In vitro color stability of provisional restorative materials

Hamid Jalali, Hassan Dorriz, Farzaneh Hoseinkhezri, SF Emadian Razavi

ABSTRACT

Background: Discoloration of provisional restorations can result in esthetic problems which are critically important in, for example, anterior areas and may compromise the acceptability of the restoration.

Aims: The purpose of this study was to investigate the effect of tea on provisional restorative materials.

Setting and Design: This study was designed to measure the degree of color change of three acrylic resin provisional materials, before and after immersion in artificial saliva and artificial saliva-tea solution for 2 and 4 weeks.

Materials and Methods: Three types of acrylic provisional materials (duralay, tempron, acropars TRP), were studied. Twenty disks (20±0.1 mm by 2±0.05 mm) were fabricated from each material. Specimens were polished with acrylic bur using pumice and diamond polishing paste. Base line color was measured using a spectrophotometer. Ten disks were stored in artificial saliva and 10 were stored in a solution of artificial saliva and tea at room temperature. Color measurements were made after 2 and 4 weeks of immersion.

Statistical analysis used: Differences in color changes were compared by two way ANOVA, across the six groups, followed by a Turkey-Kramer’s multiple comparison test.

Results: For specimens immersed in artificial saliva, the color change of methyl methacrylate materials; duralay (ΔE=4.94) and tempron (ΔE=6.54), was significantly more than butyl methacrylate material; acropars (ΔE=4.10). After immersion in an artificial saliva-tea solution, tempron exhibited less color change (ΔE=8.50) compared to duralay (ΔE=10.93) and acropars (ΔE=15.64).

Conclusion: Color stability of methyl methacrylate is higher than butyl methacrylates so if provisional materials are used for extended periods of time; tempron is preferred.

Key words: Acrylic resin, color stability, provisional restoration, spectrophotometer

Provisional crowns and fixed partial dentures (FPDs) are an integral part of prosthodontic treatment.[1] A provisional restoration must protect the prepared tooth, provide comfort and function, and be esthetically acceptable and color stable.[2] Often such prostheses are used to assist in determination of the therapeutic effectiveness of a specific treatment plan or the form and function of the planned for definitive prosthesis.[3]

The requirements for satisfactory provisional restorations differ only slightly from definitive crowns and fixed partial dentures (FPDs).[4] The role of these restorations used for indirect restorative and prosthodontic procedures has changed dramatically in the past several years. Provisional restorations have become a vital diagnostic and assessment tool to evaluate function, color, shape, contour, occlusion, periodontal response, implant healing, and overall esthetics.[5] The prognosis of a fixed restorative procedure is largely dependent upon the quality of the interim treatment restoration.[6]

In esthetically critical areas, the provisional restoration must not only provide an initial shade match, but also must maintain its esthetic appearance over the period of service.[7] Discoloration of provisional materials for fixed prosthodontics may lead to patient dissatisfaction and additional expense for replacement. This is particularly problematic when provisional restorations are subjected to prolonged exposure to colorants during lengthy treatment.[8]
Color stability of provisional restorations is an important quality of the resin used, particularly for extensive reconstruction over a long period of time. Perceptible color change of the provisional restorative material may compromise the acceptability of the provisional restoration. Hence, color stability may be a significant criterion in the selection of a particular provisional material for use in an esthetically critical area. Color stability of provisional materials is a concern, particularly when the provisional restoration is in the esthetic zone and must be worn for extended periods of time. Ideally, dental resin should not change in color or appearance subsequent to fabrication. Material that undergoes significant discoloration may be a source of embarrassment for both the patient and dentist. Precise control of color, translucency, and surface texture provide excellent interim esthetics and a better guide for the definitive prosthesis.

Materials available for fabricating provisional fixed partial dentures include autopolymerizing polymethyl methacrylate, polyethylene methacrylate, polyvinyl methacrylate, urethane methacrylate, bis-acryl, and microfilled resin. Historically, polyethylene methacrylate has been shown to have poor esthetics and wear resistance. Thus, polymethyl methacrylate and bis-acryl resin composite materials possess a larger market share. Most provisional materials are subject to sorption, a process of absorption and adsorption of liquids that occurs relative to environmental conditions. When provisional materials contact pigmented solutions such as coffee or tea, discoloration is possible. Porosity and surface quality of provisional restorations, as well as oral hygiene habits, can also influence color changes. Incomplete polymerization and chemical reactivity are other factors that may affect color stability.

Therefore the purpose of this study was in vitro comparative evaluation of the color variations of 3 acrylic resins used for provisional restorations, as determined using computerized spectrophotometry before and after 14 and 28 days of immersion in artificial saliva and artificial saliva-tea solutions.

MATERIALS AND METHODS

In the present study, commonly used and commercially available provisional materials were investigated. Brand name, resin type, manufacturers, batch number, and shade of each material are listed in Table 1.

Table 1: Materials used in the study

<table>
<thead>
<tr>
<th>Brand name</th>
<th>Type</th>
<th>Batch number</th>
<th>Manufacturer</th>
<th>Shade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duralay</td>
<td>Methyl methacrylate</td>
<td>De X002</td>
<td>Reliance (packed by Asia Chemi. Teb. Co.) (aria dent)</td>
<td>69</td>
</tr>
<tr>
<td>Acropars TR</td>
<td>Butyl methacrylate</td>
<td>PCB9073</td>
<td>Marlic medical Industries Co.</td>
<td>A1</td>
</tr>
<tr>
<td>Tempron</td>
<td>Methyl methacrylate</td>
<td>0305081</td>
<td>GC corporation Tokyo ,Japan</td>
<td></td>
</tr>
</tbody>
</table>

Twenty disk shape specimens (20±0.1 mm×2±0.05 mm) were fabricated from each material. Materials were mixed according to manufacturers’ directions, using a silicone mold (putty, speedex, coltene, packed in IRAN by Apadana tak company) placed on a flat glass plate that covered with another glass slab. Upon polymerization, specimens were removed from the mold and examined for consistency of the polymerized surface. The thickness allowed ease of manipulation and polishing to approximately 2.0 mm, generally, the maximum facial or occlusal thickness of a provisional crown. The surface of a provisional restoration can be finished using a variety of techniques. In this study, polishing media were coarse pumice, flour of pumice (Bimstein pulver, Wiegellman Dental GmbH Landsberger Str. 6, D 53119 Bonn Germany), and diamond polishing paste (Temrex Corp., 112 Albany Ave, Freeport, NY, 11520, USA). Pumice and distilled water were measured to obtain a consistent mix for polishing each specimen. An electric hand piece operating at 15,000 rpm was used for all polishing procedures. One operator polished all specimens. Specimens were polished using a 15-second application of coarse pumice applied with a moist muslin wheel. Then specimens were polished with a prophylactic cup mounted on an electric handpiece (WandH Dentalwerk Bürmoos GmbH Ignaz-Glaser – Str.53 A-5111 Bürmoos,Austria) at 15,000 rpm using diamond polishing paste (TemrexCorp., 112 Albany Ave, Freeport, NY 11520, USA) for 15 seconds. Before initial color measurement, visual observation of polished surfaces of all specimens was made and presence of any obvious porosity noted. The specimens were rinsed with distilled water to remove any debris before immersion.

The 20 specimens were randomly divided into two groups (n=10) for two tests. For the first testing environment, specimens of each material were stored in artificial saliva (1 1 double-distilled H2O, 1.6802 g NaHCO3, 0.41397 g Na2HPO4·H2O, and 0.11099 g CaCl2) for 14 and 28 days in room temperature. The stain resistance test consisted of specimens immersed in artificial saliva and tea solution. The tea solution was prepared by immersing five prefabricated doses of tea (yellow label tea, Lipton Corp., Unit 9, 27 Khansari Alley, Somayyeh Street, Tehran, Iran) into 500 ml of boiling distilled water for 10 minutes. The tea was diluted with artificial saliva to simulate oral conditions. Artificial saliva and tea were mixed in a ratio of 300 cc tea to 600 cc saliva. The solution was changed every 2 days. Before measurements were made, each specimen was rinsed with distilled water for 30 seconds and gently cleansed with a soft bristle toothbrush to remove any loose sediment resulting from the immersion solution.
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Color measurement (\(L^*, a^*, b^*\) coordinates, and \(\Delta E\)) were made at baseline (just before immersion), 2 and 4 weeks following immersion in two solutions. These values were used in calculating the \(\Delta E\) values from the color difference formula. \(L^*\) coordinate (range 0–100) measures the quantity white-black; the greater the \(L^*\) value, the whiter the sample (0= black, 100= white); \(a^*\) coordinate measures the color among the red-green axis: a positive value refers to the amount of red in the sample, a negative value refers to the amount of green; the \(b^*\) coordinate measures the color among the yellow-blue axis: a positive \(b^*\) value is yellow, a negative \(b^*\) is blue.

All specimens were analyzed using a spectrophotometer (Macbeth color-Eye 7000 Colourspec Pty. Ltd. Unit 1, 6 Commercial Court, Tullamarine, Victoria, 3043 Australia) using standard D65 illuminant. The unit is able to analyze 100 specimens per hour and is connected to a computer to record the spectrophotometric data.

Before colorimetric measurement, the colorimeter was calibrated according to the manufacturer’s recommendation by using the supplied white calibration standard.

The calculation of the color variation (\(\Delta E\)) between the three color measurements (after 2 and 4 weeks storage and baseline in the 3-D \(L^*a^*b^*\) color space is as follows:

\[
\Delta E = [((\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2)]^{\frac{1}{2}}.
\]

Data were presented as mean standard deviation (SD). The differences in color changes were compared by two-way ANOVA, across the six groups, followed by Tukey–Kramers multiple comparison test. Mean changes from baseline were compared using one-way ANOVA, among the groups, followed by Tukey’s multiple comparison tests. Statistical significance was set at 0.05.

RESULTS

The results (mean and standard deviations) of \(\Delta L^*, \Delta a^*,\) and \(\Delta b^*\) of the three provisional prosthodontic materials after immersion in two testing solutions are presented in Tables 2 and 3.

Mean and SD of total color difference (\(\Delta E\)) of the three provisional acrylic resins after immersion in two testing solutions along with results after 2 and 4 weeks are listed in Table 4.

Because changes after 4 weeks of storage were deemed to be of greatest clinical importance when considering a provisional material for longer term use, detailed results describing patterns of color changes for this immersion period are presented. Most of the color change appears to differ between tea and saliva solutions in all materials.

Table 2: \(\Delta L^*, \Delta a^*,\) and \(\Delta b^*\) values after 2-week immersion in two testing solutions

<table>
<thead>
<tr>
<th></th>
<th>Tea</th>
<th>Artificial saliva</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\Delta L^*)</td>
<td>(\Delta a^*)</td>
</tr>
<tr>
<td>Duralay</td>
<td>Mean</td>
<td>-4.39</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.31</td>
</tr>
<tr>
<td>Acropars</td>
<td>Mean</td>
<td>-5.65</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.84</td>
</tr>
<tr>
<td>Tempron</td>
<td>Mean</td>
<td>-3.01</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Table 3: \(\Delta L^*, \Delta a^*,\) and \(\Delta b^*\) values after 4 weeks immersion in two testing solutions

<table>
<thead>
<tr>
<th></th>
<th>Tea</th>
<th>Artificial saliva</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\Delta L^*)</td>
<td>(\Delta a^*)</td>
</tr>
<tr>
<td>Duralay</td>
<td>Mean</td>
<td>-7.72</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>2.05</td>
</tr>
<tr>
<td>Acropars</td>
<td>Mean</td>
<td>-12.33</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>3.30</td>
</tr>
<tr>
<td>Tempron</td>
<td>Mean</td>
<td>-3.99</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.22</td>
</tr>
</tbody>
</table>

Table 4: \(\Delta E\) values after immersion in two testing solution along with results after 2 and 4 weeks

<table>
<thead>
<tr>
<th></th>
<th>Tea</th>
<th>Artificial saliva</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\Delta E)</td>
<td>(\Delta E)</td>
</tr>
<tr>
<td>Duralay</td>
<td>Mean</td>
<td>6.28</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.33</td>
</tr>
<tr>
<td>Acropars</td>
<td>Mean</td>
<td>7.31</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>2.39</td>
</tr>
<tr>
<td>Tempron</td>
<td>Mean</td>
<td>4.54</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.05</td>
</tr>
</tbody>
</table>
After immersion in the tea solution, $\Delta L^*$, $\Delta a^*$, and $\Delta b^*$ values of acropars are significantly more than two other materials. ANOVA results show that the total color change ($\Delta E=15.64$) in this solution, in acropars, is significantly more than duralay ($\Delta E=10.93$) and tempron ($\Delta E=8.50$). Tempron had the least amount of color difference although was not statistically significant with duralay.

After immersion in artificial saliva, Acropars had the least $\Delta a^*$ and $\Delta b^*$ and duralay had the least change in $L^*$ value. In this immersion solution, acropars had the lowest ($\Delta E=4.10$) and tempron ($\Delta E=0.56$) had the highest $\Delta E$ among three materials tested.

Therefore according to ANOVA, the restorative materials, staining agents, and their interactions were statistically significant ($P=0.05$).

To relate the color differences ($\Delta E$) to a clinical environment, the data were quantified by the National Bureau of Standards (NBS) units through the formula NBS units $= \Delta E \times 0.92$. The results are presented in Table 5. The NBS units after 4 weeks of immersion in tea solution for duralay (10.05) were closed to that of Tempron (7.82) and both of them were significantly lower than Acropars (14.38).

After immersion in artificial saliva for 4 weeks the NBS units’ result was the highest for tempron (0.51) and the lowest for acropars (3.77) which indicates the undeniable clinical differences between these three materials and their reaction once they are exposed to saliva and colorful drinks such as tea.

**DISCUSSION**

Color reproduction is an important consideration for an esthetic restoration. Color stability is critical for the esthetics of long-term provisional restorations and has been previously studied in vitro for a variety of provisional restorative materials. Provisional crown materials undergo color changes when exposed to various environmental conditions. This study evaluated the color change that occurred when three provisional crown and FPD resins were subjected to immersion in artificial saliva and artificial saliva–tea solutions over time intervals of 2 and 4 weeks. The hypothesis that significantly different color change was found in at least one of the three provisional prosthodontic materials before and after each of the tests was accepted. Data collected by spectrophotometer can be significantly altered by the inability of the spectrophotometer to read translucent materials, standardized illuminating light emitted from the device, and background in the present study; standard illuminant D65 was used. However, since color differences were being tested, the choice of the illuminant was not important. When measuring reflective surfaces, the measured color will depend on both the actual colors of the surface and the lighting conditions under which the surface is measured. Thickness and smoothness of the specimen surface also affect color. In this study, the thickness of PR material specimens was prepared according to clinical requirements. In this study, the provisional prosthodontic materials behaved differently when exposed to different testing environments.

Crispin and Caputo studied the color stability of provisional materials. They found that methyl methacrylate materials exhibited the least darkening, followed by ethyl methacrylate and vinyl-ethyl methacrylate materials. In the Guler study, the color stability of four provisional restorative materials was evaluated after 48 hours of immersion in a staining solution, according to the different finishing procedure. According to the results of this study, the methyl methacrylate-based provisional restorative material was found to be more color stable than the auto polymerized and light- polymerized composite provisional materials tested. Yannikakis et al. immersed provisional materials in various staining solutions for up to 1 month.

After immersion in the tea solution the methyl methacrylate resin showed significantly less color change compared to butyl methacrylate material (acropars).

The discoloration by tea might be due to both surface adsorption and absorption of colorants. Fine coffee particles may have deposited into the pits of the methyl methacrylate. The pits may have formed due to the polymerization shrinkage of the resin. The less polar colorants and watersoluble polyphenols in tea, for example, tannin, might have penetrated deep into the materials. Extrinsic factors for discoloration include staining by adsorption or absorption of colorants as a result of contamination from exogenous sources. Extrinsic factors for discoloration are known to cause staining of oral tissues and restorations especially in combination with dietary factors. Among these, coffee, tea, nicotine, and beverages have been reported.

Conversely, $\Delta E$ values in the solution of artificial saliva showed that the acropars is more color stable than two other material tested. The more significant color change exhibited by methyl methacrylate resin may be due to higher water sorption.5.
Proprietary variations in chemistry, such as size distribution of the polymethyl methacrylate particles, polarity of the monomers, pigment stability, and efficiency of the initiator system for provisional resins may lead to differing degrees of polymerization, water sorption, and, consequently, color stability.\cite{10}

Changes in optical properties within the materials could have been responsible for the color change. Chemical discoloration has been attributed to the oxidation of the polymer matrix or oxidation of unreacted double bonds in the residual monomers and the subsequent formation of degradation products from water diffusion.\cite{8}

The present study has following limitations:

There is not enough knowledge in the previous studies that how storage solutions can exactly reflect the clinical situations. The solutions that used in this study don’t consider all substances that provisional materials are exposed to in oral cavity; however the method of our research has used in similar researches\cite{6,8,10,13} and is a standard method. In addition, the specimen’s surfaces were flat, whereas, provisional restorations have irregular shape with convex and concave surfaces. The authors suggest that the results of present study confirm by in vivo studies.

Three acrylic provisional resins were evaluated after 2 and 4 weeks of immersion in two solutions. Under the limitations of this study, the following conclusions were drawn:

- The type of provisional materials, immersing solutions, and exposure time are significant factors that affect color stability.
- The methyl methacrylate base resin material tested (Duralay and Tempron) was found to be more color stable than butyl methacrylate base resins (Acropars) in the tea solution. The lowest color difference in three material tested in this media was observed in Tempron.
- Butyl methacrylate resin used in this study showed significantly lower discoloration in artificial saliva.
- Time is a critical factor for color stability of provisional materials. As immersion time increases, color changes become more intensive.

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REFERENCES


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