Original Article

Discolouration of Polymethyl Methacrylate versus Bis-Acrylic based Provisional Crown and Bridge Dental Resins: Effect of Storage Media and Duration

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Abstract

Background: Provisional restorations are frequently needed for several days to weeks, demanding them to be well made and stable with distinctive functions and purposes. In aesthetically critical region, the provisional restoration must not only deliver an initial shade match, furthermore must preserve its aesthetic appearance over the service period. Noticeable colour change may compromise the suitability of provisional restorations. **Aim:** This study aimed to determine the discolouration of poly (methyl methacrylate) (PMMA) and bis-acrylic based provisional crown and bridge auto-polymerizing resins when exposed to coffee, tea, orange and cranberry juice. **Materials and Methods:** Four auto-polymerizing provisional crown and bridge resins, two methyl methacrylate and two bis-acrylic were used. Specimens were randomly divided into five groups (N=120, n=30) to be stored in artificial saliva, artificial saliva+tea, artificial saliva+coffee, artificial saliva+orange juice and artificial saliva+cranberry juice. Colour measurements were taken before immersion, after 1 week and 1 month of immersion with the Spectrophotometer. Data were analysed using analysis of variance (ANOVA), independent samples t-test, Scheffe's post-hoc test, and paired t-test. A significance level of a = 0.05 was used for all statistical analyses. **Results:** After the immersion period of 1 week and 1 month period, the post hoc analysis indicated that highest ΔE values were observed for Protemp II-artificial saliva + coffee as compared to other materials. **Conclusion:** The degrees of discolouration increased with immersion time. Methyl methacrylate resins were more resistant to discolouration than bis-acrylic resins. After immersion for 1 month, artificial saliva + coffee solution resulted in unacceptable discolouration for all the tested materials.

Keywords: Crown and bridge resins, Discolouration, Duration, Provisional, Storage media

Introduction

Aesthetic provisional restorations are frequently needed for several days to weeks, demanding them to be well made and stable with distinctive functions and purposes. They act as a vital diagnostic and assessment tool for evaluating function, colour, shape, contour, occlusion, periodontal response, implant healing and largely aesthetics [1,2]. Although provisional restorations are usually intended for short-term use and then discarded, irrespective of that they should always be made to provide pleasing aesthetics, adequate support and good protection for teeth while maintaining periodontal health [3]. In aesthetically critical region, the provisional restoration must not only deliver an initial shade match, furthermore must preserve its aesthetic appearance over the service period. Noticeable colour change may compromise the suitability of provisional restorations. Staining of provisional materials may perhaps result in patient discontent and surplus expense for replacement. This is predominantly challenging when provisional restorations are exposed to pigments during lengthy treatment [4]. Henceforth, colour stability is a significant criterion in the selection of a particular provisional material for usage in aesthetically critical area. Amongst the materials used for constructing provisional fixed partial dentures polymethyl methacrylate has been extensive in practice. Poly(ethyl methacrylate), poly (vinylethyl methacrylate), bis-acrylic composite resin, and visible light-cured (VLC) urethane dimethacrylate and microfilled have originated in current years. Epimine resin which was used in the past is no longer been used [4-6].

Provisional restorations can be prepared chair side directly in the mouth or indirectly outside on the patient's cast [7]. The indirect technique is preferred over the direct technique for its accuracy [8,9].

Requisite of a crown and bridge interim material is to retain lasting colour stability in order to avoid replacement of restorations. Irrespective of their chemicophysical composition and the use of stabilizers [9,10]. dental resins incline to imbibe

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dietary solutions [2,11-13]. Appreciable colour change in the provisional restorative material would probably compromise its acceptability [14]. Various studies have reported different thresholds of colour difference values above which the colour change (ΔE) is perceptible by the human eye. Colour differences (ΔE) more than 3.3 unit's reveals clinically noteworthy visual discolouration [15,16].

The colour stability of these interim materials may perhaps be influenced by saliva, food components, beverages, interaction among these materials in the oral environment [17-20].

Discolouration of tooth coloured resin based materials may be affected by intrinsic and extrinsic factors. Extrinsic discolouration is due to adsorption and absorption of colourants as a consequence of contamination from exogenous sources. The staining of polymeric materials by coloured solutions as coffee, tea, nicotine, and beverages has been reported in previous studies. The magnitude of discolouration in the oral cavity possibly will be related to dietary habits of the patients [4]. Intrinsic factors encompass the discolouration of resin material itself, due to the variation in the resin matrix and in the interface of matrix and fillers. Chemical discolouration has been attributed to alteration or oxidation of the amine accelerators, polymer matrix and unreacted pendant methacrylate groups [21].

Water accumulation and photo oxidation has also been reported to be accountable for internal colour alteration. Water plays an imperative role in chemical degradation process such as oxidation and hydrolysis and the consequent shift of the optical properties of provisional restorative materials [22,23]. Incomplete polymerization, water sorption, [20]. chemical reactivity, [24,25]. diet, [26,27]. oral hygiene [28]. and surface smoothness [25]. of the restoration can affect the degree of colour changes. Colour is the result of light waves reflected by restorative materials which could be opaque or translucent [29].

Discolouration can be evaluated visually or with colour measuring devices [29]. The quantitative evaluation of colour difference (ΔE) with a spectrophotometer deliberates benefits such as repeatability, sensitivity and objectivity [30,31].

The CIELAB (Commission International ede I'Eclairage) colour coordinates system is a very useful mode that provides information about location of object colour in a uniform 3-D colour space. It quantifies the colour in terms of three coordinate values L*, a*, and b*. Here, L* represents brightness or lightness (value) and a* and b* serve as numeric correlates both for hue and chroma. The a*and b* values represent position on a red/green and yellow/blue axis [21,32].

Colour difference (ΔE*) was calculated with the formula:

$$\Delta E^* = \sqrt{(\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})}$$

Therefore, the purpose of this study was to evaluate the effect of coffee, black tea, orange juice and cranberry juice storage on discolouration of four interim crown and bridge resin in simulated oral environment comprising of saliva.

Materials and Methods

Two auto-polymerized bis-acrylic and two methyl methacrylate provisional restorative materials were evaluated for colour stability on immersion in four different staining solutions. The restorative materials and staining agents used in this study are shown in Table 1. Thirty specimens 15 _ 0.1mm were fabricated from each material using similar shade groups between methyl methacrylate and bis-acrylic provisional crowns. A total of a 30 discoid specimens of each material (Shade A1) were prepared. All the provisional materials were mixed according to manufacturer's directions. A total of 120 specimens using four different provisional materials measuring 15 _ 0.1mm in diameter and 2 _ 0.1mm in thickness were placed into a silicone impression material (3M ESPE Express TM XT Putty) mould covered with a glass slab. Specimens were kept to dry at room temperature until all specimens were fabricated. For the purpose of surface standardization, the specimens were wet-ground with 1000-grit silicon carbide abrasive paper for 15 seconds. Following which the specimen were polished with pumice using prophylactic cup for 15 seconds. Specimens were stored in distilled water at 37 degree Celsius for 24 h. The rehydration simulated the first day of service for provisional restorations in the oral environment. Thirty specimens were randomly divided into 5 groups (n = 6) for 4 staining solutions and artificial saliva. The colour of all specimens groups were measured before exposure with a Spectrophotometer (Minolta, CM-3301d) using CIE (Commission International de I'Eclairage) L*a*b* relative to standard illuminant A, against a white background. Measuring characteristics of the spectrophotometer were standard illuminant D65. Before each measurement session, the spectrophotometer was calibrated according to the manufacturer's recommendations by using the supplied white calibration standard [10,33].

Preparation of staining solutions

• The tea solution (Taj Mahal) was prepared by immersing 15 grams of tea leaves and 100 ml of boiling distilled water for 10 minutes.

Table 1: Materials used in the study

	Material Type	Manufacturer
Provisional Materials brand		
DPI self-cure tooth molding powder (Group A)	Poly (methyl methacrylate)	Dental Products of India Ltd. Mumbai, India
Temp Dent Classic (Group B)	Poly (methyl methacrylate)	Schutz-Dental Co, Germany
Protemp II (Group C)	Bis-acrylic	3m ESPE, Seefeld, Germany
Protemp 4 (Group D)	Bis-acrylic	3m ESPE, Seefeld, Germany
Staining Agents Brand		
Taj Mahal	Tea	Brooke Bond, Hindustan Unilever Ltd. Mumbai,India
Nescafe	Coffee	Nescafe, New Delhi, India
Tropicana	Orange juice	PepsiCo India, Gurgaon, Haryana
Real Cranberry	Cranberry juice	Dabur India Limited
Wet mouth	Artificial saliva	ICPA Health Products Ltd, Ankleshwar, India

Table 2: Mean colour change (ΔE) of provisional crown and bridge materials after immersion in staining solutions after 1 week and 1 month

Staining solutions	Group A		Group B		Group C		Group D	
	1 week	1 month	1 week	1 month	1 week	1 month	1 week	1 month
AS ΔE* (SD)	2.9650^{A} (0.005)	2.9663^{a} (0.005)	2.9817^{B} (0.005)	3.0827^{b} (0.007)	3.2693^{E} (0.004)	3.5647^{e} (0.005)	3.1265^{C} (0.008)	3.3733^{d} (0.008)
AS + tea ΔE* (SD)	3.2500^{D} (0.009)	4.3120^{f} (0.005)	3.3397^{F} (0.004)	4.5890^{i} (0.005)	3.6997^{J} (0.005)	4.7353^{k} (0.005)	3.6007^{H} (0.005)	4.6650^{j} (0.004)
AS + coffee ΔE* (SD)	4.3113^{O} (0.008)	5.5460^{p} (0.008)	4.4103^{P} (0.005)	5.5993^{q} (0.007)	5.7083^{R} (0.007)	6.9773^{s} (0.008)	5.6833^{Q} (0.007)	6.9523^{r} (0.008)
AS + orange juice ΔE* (SD)	2.9810^{B} (0.007)	3.2287^{c} (0.004)	3.1293^{C} (0.005)	3.3747^{d} (0.008)	3.6123^{I} (0.008)	4.5003^{h} (0.005)	3.5360^{G} (0.005)	4.4193^{g} (0.005)
AS +cranberry juice ΔE* (SD)	3.7723^{K} (0.005)	4.9633^{l} (0.008)	3.8023^{L} (0.005)	4.9957^{m} (0.005)	4.1037^{N} (0.005)	5.3387^{o} (0.007)	3.9937^{M} (0.005)	5.1553^{n} (0.005)

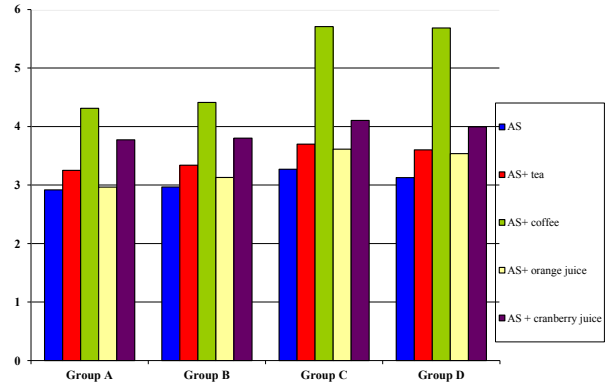

Figure 1: Mean colour differences (ΔE*), standard deviations of provisional restorative materials after immersion for 1 week (T1).

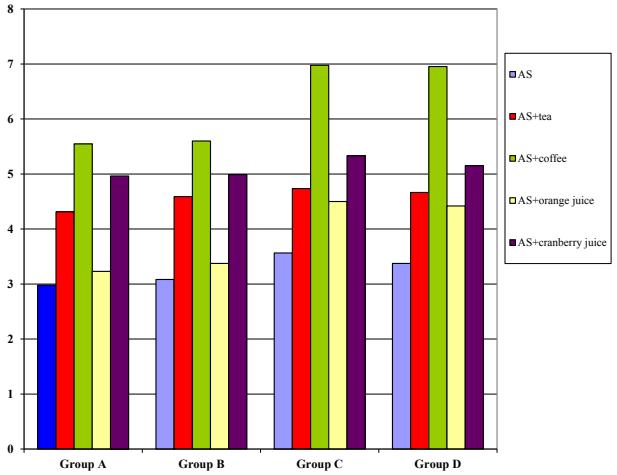

Figure 2: Mean colour differences (ΔE*), standard deviations of provisional restorative materials after immersion for 1 month (T2).

• Coffee solution (Nescafe) was prepared with commercially available drip coffee maker using 15 grams coffee and 100 ml of distilled water.

• For orange (Tropicana) and cranberry (Real Cranberry) solution, commercially available brand of juices were used.

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

Solutions were maintained at 37°C in an incubator and were freshened once every 3 days. In addition, to reduce the precipitation of particles in solutions, solutions were stirred once a day.

Specimens were evaluated for colour change before immersion (T0) after one week (T1) and one month (T2) of immersion in staining solutions. Before each colour measurement, the specimens were rinsed with distilled water for 30 seconds, gently cleansed with a soft bristle toothbrush to remove any loose sediment and then blotted dry with a tissue paper [34].

The sample size was obtained considering the power of 80% and significance level of 5%. Analysis of variance (ANOVA), independent samples t-test, Scheffe's post-hoc test, and paired t-test was used. A significance level of a = 0.05 was used for all statistical analysis. Statistical analysis was performed using the Minitab software (Minitab Inc., State College, PA, USA).

Results

Mean and standard deviation values are shown in Table 2. One-way ANOVA test indicated statistically significant difference in (ΔE) values after 1week and 1 month of immersion on intergroup and intragroup comparison ($P < 0.05$) [Figures 1 and 2]. 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 [Table 2]. Independent t-test showed statistically significant difference when comparing specimens immersed in artificial saliva with specimens immersed in various staining solutions after 1 week and 1 month ($P < 0.05$). Paired t-test revealed statistically significant difference in ΔE values of Group A specimens after immersion in various staining solutions for 1 week and 1 month 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, C and D specimens after immersion in various staining solutions for 1 week and 1 month relative to baseline. Maximum colour change (ΔE) was seen in AS + coffee solution > AS + cranberry juice solution > AS + tea solution > AS + orange solution. Group C and Group D showed more colour difference (ΔE) compared to Group A and Group B for each respective staining solution at measured time intervals [Table 2].

Discussion

Colour perception is a psychophysical phenomenon with variations, both between individuals and within an individual at different times [35]. The CIELAB colour system is used almost exclusively for colour research in dentistry around the world. It was introduced in 1976 and endorsed by the International Commission on Illumination. The strength of this system,

unlike that of the Munsell system, is its capability for clinical interpretation, as equal distances across the CIELAB colour space (colour differences or ΔE) represent approximately uniform steps in human colour perception, improving the interpretation of colour measurements [36]. Thus, the application of this system assisted the study to have precise method of colour evaluation.

It has been reported by Kuehni and Marcus [37]. and Seghi et al. [31]. that a ΔE* value equal to 1 is considered visually detectable 50% of the time, whereas a ΔE* value greater than 2 is detectable 100% of the time. Um and Ruyter [21] also recommended that the ΔE value of 1 unit is ''visually perceptible.'' In the present study, colour change values below or above the value ΔE = 3.7 are referred to as "acceptable" or "unacceptable," respectively which was in accordance to Johnston and Kao [38]. and to Yannikakis et al. [39].

The results of the present study showed that PMMA is more colour stable than bis-acrylic composite based resin, as bis-acrylic polymers are more polar than PMMA polymers and absorb water at a higher rate because of a high diffusion coefficient in contrast to PMMA-based resins [39]. Materials exhibiting high water sorption values are more easily stained by hydrophilic colourings in aqueous solutions, the water presumably acting as a penetration vehicle. Colour stability of methacrylate resins can furthermore be attributed to the fact that they are not filled [40,41]. Chemical discolouration of bis-acrylic has been credited to an oxidation of the polymer matrix [42]. or oxidation of unreacted double bonds. Otherwise, this could be ascribed to the more homogeneous composition of the methacrylate based resin materials versus bis-acrylic composite materials [43]. This finding was consistent with a study performed by Luce et al. [44]. Artificial saliva + coffee solution was found to have the most staining ability, followed by artificial saliva + cranberry juice solution, and artificial saliva + tea solution, and the least staining ability was seen for artificial saliva + orange juice solution.

The phenomenon behind discolouration by coffee may be attributed to its smaller molecular size coupled with surface adsorption and absorption of colourant particles. According to some studies, colour change may also occur due to the formation of a biofilm simultaneous with physical and chemical forces, hydrophobicity, surface free energy and surface roughness [43-46].

The soluble components of tea with blue absorption seemed as yellow as it is the complementary colour to blue. The varied reverse-phase liquid chromatographic retention times for these components of tea exposed that the yellow colourants have diverse polarities.

The materials with great value for water sorption displayed comparatively high discolouration values in all staining solutions [21]. Henceforth, the discolouration from tea was possibly due to the adsorption of polar colourant at the surface of resins [21,46]. which could be removed by tooth brushing, whereas discolouration by coffee was due to the compatibility of the polymer phase with the yellow colourants of coffee. Staining by tea and coffee may also be attributed due to the existence of tannic acid colourant in them [21].

The presence of pigment in cranberry juice and its low pH along with the surface integrity of the resins [46]. can be a contributing factor to changes in the colour characteristics of the provisional materials [35]. Orange juice displayed the least staining capacity of all the solutions. Irrespective of it low pH, its inability to penetrate deeper into the resin matrix limits its staining ability [43]. Specimens immersed in artificial saliva also displayed colour changes relative to baseline; these colour changes were presumed to be due to water absorption characteristics of the sample material [46].

The storage duration in all media of all tested groups had a substantial impact on the colour stability. As the duration of immersion increased, the colour change values of both the materials also increased in all the staining solutions. No previous studies have been found regarding staining of provisional crown and bridge dental resin caused by their immersion in orange and cranberry juice. For discolouration caused to resins when they were immersed in tea and coffee staining solutions, the results were in accordance to study conducted by Stawarczyk et al., [47]. Bayindir et al., [14]. Gujjari et al., [48]. Scotti et al., [49]. Yannikakis et al., [39]. and Haselton et al. [34].

As it is very challenging to estimate the definite period of time during which the restorative material is exposed to these staining solutions intraorally, the overall exposure period would be mainly governed by the definite quantity of the beverage consumed, their regularity of consumption, the mode of ingestion and so forth. Henceforth, the long-term immersion protocol (30 days) was used for the purpose of this study which signifies the accumulative effect of recurrent short immersions of prosthesis during prolonged usage [39].

Clinical inference of this study is that when extended period of provisionalization is necessary, the drinking practices of the patients must likewise be measured while selecting the type of provisional crown and bridge resin, particularly in the aesthetic zone. Patients must be counselled against excessive consumption of certain beverages which can deleteriously affect the properties of provisional crown and bridge resins.

Conclusion

The growing patient demands for aesthetics requires a comprehensive selection of dental materials. Discolouration of provisional restorations can be an aesthetic problem, especially when the treatment plan requires long-term usage. Methyl methacrylate resin provisional materials were more colour stable than auto-cured bis-acrylic provisional materials when exposed to staining liquids. After immersion for 1 week and 1 month all materials displayed visible colour changes. The coffee solution exhibited more staining than others in three groups.

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Conflict of interests

Nil

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