

Comparative evaluation of color stability of three commercially available provisional restorative materials: An *in vitro* study

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Abstract

Aim: Esthetics of the provisional restorations is of prime importance to the patients especially in long term in the esthetic zone. Discolouration of these restorations may result in patient dissatisfaction and an additional expense for their replacement. LuxaCrown provisional material being new in market and claimed to be semi-permanent by the company needs to be evaluated for its colour stability. This *in vitro* study was aimed to evaluate and compare the colour stability of three provisional restorations using three pigmented solutions.

Setting and Design: *In vitro* - comparative study.

Materials and Methods: LuxaCrown, Protemp4, Heat cure PMMA were evaluated. 40 specimens of each material were divided into four groups of ten specimens each. Each group was stored in three staining solutions and artificial saliva. Colour values of each specimen were measured before immersion, after one day, one week, one month, three months and six months with a spectrophotometer.

Statistical Analysis Used: One way ANOVA, Post Hoc Tukey Test, Bonferonni Test.

Results: Least colour change was seen in Heat Cure PMMA followed by Protemp4 and highest colour change was seen in LuxaCrown when immersed in artificial saliva, tea and coffee. Whereas in turmeric, Heat Cure PMMA showed the least colour change followed by LuxaCrown and highest colour change was seen in Protemp4 at all time intervals except day one, where LuxaCrown was higher than Protemp4.

Conclusion: Heat cure showed the best results as compared to Protemp4 and LuxaCrown in terms of colour stability at all time periods.

Keywords: Color stability, provisional restorative materials, staining solutions


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INTRODUCTION

Provisional crown and bridge restorations serve many purposes in prosthodontic treatment, including restoration of function, protection of the teeth and periodontal

tissues, stabilization of the occlusion, and as a diagnostic evaluation before the fabrication of the final restoration.^[1,2] Although all these purposes are important, the esthetics of the provisional restoration is of prime importance to the

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patient, especially in cases of its usage for a long period of time and/or are in the esthetic zone.^[3,4] A number of materials are currently available for fabricating provisional fixed partial dentures (FPDs) like methacrylate resin or a bis-acrylate composite resin.^[5,6] Regardless of the specific chemistry, most provisional restorative materials are subject to sorption resulting in color changes when subjected to various staining agents.^[2,7] A number of factors such as chemical and physical properties of the resin, incomplete polymerization, water sorption, chemical reactivity, diet (colorants in diet), oral hygiene, and surface roughness can affect color stability of these restorations.^[8,9] It is still a contentious issue in research as to which type of material has the better color stability (polymethyl methacrylates, polyethyl methacrylates, or bis-acryl composite resins).^[10] The degree of staining is affected by the duration of time the materials are exposed to the staining agents and its concentration.^[11] Discoloration by tea is due to the adsorption of the polar colorants onto the surface of the restorative materials, whereas discoloration by coffee is due to both adsorption and absorption of the colorants into the restorative material.^[12,13] Several studies indicated that some polymethyl methacrylate (PMMA)-based resins tend to discolor less than other provisional resins, including bis-acryls.^[10,11,14] However, research has also demonstrated that there are resin composite materials of similar color stability.^[15,16] Seghi *et al.*^[17] demonstrated that color measurement using a colorimeter provides consistent color evaluation. Colorimeters often report color using the CIELAB Color System, which is a method developed in 1978 by the Commission Internationale de l'éclairage for characterizing color based on human perception. It designates color according to three spatial coordinates, L*, a*, and b*, where L represents the brightness (value) of a shade, a* represents the amount of red-green color, and b* represents the amount of yellow-blue color. L* coordinates are located along a vertical axis that ranges from a value of 0 (blackest) to 100 (whitest). The a* and b* coordinates revolve on axes around L*. As a* becomes more positive in value, the color is more red; as a* becomes more negative in value, the color becomes more green. As b* becomes more positive in value, the color becomes more yellow; as b* becomes more negative in value, the color becomes more blue. Absolute measurements can be made in L*, a*, b* coordinates and color change calculated as ΔE . A ΔE value of 3.7 or less is considered to be clinically acceptable. The purpose of this investigation was to evaluate the color change of three temporary provisional crown and FPD materials after 1 day, 1 week, 1 month, 3 months, and 6 months after immersion in artificial saliva, tea, coffee, and turmeric solutions.

MATERIALS AND METHODS

This study was approved by the Institutional Review Board.

A standardized metal mold (according to American Dental Association specification no. 27) measuring 15 mm in diameter and 2 mm thickness was made [Figure 1].

All provisional restorative materials [Table 1 and Figure 2] were mixed according to the manufacturers' instructions and placed in the mold. After polymerization, the specimens were grossly trimmed using blue-coded followed by red-coded tungsten carbides. Then, they were polished using pumice, followed by diamond polishing paste.

The staining solutions used were tea, coffee, and turmeric, and the control artificial saliva was prepared in the following concentrations:

Artificial saliva

It was prepared in the laboratory from 0.4 g sodium chloride (NaCl), 1.21 g potassium chloride (KCl), 0.78 g sodium dihydrogen phosphate dehydrate (NaH₂PO₄·2H₂O), 0.005 g hydrated sodium sulfide (Na₂S·9H₂O), 0.005 g hydrated sodium sulfide (Na₂S·9H₂O), 1 g urea CO (NH₂)₂, and 1000 ml of deionized water. 10N sodium hydroxide was added to this mixture until the pH value was measured to be 6.75 ± 0.15. It was then sterilized in the autoclave.^[18]

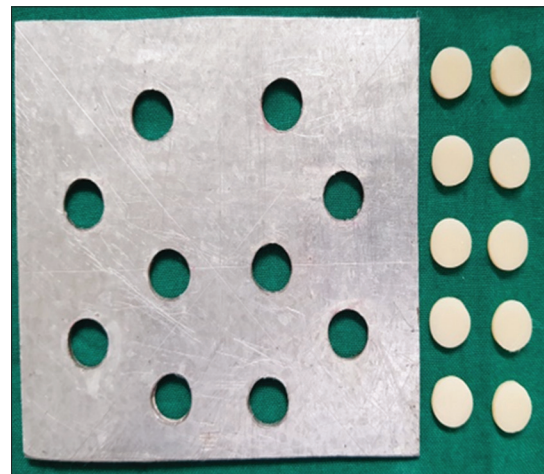


Figure 1: Standardized metal mold (15 mm × 2 mm)

Table 1: Provisional materials

Product	Manufacturer	Material type	Shade
LuxaCrown	DMG	Bis-acryl	A2
Protemp 4	3M ESPE	Bis-acryl	A2
Heat Cure Tooth Molding Powder	DPI	PMMA	B

PMMA: Polymethyl methacrylate



Figure 2: Provisional restorative materials (Prottemp 4, LuxaCrown, and Heat Cure polymethyl methacrylate)

Tea solution

About 2.8 g of tea was added to 150 ml of boiling distilled water.

Coffee solution

About 2.8 g of coffee was added to 150 ml of boiling distilled water.

Turmeric solution

About 0.5 g of turmeric was added to 150 ml of boiling distilled water.

120 samples were prepared and were divided into three groups of 40 samples each (Group A = LuxaCrown, B = Prottemp 4, and C = Heat cure PMMA) which were subdivided into four subgroups of 10 specimens each (Subgroups A1, A2, A3, A4; B1, B2, B3, B4; C1, C2, C3, C4) according to the staining solution used. The staining solutions used were:

- Subgroup 1: Artificial saliva (660 ml) control
- Subgroup 2: A mixture of tea (330 ml) and artificial saliva (660 ml)
- Subgroup 3: A mixture of coffee (330 ml) and artificial saliva (660 ml)
- Subgroup 4: A mixture of turmeric (330 ml) and artificial saliva (660 ml).

Specimens were immersed in their respective solutions at 37°C. The solution was changed every 3 days and stirred twice daily. Color measurements were made before immersion (T0), after 1 day (T1), 1 week (T2), 1 month (T3), 3 months (T4), and 6 months (T5). The specimens were rinsed with distilled water for 5 min and blotted dry with a

tissue paper before color measurement. Color differences were measured by a reflectance spectrophotometer with CIELAB system.

Color difference (ΔE) was calculated from the mean ΔL^* , Δa^* , and Δb^* values with the formula:

$$\Delta E = ([L^*f - L^*i]^2 + [a^*f - a^*i]^2 + [b^*f - b^*i]^2)^{1/2}$$

Where the initial (i) and final (f) are color descriptors and L^* , a^* , and b^* are differences in color parameters for the two specimens measured for comparison.

RESULTS

Mean values were compared using one-way analysis of variance (ANOVA) (statistically significant when $P < 0.05$). *Post hoc* test using Tukey's honestly significant difference was employed to identify significant groups (statistically significant when $P < 0.05$). Repeated measures ANOVA were performed to analyze the color stability of the different specimens at different time periods of storage. Significant groups were identified using the Bonferroni test.

DISCUSSION

The prime concern of patients during any restorative procedure is esthetics and function. Color stability is critical for the esthetics of long-term provisional restorations used for extensive prosthodontic rehabilitation needed to be worn for 6 months or even more.^[4] Therefore, in this study, Heat cure PMMA, LuxaCrown, and Prottemp 4 were used. A low-quality provisional restoration can bring complications, dissatisfaction, and even additional costs for its replacement.^[19-21]

Provisional crowns are typically fabricated from one of the available methyl or bisacrylate resins. Regardless of their chemistry, dental polymers do undergo a certain amount of change in color over time. This discoloration could be due to food colorants, drinks, oral habits, or even mouth rinses.^[8,9] The mechanism of staining could be explained by both the adsorption and absorption of colorants, and the latter phenomenon of stain sorption is closely related to water sorption.^[22] A number of studies have reported that water absorption is influenced by factors such as filler content, presence of residual unpolymerized monomers, the inclusion of air bubbles, and the cross-linking degree of resin molecules.^[23-26] In particular, incomplete polymerization might cause the physical properties of the resin material to deteriorate and microleakage to increase, thereby inducing color changes.^[27,28]

According to the brochure of DMG, the unique LuxaCrown is a bis-acrylic resin-based self-curing composite that allows for the simple, quick, and cost-effective manufacture of long-lasting crowns – directly chairside. The easy to make composite crown is highly esthetic and shows remarkable longevity of up to 5 years. It offers the patients an excellent and reliable alternative to laboratory-processed crowns. It can be used to protect the remaining tooth as well as to restore the anatomical form and the masticatory function. It is particularly recommended if a long-term observation of the treatment is necessary. Hence, this study has been designed to significantly evaluate the color stability of three commercially available provisional restorative materials in three staining solutions at varying time intervals ranging upto 6 months.

Discoloration can be evaluated visually and by instrumental techniques (spectrophotometer and colorimeter). The color perception by visual assessment is subjective and tends to vary from person to person due to factors such as illuminant position, object being observed, color characteristics of the illuminant, fatigue, aging, metamerism, and also the environment state.^[29,30]

Spectrophotometers contain monochromators and photodiodes that measure the reflectance curve of a product's color every 10 nm or less. A colorimeter provides an overall measure of the light absorbed, while a spectrophotometer measures the light absorbed at varying wavelengths. Because of the apparent advantages of a spectrophotometer over a colorimeter and visual method, color change in this study was measured using a spectrophotometer to potentially eliminate errors.^[21,31] The use of Commission International de L'Eclairage (CIE L*a*b*) uniform color scale has the advantage of having its arrangement in an approximately uniform three-dimensional color space.^[14,32,33]

Tea, coffee, and turmeric are identified as some of the staining substances^[34] and hence, these staining solutions were used in this study. The discoloration effect of coffee is due to adsorption and absorption of colorants particles, whereas in tea, it is due to adsorption only.^[12,13,20] The main reason for discoloration in both coffee and tea solutions is tannic acid.^[35] The present study showed significantly high values of color difference in coffee and tea for LuxaCrown compared to Prottemp 4 for all time intervals. Heat Cure PMMA showed the least color difference for tea and coffee. Major constituents of turmeric (Curcuma) are curcuminoids that cause the yellow stain. The smaller molecular size of curcumin and the water absorption properties have contributed

to stronger staining.^[5] It appears that the colorant of turmeric is more polar making it more hydrophilic and hence staining.^[13] The present research obtained similar results which showed a significantly high color change in turmeric for all the three provisional restorative materials. Prottemp 4 showed the highest staining in turmeric, followed by LuxaCrown for 1 week, 1 month, 3 months, and 6 months. The least color change was seen in Heat Cure PMMA. The present study also showed that of all the four staining solutions, turmeric was highly significant in color change, followed by coffee then tea, and lastly, artificial saliva.

In the current literature, it is assumed that darker materials are more color stable than the lighter ones.^[36-38] Therefore, A2 shade was chosen as the main color in the fabrication of specimens. Furthermore, A2 is one of the preferred shade by prosthodontists. LuxaCrown when compared to Prottemp 4 showed darker L* coordinate values, although both had the same shade. The Heat Cure PMMA resin was taken as B as it coincided with the A2 composite resin shade.

In addition, as it has been established from the previous reports that the smoothness and thickness of the specimen surface affect color stability of materials, in this study, the thickness of provisional restorative material was standardized to 2 mm.^[39] However, Costa and Lima investigated in their study that the thickness of the specimens was not important.^[40]

Prottemp 4 according to the manufacturer utilizes modified Bowen resin, which corresponds to derivatives of the bis-acryl compounds that have been rendered hydrophobic causing major reduction in water absorption and hence more color stable.^[41] This is not consistent with the present study which proved Heat Cure PMMA to be highly color stable than Prottemp 4, followed by LuxaCrown. Several authors associate this characteristic of the higher vulnerability of bisacryl resin in relation to color changes due to its composition.^[5,7,19] Most bis-acryl polymers are more polar than PMMA polymers and therefore have a greater affinity toward the water and other polar liquids.^[7,40] This is probably the reason for the larger color changes in bis-acryl resins.^[40]

Time was found to be a critical factor for the color stability of tooth-colored restorative materials. As the immersion time increased, the color changes became more intense.^[41,42] The present research obtained similar results which showed the color change was significantly high for all the three provisional materials by 6 months. The highest color

change being in LuxaCrown and the least being in Heat Cure PMMA.

The different threshold of color difference values above which the color change is perceptible or unacceptable to the human eye to varying percentages of people:

1. A value of ΔE^* of 1 unit is approximately equivalent to a color difference that is just visually perceptible to 50% of observers under controlled conditions^[43,44]
2. Values of ΔE^* between 0 and 2 represent imperceptible color differences, whereas values in the range of 2-3 represent color differences that are just perceptible^[45]
3. Values of ΔE^* greater than or equal to 3.3 are visually perceptible and clinically unacceptable to 50% of trained observers.^[33]

The present study showed that the color stability of Heat Cure PMMA was higher than the two bisacryl composite Provisional restorative materials.

Hence, during the provisional phase of treatment, the patient should avoid staining drinks. When provisional fixed prosthodontic materials are used for long periods, the acrylic resin tested may be preferred over the bis-acrylic resins for areas that are esthetically important and for the long-term provisional phase.

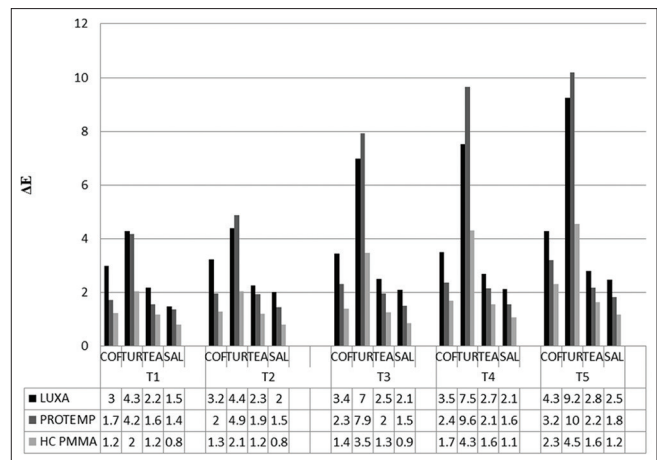
The present study had the following limitations.

- The specimen surfaces were flat, whereas, clinically, provisional restorations will have irregular shape with convex and concave surfaces
- Although very smooth surfaces can be obtained when restorations are allowed to set in contact with matrix strips, clinically, it is often necessary to remove excess materials after the fabrication of the provisional restorations with resultant rougher surfaces.

CONCLUSION

Color stability of three provisional restorative materials was evaluated after 1 day, 1 week, 1 month, 3 months, and 6 months of immersion in artificial saliva, tea, coffee, and turmeric. Under the conditions of this study, the following conclusions were drawn

1. At 1 day, LuxaCrown showed the highest color change in artificial saliva, coffee, tea, and turmeric, followed by Protemp 4 and the least color change being in Heat Cure PMMA
2. After 1 week, 1 month, 3 months, and 6 months of immersion in artificial saliva, tea, and coffee, LuxaCrown showed the highest color change compared to Protemp 4, but Protemp 4 showed the



Graph 1: Color change for different materials over a specific time period in different staining materials. COF: Coffee, TUR: Turmeric, SAL: Artificial saliva, PROTEMP: Protemp 4, HC PMMA: Heat Cure polymethyl methacrylate

highest color change in turmeric for all the above time periods compared to LuxaCrown. The least color change was seen in Heat Cure PMMA in all the staining solutions for all time intervals.

The color stability of Heat Cure PMMA is the highest, followed by Protemp 4 and then LuxaCrown.

Of the four staining solutions, turmeric shows the highest color difference, followed by coffee, tea, and lastly artificial saliva.

With the increase in the time period, the color change also increased for all the provisional materials in all the staining solutions [Graph 1].

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Conflicts of interest

There are no conflicts of interest.

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