resins exposed to tea, coffee, cola, and food dye.

Materials and Methods: Two provisional crown and bridge resins, one DPI self-cure tooth molding powder (PMMA) (Group A), and one Protemp 4 Temporization Material (bis-acrylic composite) (Group B) were used. Disk-shaped specimens for color stability testing ($n = 30$ for each material) and bar-shaped specimens for flexural strength testing ($n = 30$ for each material) were fabricated using a metal mold. The specimens were immersed in artificial saliva, artificial saliva + tea, artificial saliva + coffee, artificial saliva + cola, and artificial saliva + food dye solutions and stored in an incubator at 37°C. Color measurements were taken before immersion, and then after 3 and 7 days of immersion. Flexural strength was evaluated after 7 days of immersion.

Results: Group A showed significantly higher color stability as compared to Group B, and artificial saliva + coffee solution had the most staining capacity for the resins. Test solutions had no effect on the flexural strength of Group A, but Group B specimens immersed in artificial saliva + cola showed significantly lower flexural strength values as compared to the control group.

Conclusion: The findings of the study showed that for materials used in the study, PMMA was more color stable than bis-acrylic composite based resin. Also, material based on PMMA was more resistant to damage from dietary beverages as compared to bis-acrylic composite based provisional crown and bridge resin.

Key words: Color stability, flexural strength, provisional material, staining solutions

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Provisional restorations are essential components of fixed prosthodontic treatment.^[1,2] According to Glossary of Prosthodontic Terms, provisional restoration can be defined as “a fixed prosthesis, designed to enhance esthetics, stabilization and/or function for a limited period of time, after which it is to be replaced by a definitive prosthesis.”^[3]

Often such prostheses are used to assist in determination of the therapeutic effectiveness of a specific treatment plan^[4] or the form and function of the plan for definitive prosthesis.

Contemporary materials used for the fabrication of provisional restorations include auto-polymerizing and dual curing resins, such as poly (methyl methacrylate) (PMMA), poly (ethyl methacrylate), polyvinyl (ethyl methacrylate), bis-GMA resins, bis-acryl resin composites, and visible light-cured urethane di-methacrylate resins.^[1]

When the provisional restoration is in esthetic zone and must be worn for extended periods of time,^[5] color stability of provisional materials is a concern. Color stability of provisional materials not only relates to the chemophysical properties of the resin,^[6-8] but also to patient’s drinking habits. In long-span provisional prosthesis with short height pontics and connectors and

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when the patient exhibits parafunctional habits such as bruxism and clenching, the flexural strength of provisional prosthesis is a critical property. The color stability and flexural strength of provisional materials may be influenced by saliva, food components, beverages, and interaction among these materials in the oral environment.^[9]

Hence, this *in vitro* study was conducted to evaluate the effect of simulated oral environment which comprises saliva, food components, and beverages on the color stability and flexural strength of the new generation of provisional crown and bridge resins.

MATERIALS AND METHODS

In the study, two different provisional restorative materials and four staining solutions were used Table 1.

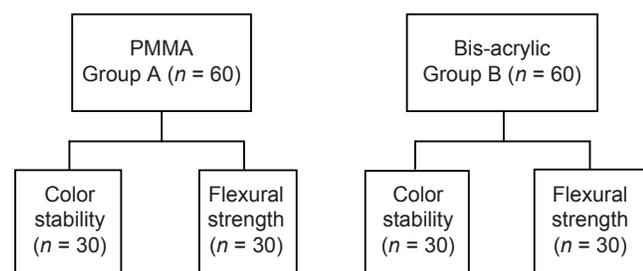
For color stability, disk-shaped specimens with a diameter of 15 ± 0.1 mm and thickness of 0.5 ± 0.1 mm, and for flexural strength, bar-shaped specimens with dimensions of $25 \text{ mm} \times 2 \text{ mm} \times 2 \text{ mm}$ were fabricated (according to ADA specification no. 27). For each provisional crown and bridge material, 60 specimens were fabricated and divided as shown in the Flow chart below.

Fabrication Group A (PMMA) specimens

Monomer and powder were mixed in the ratio of 1:2 by volume (according to manufacturer's instructions). They were mixed for 30 s until a homogeneous mixture was obtained. When the material reached the dough stage, it was packed into the metallic mold, covered with a glass plate, and a 5 kg weight was placed on top of the assembly to extrude the excess material. After 30 min of polymerization, the glass slabs were separated and the specimen was retrieved from the mold using air pressure.

Fabrication of Group B (bis-acryl) specimens

Material was directly dispensed into the metal mold placed on a glass slab, through a dispensing gun. The mold along with the material was then covered with a glass slab and a 5 kg wt was placed on top of the assembly to extrude the excess material. The specimen was allowed to polymerize for 5 min, and then glass slabs were separated and the specimen retrieved from the mold using air pressure.



Flow chart: Total number of specimens fabricated

Specimens were then evaluated for any surface irregularities and porosities, and if found, the specimens were excluded from the study. Selected specimens were then polished by one operator using time-controlled steps.

Preparation of staining solutions

- The tea solution was prepared by immersing 1 tea bag (2 g) into 100 ml of boiling distilled water for 10 min.
- Coffee solution was prepared with commercially available drip coffee maker using 15 g coffee and 100 ml of distilled water.
- For cola solution, commercially available brand of cola was used.
- A food dye solution was prepared by mixing 500 mg of food dye powder in 100 ml of distilled water.

Staining solution and artificial saliva were mixed in a ratio of 1:2 by volume.

Experimental procedure

For color stability, randomly selected disk-shaped specimens from each group were divided into five subgroups of six each as shown in Table 2; baseline color readings were taken and immersed in five staining solutions as mentioned above.

Solutions were maintained at 37°C in an incubator and freshly prepared solutions were supplemented every day.^[5] Specimens were evaluated for color change after 3 and 7 days of immersion in staining solutions. Before each color measurement, the specimens were rinsed with distilled

Table 1: Materials

Material type	Brand	Manufacturer
Poly (methyl methacrylate)	DPI self-cure tooth molding powder	Dental Products of India Ltd. Mumbai, India; Batch no. 8111
Bis-acrylic composite	Protemp 4 temporization material	3m ESPE, Seefeld, Germany; Lot-463865; Order no. 46956, Id no. 70201132613
Artificial saliva	Wet mouth	ICPA Health Products Ltd; Batch-0C100; Ankleshwar, India
Tea	Taj Mahal tea	Brooke Bond, Hindustan Unilever Ltd. Mumbai, India; Code no. W28A1
Coffee	BRU	Hindustan Unilever Ltd. Mysore, India; Code no. M02B2
Cola	Pepsi	Pepsico India Holdings Private Ltd. Mumbai, India; Batch 663
Food dye	999 orange red	Asian Food Products, Ahmedabad, India; Batch no. 16734
Distilled water	DM-water	Quality Chemicals, Mysore, India

Table 2: Distribution of specimens

	Group A (n=30)		Group B (n=30)	
Artificial saliva	A1 (n=6)	AS	B1 (n=6)	
AS+tea	A2 (n=6)	AS+tea	B2 (n=6)	
AS+coffee	A3 (n=6)	AS+coffee	B3 (n=6)	
AS+cola	A4 (n=6)	AS+cola	B4 (n=6)	
AS+food dye	A5 (n=6)	AS+food dye	B5 (n=6)	

water for 30 s, gently cleansed with a soft bristle toothbrush to remove any loose sediment, and then blotted dry with a tissue paper.^[5] The color was measured by Hunter's Labscan spectrophotometer.

For flexural strength, randomly selected specimens from each group were divided into five subgroups of six each as shown in Table 2. After 7 days of immersion, the specimens were positioned on a flexural strength testing apparatus with a 20 mm separation. A 3-point bending test was carried out in an Instron universal testing machine with a 10 kN load cell at a crosshead speed of 2 mm/min. From the failure loads (kN) obtained, the flexural strength was calculated using the formula:

$$\text{flexural strength} = 3FL/2bd^2,$$

where

- *F* is the load (force) at the fracture point,
- *L* is the length of the support span,
- *b* is width of specimen, and
- *d* is thickness of specimen.

Data were analyzed using analysis of variance (ANOVA), independent samples *t*-test, Scheffe's *post-hoc* test, and paired *t*-test. A significance level of $\alpha = 0.05$ was used for all statistical analyses.

RESULTS

Mean and standard deviation values are shown in Tables 3 and 4.

Color stability

One-way ANOVA test indicated statistically significant difference of mean color change values after 3 and 7 days of immersion on intergroup [Graphs 1 and 2] and intragroup [Graphs 3 and 4] comparison ($P < 0.05$).

Independent *t*-test showed statistically significant difference when comparing specimens immersed in artificial saliva with specimens immersed in various staining solutions in both the groups after 3 and 7 days ($P < 0.05$).

Paired *t*-test revealed statistically significant difference in ΔE values of Group A specimens after immersion in various staining solutions for 3 days (ΔE_3) and 7 days (ΔE_7) relative to baseline, except for Group A specimens immersed in artificial saliva solution. Similarly, there was statistically significant difference seen in ΔE values of Group B specimens after immersion in various staining solutions for 3 days (ΔE_3) and 7 days (ΔE_7) relative to baseline.

Flexural strength

One-way ANOVA demonstrated a statistically non-significant difference between the mean values of

Table 3: Mean color change (ΔE) of provisional crown and bridge materials after immersion in staining solutions for 3 and 7 days

Staining solutions	Group A		Group B	
	3 days	7 days	3 days	7 days
AS ΔE^* (SD)	2.9950 ^A (0.005)	2.9967 ^I (0.005)	2.9900 ^A (0.008)	3.1933 ^{II} (0.008)
AS+tea ΔE^* (SD)	3.2483 ^C (0.009)	3.9950 ^V (0.005)	3.5933 ^F (0.005)	4.5617 ^{VIII} (0.004)
AS+coffee ΔE^* (SD)	3.2900 ^D (0.008)	4.9633 ^X (0.008)	5.8783 ^G (0.007)	7.5433 ^X (0.008)
AS+cola ΔE^* (SD)	3.0983 ^B (0.007)	3.2917 ^{IV} (0.004)	3.5267 ^E (0.01)	4.3433 ^{VII} (0.005)
AS+food dye ΔE^* (SD)	2.9950 ^A (0.007)	3.2283 ^{III} (0.004)	3.0917 ^B (0.009)	4.1033 ^{VI} (0.005)

**Post-hoc* analysis shows the mean values marked with the same letter are not statistically significant ($P > 0.05$) and the mean values marked with different letters are statistically significant, SD=Standard deviation, AS=Artificial saliva

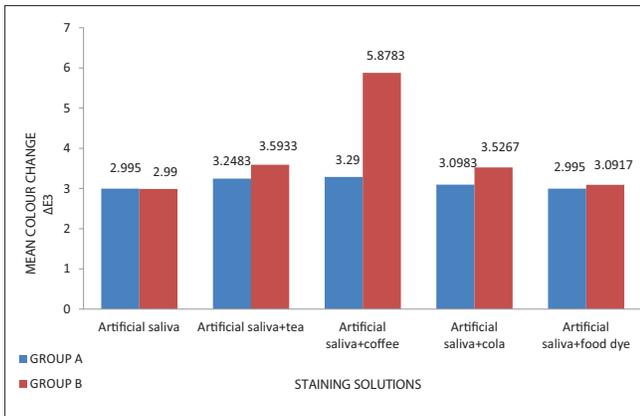
Table 4: Mean flexural strength of provisional crown and bridge materials after immersion in solutions for 7 days

Groups	<i>n</i>	Mean (MPa)	Std. deviation
A1	6	95.6550 ^A	0.00548
A2	6	95.6567 ^A	0.00516
A3	6	95.6550 ^A	0.00548
A4	6	95.6550 ^A	0.00548
A5	6	95.6550 ^A	0.00548
B1	6	143.9267 ^C	0.00516
B2	6	143.9250 ^C	0.00548
B3	6	143.9233 ^C	0.00516
B4	6	142.8567 ^B	0.00516
B5	6	143.9233 ^C	0.00516

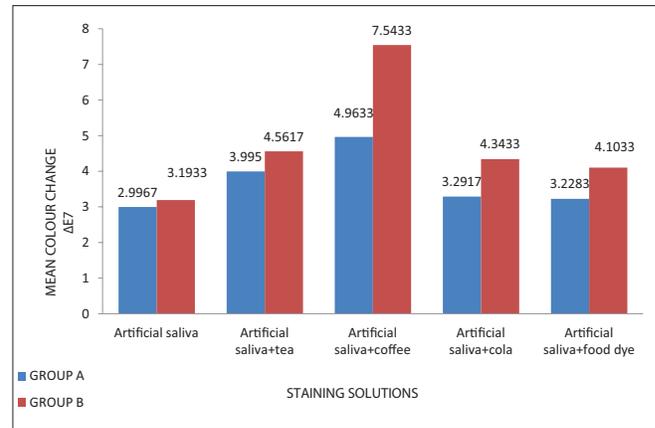
Post-hoc analysis shows the mean values marked with the same letter are not statistically significant ($P > 0.05$)

flexural strength of Group A specimens immersed in various solutions ($P = 0.977$), but there was a statistically significant difference seen for mean flexural strength of Group B specimens ($P = 0.00$). Intergroup comparison also showed statistically significant difference ($P = 0.000$) [Graph 5].

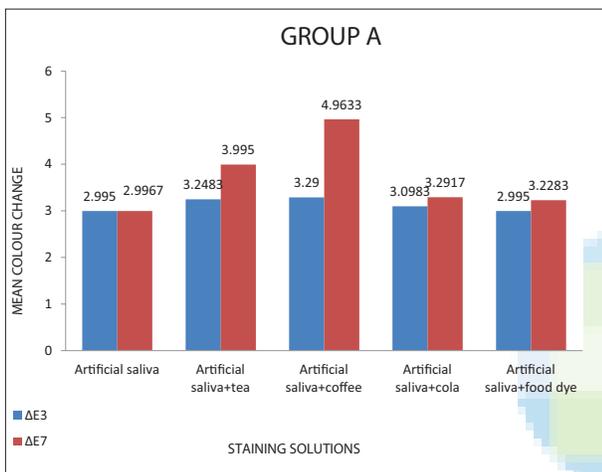
Independent *t*-test showed non-significant difference when comparing Group A specimens immersed in artificial saliva (control group) with Group A specimens immersed in various staining solutions after 7 days ($P > 0.05$), whereas for Group B, independent *t*-test showed non-significant difference when comparing specimens immersed in artificial saliva (control group) with specimens immersed in tea, coffee, and food dye staining solutions after 7 days ($P > 0.05$). But a statistically significant relationship was seen when comparing Group B specimens immersed in artificial saliva with Group B specimens immersed in artificial saliva + cola ($P = 0.00$). Intergroup comparison for each staining solution showed significant difference ($P = 0.00$).



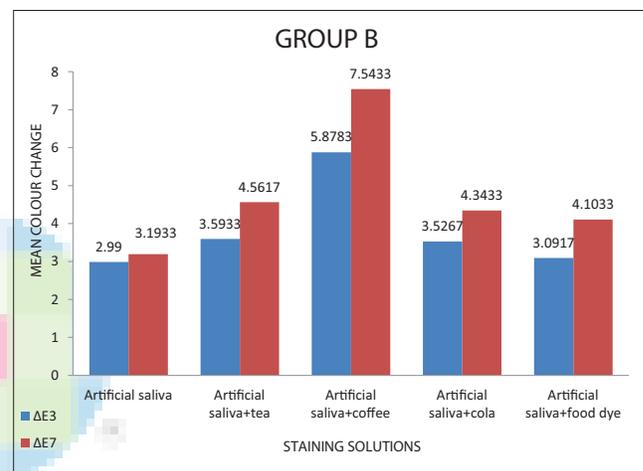
Graph 1: Comparison of mean color change values (ΔE) of Group A and Group B specimens after 3 days (ΔE_3) of immersion in various staining solutions, relative to baseline



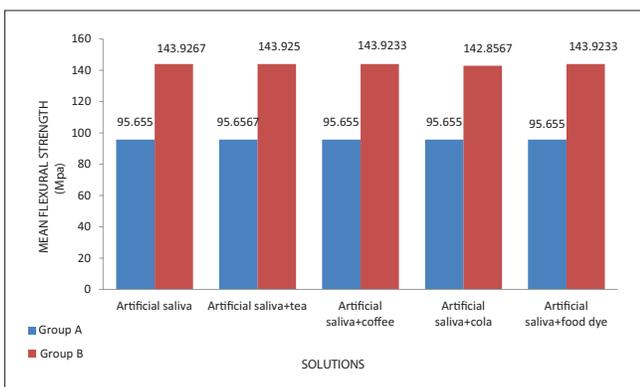
Graph 2: Comparison of mean color change values (ΔE) of Group A and Group B specimens after 7 days (ΔE_7) of immersion in various staining solutions, relative to baseline



Graph 3: Comparison of mean color change values (ΔE) between Group A specimens immersed in various staining solutions after 3 days (ΔE_3) and after 7 days (ΔE_7)



Graph 4: Comparison of mean color change values (ΔE) between Group B specimens immersed in various staining solutions after 3 days (ΔE_3) and after 7 days (ΔE_7)



Graph 5: Comparison of mean flexural strength values of Group A and Group B specimens after immersion in various staining solutions for 7 days

environment was 3.7 (ΔE).^[10] Yannikakis *et al.* referred to color change values below or above the value $\Delta E = 3.7$ as “acceptable” or “unacceptable,” respectively.^[11] In the present study, color change values below or above the value $\Delta E = 3.7$ are referred to as “acceptable” or “unacceptable,” respectively.

The results of the present study revealed that PMMA is more color stable than bis-acryl composite based resin, as bis-acryl polymers are more polar than PMMA polymers and absorb water at a higher rate because of a high diffusion coefficient in comparison to PMMA-based resins.^[11] Color stability of methacrylate resins can also be attributed to the fact that they are not filled; they are more subject to wear, and hence more responsive to traditional polishing techniques.^[12]

Artificial saliva + coffee solution was found to have the most staining capacity, followed by artificial saliva + tea solution, and artificial saliva + cola solution, and the least staining capacity was seen for artificial saliva + food dye solution.

DISCUSSION

Johnston and Kao reported that the average color difference between compared teeth rated as a “match” in the oral

The staining capacity of coffee has been reported to be due to the smaller molecular size of coffee coupled with water absorption characteristic of the tested materials, creating a stronger staining effect.^[12]

Compounds present in tea play an important role in the color characteristics of provisional restorative materials. Discoloration from tea was probably due to the adsorption of polar colorant from tea at the surface of resins.^[12,13] Possible explanation for the staining capacity of cola is that it is a low pH medium and affects the surface integrity of the resins.^[12] Artificial saliva + food dye solution showed the least staining capacity of all the solutions. These food dyes are soluble in water, and as they have electrostatic charges on their molecules, they may stain the resin surfaces; but probably electrostatic forces played an insignificant role in the staining process because of the less hydrophilic nature of the tested materials. Thus, the dye molecules were unable to penetrate deeper into the resin matrix due to water absorption.^[14] Specimens immersed in artificial saliva also showed color changes relative to baseline; these color changes were assumed to be due to water absorption characteristics of the sample material.^[12]

As the duration of immersion increased, the color change values of both the materials also increased in all the staining solutions. Thus, time is also an important factor in the staining of provisional crown and bridge resins.

The results of the study are similar to those of Scotti *et al.*,^[15] Yannikakis *et al.*,^[11] and Haselton *et al.*^[5]

The results of the present study also indicated that flexural strength of bis-acryl was significantly higher than that of PMMA after conditioning in all the solutions and there was no effect of the staining solutions on the flexural strength values of PMMA specimens as compared to the control group (A1), but a significant decrease in the flexural strength values was seen for bis-acryl after immersion in artificial saliva + cola solution for 7 days as compared to the control group (B1).

The differences between flexural strength of PMMA and bis-acryl are a result of the different monomer composition. The bis-acryl composite resins contain multifunctional monomers which increase the strength due to cross-linking with other monomers.^[16] Additional inorganic fillers in composites further improve strength and microhardness.^[17] Conventional methacrylate resins are monofunctional, of low molecular weight, and linear molecules that exhibit decreased strength and rigidity.^[16,18]

The decreased flexural strength value of bis-acryl composite resin specimens after immersion for 7 days in artificial saliva + cola solution can be attributed to the deleterious effects of the low pH on the inorganic fillers of the bis-acryl composite material.^[19]

Limitations of the study

- The problem encountered in all *in vitro* studies, that is, correlation of properties measured on a laboratory bench with those measured under clinical conditions.
- The specimen surfaces were flat, whereas clinically, provisional restorations will have an irregular shape with convex and concave surfaces.
- The test specimens were dipped in the test solutions which were static unlike the oral cavity where the solutions are in a dynamic state.
- Factors such as thermal cycling/abrasions were not included in this study.

CONCLUSIONS

Within the limitations of this study, the following conclusions can be drawn:

- PMMA showed acceptable color change values after 3 days of immersion in all staining solutions, but it showed unacceptable color change values after 7 days of immersion in artificial saliva + coffee and artificial saliva + tea solutions.
- Bis-acryl showed unacceptable color change values in artificial saliva + coffee solution after 3 days of immersion, and after 7 days of immersion it showed unacceptable color change values in artificial saliva + coffee solution, artificial saliva + tea solution, artificial saliva + cola solution, and artificial saliva + food dye solution.
- Artificial saliva + coffee solution was found to have the most staining capacity, followed by artificial saliva + tea solution and artificial saliva + cola solution, and the least staining capacity was seen for artificial saliva + food dye solution.
- As the duration of immersion increased, the color change values of both the materials also increased in all the staining solutions. Thus, time is also an important factor in the staining of provisional crown and bridge resins.
- PMMA is more color stable than bis-acryl composite resin, as PMMA showed lower color change values as compared to bis-acrylic resin for all staining solutions.
- Flexural strength of bis-acryl was significantly higher than that of PMMA after immersion in all the solutions.
- There was no effect of the solutions on the flexural strength values of PMMA as compared to the control group, but a significant decrease in the flexural strength values was seen for bis-acryl after immersion in artificial saliva + cola solution for 7 days as compared to the control group.

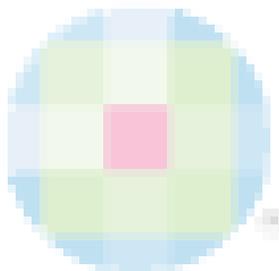
Clinical implication of this study is that when long-term provisionalization is required, the drinking habits of the patients must also be considered while choosing the type of provisional crown and bridge resin, especially in the esthetic zone, and patients should be advised against excessive use of certain beverages which can negatively affect the properties of provisional crown and bridge resins.

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