



**RESINAS COMPOSTAS COM EFEITO CAMALEÃO NA ODONTOLOGIA
RESTAURADORA: REVISÃO INTEGRATIVA SOBRE MIMETISMO
ÓPTICO E APLICAÇÃO CLÍNICA**

**CHAMELEON EFFECT COMPOSITE RESINS IN RESTORATIVE
DENTISTRY: AN INTEGRATIVE REVIEW ON OPTICAL MIMICRY AND
CLINICAL APPLICATION**

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RESUMO

Objetivo: Analisar o desempenho óptico e clínico de resinas compostas com efeito camaleão, com ênfase na sua capacidade de mimetização da cor dentária. **Método:** Foram incluídos 12 estudos, sendo 8 experimentais/laboratoriais (in vitro), 1 ensaio clínico randomizado e 3 relatos de caso clínico, publicados entre 2006 e 2025. A metodologia consistiu na seleção de artigos que avaliaram propriedades como translucidez, espessura, índice de refração e tipo/tamanho das partículas de carga. **Resultados:** As resinas com partículas supranano e elevada translucidez apresentam maior dispersão da luz, favorecendo o efeito camaleão; além disso, ensaios clínicos e relatos de caso evidenciaram boa estabilidade de cor, adaptação marginal satisfatória e simplificação do protocolo restaurador, otimizando o tempo clínico. Contudo, constatou-se significativa heterogeneidade metodológica nos estudos, variando-se os substratos, métodos de avaliação (ΔE objetiva versus análise visual) e ausência de ensaios clínicos de longo prazo, o que limita a comparabilidade dos dados. Recomenda-se que pesquisas futuras explorem materiais inteligentes com adaptação óptica dinâmica e conduzam estudos longitudinais em ambiente clínico para consolidar sua eficácia e aplicabilidade. **Conclusão:** Apesar de promissoras e alinhadas ao ideal biomimético, as resinas com efeito camaleão requerem validação clínica mais robusta e padronização de protocolos de avaliação.

Palavras-chave: Resinas compostas. Cor. Materiais dentários. Espectrofotometria. Biomimética.

ABSTRACT

Objective: This study, through an integrative literature review, analyzes the optical and clinical performance of chameleon-effect composite resins, with an emphasis on their ability to mimic tooth color. **Method:** Twelve studies were included, comprising 8 experimental/laboratory (in vitro) investigations, 1 randomized clinical trial, and 3 clinical case reports, published between 2006 and 2025. The methodology consisted of selecting articles that evaluated properties such as translucency, thickness,

refractive index, and filler particle type/size. **Results:** Resins with supranano particles and high translucency exhibit greater light scattering, favoring the chameleon effect. Furthermore, clinical trials and case reports have demonstrated good color stability, satisfactory marginal adaptation, and simplified restorative protocols, optimizing clinical time. However, significant methodological heterogeneity was observed in the studies—with varying substrates, assessment methods (objective ΔE versus visual analysis), and a lack of long-term clinical trials—which limits data comparability. Future research is recommended to explore smart materials with dynamic optical adaptation and conduct longitudinal studies in a clinical setting to consolidate their efficacy and applicability. **Conclusion:** Although promising and aligned with the biomimetic ideal, chameleon effect resins require more robust clinical validation and standardization of evaluation protocols.

Keywords: Composite resins. Color. Dental materials. Spectrophotometry. Biomimetics.

INTRODUCTION

Contemporary dentistry is characterised by continuous technological advances that directly impact various areas of clinical practice. These advancements range from diagnostic imaging methods, such as digital radiography and computed tomography, to the development of high-performance restorative materials. A significant milestone in history of restorative dentistry occurred in the 1960s with Bowen's studies at Northwestern University, which led to the creation of the first composite resin. Initially formulated with the monomer bisphenol Aglycidyl methacrylate (Bis-GMA) and the cross-linking agent PDMS–dimethacrylate (DMA), successive improvements to this technology have been made over the decades. The incorporation of new monomers, such as triethylene glycol dimethacrylate (TEGDMA), urethane dimethacrylate (UDMA) and ethylene glycol dimethacrylate (EGDMA) resulted in significant improvements in mechanical strength, dimensional stability and clinical handling of the material (Bortolon, 2024; Donato, 2022).

The evolution also involved inorganic filler particles, whose variation in size, morphology, and composition resulted in different generations and classifications of composite resins, with specific properties of strength, aesthetics, and polishability (Oliveira, 2024; Paravina, 2006). In recent years, driven by growing demand for more natural-looking, the dental industry has focused on the development of composite resins with advanced optical properties, including universal-color resins and chameleon-effect resins. In the Brazilian context, recent studies have also highlighted the growing adoption of single-shade composite resins as an alternative to simplify the restorative process (Bortolon, 2024), while also demonstrating esthetic benefits and reduced clinical time (Castro et al, 2024).

These innovative materials can adapt chromatically to the adjacent dental structure, matching the color of natural teeth more efficiently and thus reducing the need to select multiple shades at the time of restoration (Anwar, 2024; Guimarães, 2023). This property, known as the “chameleon effect,” is the result of a complex interaction between the translucency of the material, the refractive index of the matrix and fillers, and the thickness of the restoration (Vattanaseangsiri, 2022; Yamaguchi, 2021).

In this context, it is essential to understand the optical principles underlying the clinical performance of these resins, as well as to evaluate their advantages and limitations relative to conventional composite resins. Accordingly, this literature review aims to address the following research question: What optical mechanisms are responsible for the chameleon effect in composite resins, and how do these materials perform clinically compared to conventional resins?

The objective of this work is to review the scientific literature on chameleon-effect composite resins, analyzing the optical mechanisms that enable their chromatic adaptation and comparing their clinical performance, advantages, and limitations in relation to conventional composite resins.

METHODS

The current study is an integrative literature review with a descriptive approach, which aims to analyze scientific publications related to chameleon-effect

composite resins, especially with regard to their optical mechanisms and clinical performance. The search was conducted between April and June 2025 in the PubMed, Scopus, and SciELO databases, using the following descriptors combined with Boolean operators: “chameleon effect resin composite,” “single-shade composite,” “universal shade resin,” “esthetic dentistry,” and their equivalents in Portuguese.

Original articles published between 2006 and 2025, written in Portuguese or English, that addressed clinical or laboratory aspects of chameleon effect composite resins were included. To ensure the practical and scientific relevance of the findings, only well-documented in vitro, in vivo, clinical trials, or clinical case reports were considered.

Nineteen articles were initially selected. Literature reviews, systematic reviews, academic works (such as term papers, dissertations, and theses), duplicate articles, and publications with insufficient methodological description were excluded. After reading the titles, abstracts, and full texts, 12 articles remained that fully met the established criteria and were used in the results section.

RESULTS

After a rigorous literature review, 12 articles were selected. For clarity in data presentation, the studies were organized into two tables: Table 01 provides a comprehensive overview of the analyzed articles, while Table 02 classifies them according to thematic categories and main findings, facilitating a systematic and detailed understanding of the properties of chameleon-effect composite resins.

Table 1: Selected Studies for Analysis.

Título	Autoria	Periódico
Use of chameleon composite resins in Dentistry: case report	Freitas <i>et al.</i> (2024)	Revista Sul-Brasileira de Odontologia
Color match analysis of single-shade and multi-shade composite resins using spectrophotometric and visual methods after bleaching	Cubukcu <i>et al.</i> (2023)	Dental Materials

Color matching ability of resin composites incorporating supra-nano spherical filler producing structural color	Yamaguchi <i>et al.</i> (2021)	Dental Materials
Influence of restorative material translucency on the chameleon effect	Vattanaseangsiri <i>et al.</i> (2022)	Scientific Reports
Optical behavior and marginal discoloration of a single shade resin composite with a chameleon effect: a randomized controlled clinical trial	Anwar <i>et al.</i> (2024)	British Dental Journal Open
Color adjustment potential of two single shade resin-based composites before and after staining	Karadağ <i>et al.</i> (2024)	Cumhuriyet Dental Journal
Evaluation of color stability in single-shade composite resins using spectrophotometer and cross-polarized mobile photography	Tepe <i>et al.</i> (2025)	BioMed Central Oral Health
Influence of depth and translucency on the color matching of single-shade resin composites: An in vitro study.	Fernandes-e-Silva <i>et al.</i> (2025)	Brazilian Dental Journal
Restoration in posterior tooth with monochrome resin: case report	Queiroz <i>et al.</i> (2022)	Brazilian Journal of Development
Color-Matching and Blending-Effect of Universal Shade Bulk-Fill-Resin-Composite in Resin-Composite-Models and Natural Teeth.	Abdelraouf & Habib (2016)	BioMed Research International
Color interaction of dental materials: Blending effect of layered composites.	Paravina <i>et al.</i> (2006)	Dental Materials
Resinas compostas monocromáticas: Uma abordagem em caso clínico. Monochromatic composite resins: A clinical case approach.	Silva <i>et al.</i> (2023)	Research, Society and Development

Source: elaborated by the authors.

Table 02: Summary of key findings by topic category.

Thematic category	Related studies	Main findings
Optical properties and Chromatic adaptation	Yamaguchi <i>et al.</i> (2021) (in vitro); Vattanaseangsiri <i>et al.</i> (2022) (in vitro); Fernandes-e-Silva <i>et al.</i> (2025) (in vitro); Karadağ <i>et al.</i> (2024) (laboratorial); Paravina <i>et al.</i> (2006) (experimental)	Studies have demonstrated that translucency, thickness, and particle size are critical determinants of tooth-color matching. The incorporation of suprananometer-scale particles facilitates the chameleon effect through structural color mechanisms
Clinical behavior and color stability	Anwar <i>et al.</i> (2024) (ensaio clínico); Cubukcu <i>et al.</i> (2023) (experimental pós-	Color stability of monochromatic resins was found to be satisfactory in most

	clareamento); Tepe <i>et al.</i> (2025) (experimental); Abdelraouf & Habib (2016) (in vitro)	studies, even following bleaching or pigmentation procedures. Marginal adaptation was considered clinically acceptable.
Clinical applications (Case report)	Freitas <i>et al.</i> (2024); Queiroz <i>et al.</i> (2022); Silva <i>et al.</i> (2023) (todos relatos de caso clínico)	The cases demonstrated ease of clinical use and good aesthetic results, with shorter color selection time and favorable visual integration.

Source: elaborated by the authors.

DISCUSSION

Optical properties and tooth color matching

The tooth color matching using composite resins with a chameleon effect is the result of a set of optical properties that act synergistically. Among the most relevant factors are the translucency of the material, the refractive index of the matrix and inorganic fillers, the thickness of the application, and the size and type of filler particles. In vitro studies indicate that resins with supra-nano particles and a homogeneous matrix tend to disperse light more efficiently, favoring blending with the surrounding tooth structure (Karadağ et al, 2024; Yamaguchi et al, 2021). Brazilian academic works have also highlighted the esthetic mimicry potential of these materials, especially in anterior restorations (Oliveira, 2024).

This behavior is associated with structural color mechanisms, in which the interaction of light with nanoscale particles generates visual effects similar to those found in nature, such as in butterfly wings and seashells (Paravina et al., 2006). Unlike simple pigmentation, this effect is based on the physics of light, meaning that optical adaptation is less sensitive to minor variations in the color of the underlying tooth substrate.

The resin thickness applied also directly influences its ability to match the color. Thinner layers allow greater light transmission and, consequently, better visual integration with adjacent tissues (Fernandes-e-Silva et al, 2025; Paravina et al, 2006). When the thickness increases, there is greater absorption and less light transmission, which can compromise the chameleon effect if the material is not

properly formulated (Vattanaseangsiri et al, 2022; Yamaguchi et al, 2021). The combination of composition and restorative technique, therefore, must be carefully planned to maximize optical performance.

Color Stability and Clinical performance

In the clinical context, color stability is essential to ensure the long-term esthetic longevity of restorations. The studies shows that universal shade resins maintain satisfactory chromatic stability over time, even when subjected to challenges such as dental bleaching or exposure to dietary staining agents (Anwar et al, 2024; Cubukcu et al, 2023). This resistance to color changes can be attributed both to the quality of the resin matrix and to the integrity of the interfaces between the components of the materials. These findings are consistent with studies evaluating the impact of bleaching agents on the color stability and optical behavior of composite restorations (Donato, 2022; Marzullo et al, 2025).

In addition to color stability, marginal adaptation is clinically relevant, as failures in this region can compromise the seal, leading to marginal leakage and recurrent caries. The reviewed studies generally reported that chameleon-effect resins exhibited clinically acceptable marginal adaptation, even in restorations subjected to accelerated aging (Tepe et al., 2025). This indicates that the esthetic performance of these materials is not achieved at the expense of technical quality.

However, the optical behavior may vary depending on the product line and type of application. Bulk-fill resins, for example, may exhibit reduced mimicry performance if their translucency is excessive, as the insertion thickness in these cases is greater. Controlling these factors is essential to prevent undesirable outcomes, particularly in regions with high esthetic demand (Abdelraouf; Habib, 2016; Fernandes-e-Silva et al., 2025; Paravina et al, 2006).

Clinical applications and Operative advantages

The clinical case reports included in the review demonstrated positive aesthetic results in different types of restorations, especially in posterior teeth, where the speed and simplicity of the restorative procedure are valued (Freitas et al, 2024;

Silva et al, 2023). The main advantage reported was the elimination of the precise color selection step, which represents a significant time saving and reduces the subjectivity associated with the color scale. Additional Brazilian clinical reports have also described satisfactory esthetic outcomes and simplified restorative protocols using single-shade resins (Esvercutti et al, 2023).

For early-career professionals or clinics with a high patient turnover, monochromatic resins offer a practical and efficient approach without compromising the final esthetic outcome of restorations. Their ease of application and versatility across different tooth substrate shades make these materials an attractive option, particularly in contexts where esthetics are desired but clinical time is limited.

Furthermore, the use of these resins can facilitate the work of trainees or in teaching environments, where the complexity of conventional stratification may hinder the achievement of restorations with satisfactory esthetic finish. Nevertheless, it is important to emphasize that, despite these advantages, technical proficiency remains essential to ensure restoration success, including moisture control, proper adhesive selection, and appropriate finishing procedures.

Methodological limitations and future perspectives

Despite demonstrated advances, the current literature exhibits considerable methodological heterogeneity, which hinders direct comparisons between studies and limits the generalizability of results. Differences in color assessment protocols—such as the use of spectrophotometry (ΔE) versus subjective visual analysis—as well as variations in substrate type, ambient lighting, and the number of evaluators compromise the reproducibility of the findings (Abdelraouf; Habib, 2016; Vattanaseangsiri et al, 2022). Recent systematic reviews have also highlighted the scarcity of long-term clinical trials and the methodological heterogeneity among studies (Guimarães et al, 2023).

Furthermore, most of the reviewed studies are either laboratory-based or isolated clinical reports, with a scarcity of long-term randomized clinical trials. Despite the demonstrated advances, the current literature exhibits considerable methodological heterogeneity, which makes direct comparisons difficult and limits

generalization. Differences in color assessment protocols, such as the use of spectrophotometry (ΔE) versus subjective visual analysis, as well as variations in substrate type, ambient lighting, and the number of evaluators, compromise the reproducibility of the findings. This gap weakens the evidence base and highlights the need for methodologically rigorous studies assessing not only esthetic stability but also mechanical strength and clinical behavior of these resins across various regions of the oral cavity

A promising avenue for the future of restorative dentistry lies in the development of smart materials capable of dynamically responding to variations in the oral environment, such as changes in humidity, temperature, and lighting. The integration of nanotechnology with optical engineering may enhance the potential of biomimetic resins, enabling continuous, real-time, and personalized color adaptation, in line with the principles of minimally invasive and esthetic dentistry.

CONCLUSION

This review demonstrated that the chameleon effect is a relevant property of modern composite resins, allowing efficient optical integration between the restorative material and the tooth structure, especially in aesthetic contexts. Characteristics such as translucency, application thickness, refractive index, and filler particle size were decisive for the mimetic performance observed. Resins with supra-nano particles and a homogeneous matrix stood out for their light diffusion and chromatic adaptation capabilities, contributing to satisfactory esthetic results even with less color complexity. Clinical studies and case reports reinforced the clinical practicality of these resins, with reduced operating time and ease of application, maintaining color stability and good marginal adaptation over time.

However, the literature still presents significant methodological heterogeneity, making direct comparisons between studies difficult. In addition, there are few long-term clinical trials evaluating the aesthetic and functional durability of these resins under real conditions. It can therefore be concluded that the use of chameleon-effect resins represents an innovative, biomimetic, and clinically viable solution, but one that requires greater standardization in studies and ongoing

clinical validation. Future research should explore even more advanced technologies, such as smart materials with dynamic optical adaptation, expanding the restorative potential based on natural aesthetics and technological advances in contemporary dentistry.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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