Color Stability of Provisional Restorative Materials after Exposure to Commonly consumed Beverages: A Systematic Review

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ABSTRACT

Purpose: The purpose of this systematic review was to find the effects of commonly consumed beverages on the color stability of provisional restorative materials.

Materials and methods: An electronic search in the PubMed/MEDLINE database was used to find relevant papers that had been written in English exclusively and published before November 2021. Based on the population, intervention, control, and outcomes (PICO), the primary research question for this study was “is there any difference in the color stability of provisional restorative materials after exposure to commonly consumed beverages?” By evaluating the title, abstract, and full-text of the articles, if they met the inclusion criteria, the relevance of the articles was verified. The risk of bias was assessed using specific study design-related bias assessment forms.

Result: The database search yielded 1,198 items, of which 1,188 were discarded due to being irrelevant, duplicates, or lacking data. The remaining 10 full-text articles were assessed for eligibility. Eight articles were yielded by manual search and five articles were added through the search of reference list of relevant articles. A total of 23 full-text papers were evaluated for eligibility, with one article being excluded. The current systematic review includes a total of 22 studies.

Conclusion: The findings from this systematic review indicate that although the color stability of provisional restorative materials has been the subject of several investigations, there is a lot of heterogeneity in the data. Regarding different beverages, coffee caused the most noticeable color changes. Considering these facts, the authors have explored the relevance historical perspectives researches on color stability, also maintains an esthetic appearance throughout the service. If the treatment plan calls for long-term use, the discoloration can be an esthetic problem. However, the literature reveals that the majority of studies emphasize on color stability of PMMA-based resins, with little information regarding its qualitative and quantitative evaluation available.

INTRODUCTION

A provisional restoration is a fixed or removable dental prosthesis, or maxillofacial prosthesis, designed to enhance esthetics, stabilization, and/or function for a limited period, after which it is to be replaced by a definitive dental or maxillofacial prosthesis. Often such prostheses are used to assist in the determination of the therapeutic effectiveness of a specific treatment plan or the form and function of the planned definitive prosthesis.¹ When it comes to fixed prosthodontics, the ultimate reward is an aesthetic and functional outcome achieved through superb attention to detail during each stage of treatment. The provisional materials should be color-stable and esthetically acceptable. A mirror image of the final restoration must be used for interim restorative materials, with the material being the only variable.²

After fabrication, dental resins must not exhibit any change in color and/or appearance, especially if the provisional restoration is in the esthetic zone and will be worn for a long time.³ Provisional fixed partial dentures can be fabricated with PMMA, poly(ethylene methacrylate), polyvinylmethacrylate, urethane methacrylate, and bis-acryl. Materials can be polymerized either chemically, by light, or both chemically and by light. According to several studies, PMMA-based resins are more color stable than other provisional restorative materials, including bis-acrylates.⁴ It is important that the provisional restoration not only matches the initial shade but also maintains an esthetic appearance throughout the service. If the treatment plan calls for long-term use, the discoloration can be an esthetic problem. However, the literature reveals that the majority of studies emphasize on color stability of PMMA-based resins, with little information regarding its qualitative and quantitative evaluation available.

Extensive research done in the past failed to identify the color stability of provisional restorative material that can withstand color changes. Considering these facts, the authors have explored the relevant historical perspectives researches on color stability, difficulties, and current opinions on color stability in provisional...
restorative materials. The purpose of this systematic review was to assess the results of such studies evaluating the effects of commonly consumed beverages on the color stability of provisional restorative materials.

Materials and Methods
Using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement checklist recommendations, this systematic review was planned and conducted, and registered under the International Prospective Register of Systematic Reviews with protocol #CRD42021244337.

Primary Research Question
Is there any difference in the color stability of provisional restorative materials after exposure to commonly consumed beverages?

PICO Question
Provisional restorations (P) exposed to routinely consumed beverages such as tea, coffee, soft drinks, wine, and sambar (I) were compared (C) for the color stability with unexposed (control) provisional restorative materials for changes in provisional restorative materials evaluated by spectrophotometer and International Commission on Illumination L°a°b° (CIELAB) system (O).

Study Design
In vitro studies evaluating the color stability of provisional restorative materials exposed to commonly consumed beverages were included.

Inclusion
Original in vitro research studies regarding the color stability of provisional restorative materials published in the period of 1997–2021 were included in this systematic review.

Exclusion
Letters to the editor, clinical cases, literature reviews, case series, books, reports, and research that were unable to gather data, as well as other than English-language publications were excluded.

Exposure Time and Outcome Measures
The studies with the exposure time for provisional materials in beverages ranging from 2 days to 6 months were included in this study. Color stability was assessed using a reflectance spectrophotometer and evaluated quantitatively (lab parameters) in terms of ∆E or qualitatively using visual method (subjective characteristics), especially examining impact measurements like period of stability and decrease in the grade of color shift after exposure to commonly consumed beverages.

Search Strategy
To identify relevant articles published before November 2021, an automated method was conducted in the scientific database in Elsevier (Scopus), National Library of Medicine PubMed as well as Google Scholar, with relevant articles in English only. Controlled lexicons were used to browse all databases (Medical Subject Headings terms in PubMed) and free text terms in the titles and/or abstracts. Keywords were used to establish search strategies based on each division of the PICO question, separated using the Boolean operator OR, and then combining all sections using the Boolean operator AND (Table 1). Additional studies were found by searching references within articles from these journals that would be of interest.

Data Extraction
A reviewer (R1) gathered information about the included studies and a second reviewer (R2) independently cross-checked the collected data. Publication details (authors, country, and year), characteristics related to outcomes (relevant findings, colorimetric, and spectrometrical analysis), study methodology (material used, exposure time, and beverages), sample characteristics (sample size), and outcome (∆E values) were all systematically collected from each included study (Table 1).

Risk of Bias Assessment
The risk of bias was assessed using specific study design-related bias assessment forms. Based on elements including randomization, blinding, outcome data, and sample characteristics at baseline, criteria were classified into six primary categories. Each study criterion was rated as “yes” (low-risk of bias), “no” (high-risk of bias), or “unclear” to evaluate the risk of bias (not possible to find the information or uncertainty over the potential for bias). One of the reviewers assessed the potential for bias, while the other cross-checked it (Table 2).

Results
The selection criteria were based on the flowchart of the PRISMA statement (Flowchart 1). The database search (P) yielded 1,198 items, of which 1,188 were discarded due to being irrelevant, duplicates, or lacking data. Eight articles were yielded by manual search and five articles were added through the search of reference list of relevant articles. A total of 23 full-text papers were evaluated for eligibility, with one article being further excluded. The current systematic review includes a total of 22 studies.

Among 22 articles included in this study, 15 articles compared color stability between chemically-cured provisional materials, and four articles compared color stability between heat-cured and chemically-cured provisional materials. Three articles compared the color stability of computer-aided design (CAD)/computer-aided manufacturing (CAM)—manufactured temporary restorations to that of traditional restorations (Table 2). Amongst the included studies 21 studies showed a high risk of bias (Table 3).

In this systematic review, various beverages like tea, coffee, chlorhexidine, carrot juice, Coca-Cola, and sambar were investigated. Coffee was the beverage that caused the most color change in all of the materials and time periods that were tested. Coffee discoloration might be caused by surface adsorption and absorption of colorant particles.
## Table 2: Key features of datasets from included research

<table>
<thead>
<tr>
<th>Author, year, and references</th>
<th>Provisional material</th>
<th>Beverages</th>
<th>Exposure time</th>
<th>Color stability method</th>
<th>DE</th>
<th>Findings of the study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scotti et al. 19977</td>
<td>Vinyl-ethyl-PMMA, di-acrylic, bis-acryl (methacrylic esters), methyl PMMA Chemically-cured</td>
<td>Synthetic saliva, tea, coffee, chlorhexidine</td>
<td>30 days</td>
<td>Spectrophotometry</td>
<td>7.31</td>
<td>Color stability was found to be lowest with bis-acryl (methacrylic esters) in coffee solution.</td>
</tr>
<tr>
<td>Yannikakis et al. 19988</td>
<td>Chemically-cured PMMA, chemically-cured bis-acryl, dual cured composite based resin, heat-cured PMMA</td>
<td>Water, coffee, tea</td>
<td>30 days</td>
<td>CIELAB</td>
<td>14</td>
<td>Dual-cured composite based resin showed lowest color stability in coffee solution.</td>
</tr>
<tr>
<td>Sham et al. 20049</td>
<td>Poly(ethyl methacrylate), PMMA, bis-acryl methacrylate Chemically-cured</td>
<td>Distilled water, coffee, ultraviolet light exposure</td>
<td>20 days</td>
<td>CIELAB</td>
<td>14.3–2.2</td>
<td>Bis-acryl methacrylate was the most color-stable provisional material. Coffee was the most staining solution.</td>
</tr>
<tr>
<td>Ergün et al. 20052</td>
<td>Chemically-cured bis-acryl</td>
<td>Carrot juice, Cola, light Cola, tea, distilled water</td>
<td>30 days</td>
<td>CIELAB</td>
<td>3.99</td>
<td>Carrot juice was the most staining solution.</td>
</tr>
<tr>
<td>Haselton et al. 200510</td>
<td>PMMA, bis-acryl methacrylate Chemically cured</td>
<td>Artificial saliva, coffee</td>
<td>30 days</td>
<td>CIELAB</td>
<td>9.4</td>
<td>Bis-acryl methacrylate demonstrated a significant degree of color instability in both artificial saliva and coffee.</td>
</tr>
<tr>
<td>Guler et al. 200511</td>
<td>Chemically-cured bis-acrylic composites, a light polymerized composite, and a methyl methacrylate</td>
<td>Coffee</td>
<td>2 days</td>
<td>Colorimeter</td>
<td>10.2</td>
<td>The provisional material based on methyl methacrylate was found to be more color stable.</td>
</tr>
<tr>
<td>Givens et al. 200812</td>
<td>Poly(ethyl methacrylate), dual-cured bis-acryl, auto-cured bis-acryl Chemically-cured</td>
<td>Tea</td>
<td>1 week</td>
<td>Colorimeter</td>
<td>4.33</td>
<td>When compared to conventional acrylic resin materials, dual-cured and auto-cured bis-acryl provisional materials exhibit comparable color stability.</td>
</tr>
<tr>
<td>Rutkunas et al. 201013</td>
<td>Bis-acryl, light polymerized, PMMA, poly(ethyl methacrylate) Chemically-cured</td>
<td>Distilled water, coffee, red wine, food colorant</td>
<td>7 days</td>
<td>CIELAB</td>
<td>35.9</td>
<td>Regardless of polishing process or staining agent, methacrylate-based resins had the best color stability. The most noticeable color difference was generated by red wine.</td>
</tr>
<tr>
<td>Gupta and Gupta, 201114</td>
<td>PMMA, bis-acryl composite, light polymerized composite resin Chemically-cured</td>
<td>Artificial saliva, tea, coffee, Pepsi, turmeric</td>
<td>15 days</td>
<td>CIELAB</td>
<td>8.5</td>
<td>The most color stable temporary restorative substance was observed to be light polymerized composite resin. Turmeric was the maximum staining solution.</td>
</tr>
<tr>
<td>Bayindir et al. 20124</td>
<td>Auto-polymerized bis-acryl, auto-polymerized PMMA Chemically-cured</td>
<td>Coffee, Coca-Cola, burn Coca-Cola, distilled water</td>
<td>30 days</td>
<td>CIELAB</td>
<td>9.3</td>
<td>The PMMA resin was more color stable than bis-acryl resins. For all of the materials tested, the coffee solution caused unacceptable discoloration.</td>
</tr>
<tr>
<td>Jalali et al. 201215</td>
<td>Methyl methacrylate, butyl methacrylate Chemically cured</td>
<td>Saliva, tea</td>
<td>28 days</td>
<td>Spectrophotometer</td>
<td>15.64</td>
<td>Color stability of methyl methacrylate is higher than butyl methacrylate</td>
</tr>
<tr>
<td>Author, year, and references</td>
<td>Provisional material</td>
<td>Beverages</td>
<td>Exposure time</td>
<td>Color stability method</td>
<td>ΔE</td>
<td>Findings of the study</td>
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<tr>
<td>Gujari et al. 2013&lt;sup&gt;16&lt;/sup&gt;</td>
<td>PMMA, bis-acryl composite Chemically-cured</td>
<td>Tea, coffee, Cola, and food dye</td>
<td>7 days</td>
<td>Spectrophotometer</td>
<td>7.54</td>
<td>When compared to bis-acryl composite resin, PMMA is more color stable. The staining capability of artificial saliva + coffee solution was determined to be the highest.</td>
</tr>
<tr>
<td>Mazaro et al. 2015&lt;sup&gt;17&lt;/sup&gt;</td>
<td>Acrylic resin, bis-acryl resin Chemically-cured</td>
<td>Artificial saliva, Coke, coffee</td>
<td>15 days</td>
<td>CIELAB</td>
<td>7.07–0.67</td>
<td>In compared to bis-acryl resins, acrylic resin has better color stability. The most significant color difference was induced by coffee.</td>
</tr>
<tr>
<td>Köroğlu et al. 2015&lt;sup&gt;18&lt;/sup&gt;</td>
<td>PMMA, bis-acryl resin Chemically-cured</td>
<td>Coffee</td>
<td>7 days</td>
<td>Spectrophotometer</td>
<td>3.67</td>
<td>In compared to bis-acryl resins, acrylic resin has better color stability.</td>
</tr>
<tr>
<td>Mickeviciute et al. 2016&lt;sup&gt;19&lt;/sup&gt;</td>
<td>PMMA, heat-cured PMMA, bis-acrylic resin</td>
<td>Cola, coffee</td>
<td>30 days</td>
<td>CIELAB</td>
<td>20.50</td>
<td>PMMA, rather than bis-acryl resins, showed greater color stability in polished and unpolished specimens. Coffee was found to have the highest ΔE values. Color and roughness stability were better with cold-polymerization PMMA than with hot-polymerization PMMA.</td>
</tr>
<tr>
<td>da Fonseca Costa and Lima, 2018&lt;sup&gt;20&lt;/sup&gt;</td>
<td>Acrylic and bis-acryl resins Chemically-cured</td>
<td>Distilled water, cola favored soft drink, wine, coffee.</td>
<td>7 days</td>
<td>Spectrophotometer</td>
<td>11.73</td>
<td>Color stability was better in acrylic resins than in bis-acryl resins. In the provisional prosthetic materials studied, both coffee and wine caused more color changes.</td>
</tr>
<tr>
<td>Almohareb et al. 2019&lt;sup&gt;21&lt;/sup&gt;</td>
<td>Prepolymerized PMMA, bis-acrylic resin</td>
<td>Pepsi, coffee, tea, distilled water</td>
<td>30 days</td>
<td>CIELAB</td>
<td>4.81</td>
<td>PMMA showed better color stability compared to bis-acryl resin. Coffee was found to have the highest ΔE values.</td>
</tr>
<tr>
<td>Elagra et al. 2019&lt;sup&gt;22&lt;/sup&gt;</td>
<td>Prepolymerized PMMA, bis-acrylic resin, dual-cured composite resin</td>
<td>Tea</td>
<td>7 days</td>
<td>Spectrophotometer</td>
<td>7.74</td>
<td>Color change was clinically noticeable in bis acryl resin composite materials, however color stability was greater in PMMA materials.</td>
</tr>
<tr>
<td>Soares et al. 2019&lt;sup&gt;23&lt;/sup&gt;</td>
<td>PMMA, bis-acryl resin Chemically-cured</td>
<td>Coffee</td>
<td>7 days</td>
<td>CIELAB</td>
<td>8.89</td>
<td>PMMA showed better color stability compared to bis-acryl resin.</td>
</tr>
<tr>
<td>Nupur S et al. 2020&lt;sup&gt;24&lt;/sup&gt;</td>
<td>Heat-cured acrylic resin, chemical-cured acrylic resin, dual-cured acrylic resin</td>
<td>Coffee, sambhar</td>
<td>30 days</td>
<td>CIELAB</td>
<td>9.34</td>
<td>Heat-cured PMMA has the best color stability. Sambhar showed higher staining ability.</td>
</tr>
<tr>
<td>Coutinho et al. 2021&lt;sup&gt;25&lt;/sup&gt;</td>
<td>Heat-cured PMMA, bis-acrylic resin</td>
<td>Artificial saliva, tea, coffee, and turmeric solutions.</td>
<td>6 months</td>
<td>Spectrophotometer</td>
<td>9.2</td>
<td>Heat-cured PMMA has the best color stability, followed by Protemp 4 and LuxaCrown. Turmeric has the greatest color difference among the four staining solutions, followed by coffee, tea, and artificial saliva.</td>
</tr>
<tr>
<td>Lee and Oh, 2021&lt;sup&gt;26&lt;/sup&gt;</td>
<td>Prepomerized PMMA, bis-acrylic resin</td>
<td>Coffee, wine</td>
<td>4 weeks</td>
<td>CIELAB</td>
<td>8.33</td>
<td>PMMA showed better color stability compared to bis-acryl resin. Coffee was found to have the highest ΔE values.</td>
</tr>
</tbody>
</table>
Regarding different beverages, coffee caused the most noticeable color changes in the materials tested. Regarding color stability heat-cured PMMA showed better performance than chemically-cured PMMA followed by bis-acryl resin. The decrease in color stability of the temporary materials was significantly influenced by increasing the immersion period of the test specimens.

**Discussion**

When provisional crowns and bridges are used for a long period of time, color changes are a serious cosmetic issue. In practice, a provisional prosthesis can be used for several days to months or longer, suggesting that poor-quality provisional restorations might cause difficulties, discomfort, and even additional costs for replacement. When exposed to a variety of widely consumed drinks, provisional crown materials change color, as a result, all of these domains must be investigated. Extensive literature done in the past failed to identify the color stability of provisional restorative material that can withstand color changes. They may cause color changes even throughout the retention period. Prospective, randomized controlled trials may be the only source of convincing evidence. *In vivo* trials, however, would not be ethical if patients were directly exposed to such therapies. For the purpose of determining the color stability of temporary materials when exposed to widely consumed beverages, as a foundation for gathering additional clinical information, *in vitro* studies may be an appropriate and practical alternative to retrospective evaluation.

**Methods to check Color Stability**

Visual and instrumental procedures (spectrophotometer and colorimeter) can both be used to assess discoloration.14 Because of
Color Stability of Provisional Restorative Materials

Flowchart 1: Prisma flowchart

Articles identified through data base searching (n = 1,198) → Articles excluded by title/abstract (n = 1,188) → Additional articles added through manual search (n = 8) → Potential relevant articles (n = 10) → Additional articles added through manual search of reference list of potential articles (n = 5) → Full articles accessed for eligibility (n = 23) → Full articles excluded (n = 1) → Studies included in qualitative analysis (n = 22)

Differences in color perception requirements across observers, color assessment by visual comparison is unreliable. The most commonly used instruments have been colorimeters and spectrophotometers to assess color change in dental materials because the subjective perception of visual color comparisons is excluded by objective measurements.

Monochromators and photodiodes are used in spectrophotometers to measure the reflectance curve of a product’s color every 10 nm or less, as a result, they are more precise than colorimeters at measuring color change.

Various investigations have highlighted different levels of color difference values beyond which the human eye can perceive the color change when ΔE value crosses 3.7 it becomes markedly perceptible to the human eye.

Beverages

Resins are stained by fluid colors and beverages due to the adsorption or absorption (the uptake of substances into or through tissues) of colorants by resins. In this systematic review, various beverages like tea, coffee, chlorhexidine, carrot juice, Coca-Cola, and sambhar were investigated. Coffee was the beverage that caused the most color change in all of the materials and time periods that were tested. Coffee discoloration might be caused by surface adsorption and absorption of colorant particles.

Exposure Time

The decrease in color stability of the provisional materials was caused by increasing the immersion period of the test specimens. In all staining solutions, the color change values of the materials increased when the exposure duration was extended. Thus, in the staining of restorative materials, exposure duration is equally significant. The exposure time for provisional materials in beverages were ranging from 2 days, 1 week, 15 days, 20 days, 28 days, 30 days, and 6 months, however the mean exposure time found in most of the studies was 30 days.

Provisional Restoration Material

Various provisional restorative materials have been compared with each other in different combinations in the literature. When only heat-cured PMMA and bis-acryl resin were compared, heat-cured PMMA was more color stable than later when exposed to beverages. However in studies where chemically-cured PMMA and bis-acryl resin were compared, chemically-cured PMMA demonstrated higher color stability, with lower color change values than bis-acrylic resin. This is attributable to the fact that the composition of PMMA-based materials is more uniform, and thus color stability may be altered by their capacity to absorb and adsorb liquids. Since bis-acrylic resins are heterogenous, the pigmenting solution has the ability to penetrate into the material’s microscopic particles, thus leading to a higher pigmentation level.

Research by Haselton et al. explains that water and other polar liquids have a stronger affinity for bis-acryl polymers than PMMA polymers because of their polarity. As a result, liquids absorb more readily in bis-acrylic resins, facilitating the incorporation of pigments included in these liquids. The greater color changes in bis-acrylic resins are most likely due to these phenomena that were found in most of the studies.

However, contrary to the above results only one author Sham et al. conducted the study which showed that in comparison to methyl/ethyl methacrylate–based resins, bis-acryl methacrylate was the most color-stable provisional prosthodontic material evaluated. Similar aberration from common consensus was found by Gupta and Gupta, who compared the color stability of chemically-cured PMMA, light polymerized composite resin, and bis-acryl composite, and discovered that the light polymerized composite resin illustrated better color stability than other provisional restorative material.

Recent research by Almohareb et al., Elagra et al., and Lee and Oh compared the color stability of CAD/CAM-manufactured temporary restorations to that of traditional restorations. They concluded that CAD/CAM provisional materials had superior color stability than traditional materials. Prepolymerization, greater monomer conversion, and fewer preparation mistakes in CAD/CAM materials are the factors that contribute to their better performance.

Although all efforts were taken to ensure the quality of this review there were some factors beyond the control of authors like heterogeneity of data reported in the literature regarding different beverages, exposure time, different test groups, sample size, etc.
therefore the conclusions drawn should be comprehended in the light of these limitations.

**CONCLUSION**

Within the limitation this systematic review, findings conclusions can be drawn. Although, the color stability of provisional restorative materials has been the subject of several investigations, there is a lot of heterogeneity in the data. Regarding different beverages, coffee caused the most noticeable color changes in the materials tested. Regarding color stability, heat-cured PMMA showed better performance than chemically-cured PMMA followed by bis-acryl resin. The decrease in color stability of the temporary materials was significantly influenced by increasing the immersion period of the test specimens.

**REFERENCES**