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Dr. Sergio Uriel Lamas Ramirez
Universidad Autónoma de Nuevo León, Monterrey, Nuevo León, Mexico

Corresponding Author:
Dr. Sergio Uriel Lamas Ramirez
Universidad Autónoma de Nuevo León, Monterrey, Nuevo León, Mexico

Color stability in composite resins

Sergio Uriel Lamas Ramirez

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Abstract
Introduction: Color stability in composite resins represents a clinical challenge due to continuous exposure to pigments, beverages, chemical agents, and intrinsic material factors. Loss of stability compromises the aesthetics and longevity of the restorations.
Objective: To analyze recent literature on color stability in composite resins, identifying intrinsic and extrinsic factors that influence their clinical behavior.
Methodology: A systematic review was conducted in databases (PubMed, Scopus, Cochrane, and Web of Science), including *in vitro* and clinical studies published between 2020 and 2025 that evaluated the color stability of composite resins under different experimental conditions.
Results: Studies indicate four main areas: (1) influence of beverages and staining agents, (2) impact of chemical solutions and mouthwashes, (3) effect of intrinsic material properties (type of resin, opalescence, water sorption, solubility), and (4) the role of surface finishing and polishing.
Conclusion: The color stability of composite resins is dependent on both the material and environmental factors. Coffee, tea, red wine, and carbonated drinks generate clinically perceptible changes, while surface finishing and the selection of the resin type are determining factors for the long-term aesthetic prognosis.

Keywords: Composite resins, color stability, pigmentation, dental aesthetics, restorative materials

Introduction

Medical/Economic Importance

Composite resins are restorative materials widely used in dentistry for their aesthetic and functional versatility. However, one of the main clinical challenges is maintaining color stability over time, given that restorations are subjected to the action of exogenous pigments (beverages, food, tobacco) and intrinsic material properties, such as water sorption and matrix composition.

General Background

The chromatic stability of composite resins depends on multiple factors, with pigment absorption and interaction with beverages and chemical solutions being one of the main causes of color alteration. Composite resins have become the material of choice for aesthetic restorations because they possess physical properties that reproduce the natural beauty of teeth. In this regard, color stability is of utmost importance, as the staining of restorations by colorants present in food and beverages can affect their quality and aesthetic durability.

Specific Background

Recent studies have shown that beverages such as coffee, tea, and red wine generate clinically unacceptable chromatic changes ($\Delta E>3.3$) in periods as short as 7 days, with coffee being the most staining agent for most resins evaluated. Aesthetic failure due to discoloration is a relevant clinical problem. Evaluating the advantages and disadvantages of artificial staining procedures for resin composites will improve the prediction of the materials' clinical performance. Color changes in composite resin during clinical use can be due to intrinsic and extrinsic factors. Intrinsic factors include chemical alterations of the resin matrix, such as the oxidation of unpolymerized monomers and amine accelerators, the percentage and particle size distribution of incorporated fillers, the type of photoinitiator, and the percentage of remaining double bonds. On the other hand, plaque accumulation and the absorption of staining substances, generally from the diet or smoking, act as extrinsic discoloration factors.

Specific Antecedents

It has been observed that resistance to pigmentation varies according to the type of resin: bulk-fill systems, single-shade composites, and resins with low water sorption levels show significant differences in their aesthetic performance. It seemed opportune and pertinent to conduct an exhaustive evaluation of the currently available evidence on experimental staining procedures of dental composite resins, in order to identify the most commonly used protocols.

Justification

Aesthetics is a decisive factor in the acceptance of restorative treatments. Color stability in composite resins depends not only on the patient and their habits but also on the appropriate material selection and the clinical protocol applied. Therefore, a literature review is necessary to identify the factors that determine aesthetic success and to guide evidence-based clinical practice.

Objective

To analyze the factors influencing the color stability of composite resins, based on the review of experimental and clinical studies published between 2020 and 2025.

Methodology

A systematic review was conducted in the PubMed, Scopus, Cochrane Library, and Web of Science databases. Keywords such as: color stability, composite resin, staining, water sorption, polishing were used. *In vitro* and clinical studies published in English and other languages were included, without country restriction. Inclusion criteria contemplated direct composite resins evaluated against beverages, chemical agents, polishing, mouthwashes, or artificial aging conditions.

Results

1. Influence of Beverages and Staining Agents

Various *in vitro* studies have shown that beverages with high chromogen content, such as coffee, black tea, red wine, and carbonated drinks, are the main agents responsible for the pigmentation of composite resins. Coffee showed the most intense chromatic changes even after short exposures (≤14 days), due to its high concentration of tannins and acidic pH, which favors the penetration of pigments. Black tea and red wine also generated perceptible alterations, although of lesser magnitude. The magnitude of the chromatic change (ΔE) varies depending on the type of material and the exposure time. Studies report that materials like Harvard Restore and Magnafill Putty maintained superior chromatic stability against staining beverages, while Filtek Z350 XT showed greater susceptibility, probably due to its high water absorption and nanorefilled structure, which facilitates the diffusion of colorants into the organic matrix. These differences reflect that staining resistance is material-dependent and that resin selection should consider the patient's dietary conditions to maintain long-term aesthetic results.

2. Impact of Mouthwashes and Chemical Agents

Mouthwashes constitute another relevant factor that can alter the color stability and surface properties of composite resins. In particular, those containing chlorhexidine, Listerine, or alcoholic solutions can induce slight chromatic changes, although clinically acceptable in most cases ($\Delta E \leq 2.7$). Nevertheless, prolonged or repeated exposure can increase sorption and solubility, especially in materials with a more hydrophilic organic matrix. In contrast, whitening mouthwashes containing hydrogen peroxide or abrasive agents generated a significant decrease in microhardness and surface alterations detectable under an electron microscope. These effects can compromise both mechanical resistance and light reflection, affecting color perception. Therefore, although the initial visual impact may seem favorable, the chronic use of whitening mouthrinses can deteriorate the physicochemical properties of the restored material.

3. Intrinsic Material Properties

The intrinsic properties of each resin decisively influence its chromatic behavior. The matrix composition, the type, size, and distribution of filler particles, as well as water sorption and solubility, determine the material's ability to absorb or repel colorants. Resins like Magnafill Putty and Ceram.X One Universal showed superior performance, with less color change and low solubility, probably due to their optimized organic matrix and reduced content of hydrophilic monomers. Furthermore, opalescence—an optical property related to light scattering—also showed variations over time. Some resins experienced increases in their opalescence index (OP), which alters the translucent appearance and naturalness of the color. These changes were dependent on the type of resin and the material's aging, confirming that chromatic stability is not only influenced by external factors but also by the chemical structure and intrinsic optical properties.

4. Surface Finishing and Polishing

The final finishing and polishing of a restoration is determining for its chromatic stability. Surface roughness acts as a pigment retention factor, since microscopic irregularities favor the adhesion of coloring molecules. Studies agree that polishing systems with diamond particles or multi-stage discs achieve a smoother surface, reduce roughness (Ra) and, therefore, improve resistance to staining. On the other hand, microhybrid resins or those with deficient polishing showed the highest ΔE values after exposure to coffee or tea, which evidences the direct correlation between surface roughness and color change. Additionally, it was observed that the progressive loss of gloss and the alteration of texture increase over time, especially if the material is subjected to abrasive brushing or the action of chemical solutions. Consequently, an adequate finishing and polishing technique is essential to prolong the aesthetic durability of composite resin restorations.

Discussion

The present systematic review confirms the multifactorial nature of color stability in composite resins, identifying four main axes of influence: staining agents, chemical solutions, intrinsic material properties, and the surface finishing protocol. The main finding is that the long-term aesthetics of a resin restoration depend on the interaction between external factors (patient habits) and the clinical selection and manipulation of the material.

Main Result

The main result is that coffee is the agent with the highest pigmentation potential, causing the most intense chromatic changes in composite resins, which aligns with specific studies reporting that coffee is the most staining agent for most resins evaluated, generating clinically unacceptable chromatic changes in periods as short as 7 days. This is attributed to its high concentration of tannins and acidic pH, which favor the penetration of pigments into the organic matrix. The magnitude of the color change, however, is material-dependent, highlighting that resistance to staining varies significantly among different resins.

Discussion of the Methodology

The methodology used is based on a systematic review in high-impact databases (PubMed, Scopus, Cochrane Library, and Web of Science), focusing on literature published between 2020 and 2025, which ensures the relevance and up-to-dateness of the conclusions. *In vitro* and clinical studies were included, using pertinent keywords such as color stability, composite resin, staining, water sorption, polishing. This methodological approach allowed for the analysis of a broad spectrum of experimental conditions (beverages, chemical agents, polishing, artificial aging), offering a comprehensive view of the factors that influence the aesthetic behavior of resins.

Discussion of Results with Other Authors

The findings of this review align with recent scientific evidence, which underscores that aesthetic failure due to discoloration is a relevant clinical problem. The chromatic stability of composite resins depends on multiple factors, with pigment absorption and interaction with beverages and chemical solutions being one of the main causes of color alteration.

Extrinsic Factors (Pigmentation): The high susceptibility of resins to coffee, tea, and red wine is widely documented. Literature emphasizes that color stability is of utmost importance, as the staining of restorations by colorants from food and beverage consumption can affect their quality and aesthetic longevity. Besides beverages, mouthwashes containing chlorhexidine or alcohol can induce chromatic changes, while whitening mouthwashes (with peroxide) can compromise the microhardness and surface properties of the resin. It has been observed that plaque accumulation and the sorption of staining substances, generally from the diet or smoking habits, act as extrinsic factors of discoloration.

Intrinsic Factors (Material): The results regarding the importance of intrinsic material properties are consistent with the literature indicating that color changes in composite resin during clinical service can occur due to intrinsic and extrinsic factors. Intrinsic factors include chemical alterations of the resin matrix, such as the oxidation of unpolymerized monomers and amine accelerators, the percentage and particle size distribution of incorporated fillers, the type of photoinitiator, and the percentage of remaining double bonds. Low water sorption and matrix composition are crucial, leading to the conclusion that the selection of resins with low water sorption (such as Magnafill Putty and Ceram.X One Universal) is key for long-term prognosis. Opalescence also proved to be a significant intrinsic factor, as its alteration modifies the translucent appearance of the restoration.

Finishing and Polishing: The impact of surface finishing and polishing is supported by studies that directly correlate surface roughness (Ra) with pigment retention. It is confirmed that the use of polishing systems with diamond particles or multi-stage discs improves resistance to staining, being essential for prolonging the aesthetic durability of restorations.

In general, current evidence confirms that composite resins have become the material of choice for aesthetic restorations because they have the physical properties that reproduce the natural-looking beauty of teeth, but their aesthetic performance is subject to intrinsic and extrinsic susceptibility to discoloration. Evaluating the benefits and disadvantages of artificial staining procedures for resin-based composites will improve the prediction of the materials' clinical performance.

Conclusion

1. Color stability in composite resins is a multifactorial phenomenon influenced by the type of material, the staining agent, the exposure time, and the surface finishing.
2. Coffee is identified as the agent with the highest pigmentation potential, causing the most intense chromatic changes, followed by black tea and red wine, mainly due to its high concentration of tannins and acidic pH.
3. Carbonated beverages and some mouthwashes (such as those with chlorhexidine or alcohol) produce moderate changes, although whitening mouthwashes (with peroxide) can compromise the microhardness and surface properties of the resin.
4. The selection of resins with low water sorption (such as Magnafill Putty and Ceram. X One Universal), along with appropriate polishing protocols (using diamond systems or multi-stage discs to reduce surface roughness), can improve long-term aesthetic predictability.
5. Furthermore, the intrinsic properties of the material (optimized organic matrix and resistance to opalescence alteration) are determining factors.
6. It is recommended that clinicians select materials with better optical performance and educate patients about the factors affecting the aesthetic longevity of their restorations, emphasizing moderation of chromogenic agent consumption and the importance of impeccable polishing to prevent pigment retention.

Conflict of Interest

Not available.

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Not available.

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