



Systematic Review

Master's Degree in Dental Medicine

# **The aesthetic approach of restorative treatment of teeth with chromatic alteration**

*A abordagem estética do tratamento restaurador  
de dentes com alterações cromáticas*

**Beatriz Duarte Oliveira**

**Porto, 2024**



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alterações cromáticas*

**Field of studies:** Operative Dentistry

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## ABREVIATIONS INDEX

|                              |                                   |
|------------------------------|-----------------------------------|
| <b>RMGI</b>                  | Resin-Modified Glass-Ionomer      |
| <b>HP</b>                    | Hydrogen Peroxide                 |
| <b>CP</b>                    | Carbamide Peroxide                |
| <b>SP</b>                    | Sodium Perborate                  |
| <b>MTA</b>                   | Mineral Trioxide Aggregate        |
| <b>WSL</b>                   | White-Spot Lesions                |
| <b><math>\Delta E</math></b> | Color Variation                   |
| <b>TP</b>                    | Translucency Parameter            |
| <b>TAP</b>                   | Translucency Adjustment Potential |
| <b>CAP</b>                   | Color Adjustment Potential        |
| <b>RET</b>                   | Regenerative Endodontic Therapy   |
| <b>LED</b>                   | Therapylight-Emitting Diode       |

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## **I. Abstract**

Public awareness regarding the aesthetic appearance of teeth implies that dentists understand the phenomenon of color and the mechanisms associated with chromatic alterations of teeth. Intrinsic pigmentation is challenging, requiring structural interventions, thus contemporary non-invasive treatments include direct restorations, whitening, microabrasion, resin infiltration, or their combination.

Therefore, the aim of this systematic review is to provide an overview of the different restorative treatment options available for the rehabilitation of teeth with chromatic alterations of intrinsic etiology. This study was performed according to the Preferred Reporting Items for Systematic Reviews and MetaAnalyses (PRISMA) guidelines. The search was limited to the English and Portuguese language and studies published until March 2024 that included aesthetic evaluation of the restorative treatment of teeth with chromatic alterations. Fifteen articles were included. It was carried out a survey that aimed to investigate the factors influencing the effectiveness of restorative treatment on teeth with chromatic alterations.

The findings obtained underscore a significant relationship between the combined application of opaquer and resin composite. Additionally, existing literature supports the potential of minimal invasive techniques and summarizes how the substrate, shade, thickness, and aging time may influence treatment success. These findings show potential for optimizing clinical approaches to managing chromatic alterations. However, further studies are warranted to define precise guidelines in this area, ensuring optimal outcomes for patients.

## **II. Resumo**

A consciencialização pública em relação à aparência estética dos dentes, implica que médico dentista compreenda o fenómeno da cor e os mecanismos associados a alterações cromáticas dos dentes. As pigmentações intrínsecas são desafiantes, requerendo intervenções estruturais, pelo que os tratamentos contemporâneos não invasivos incluem restaurações diretas, branqueamento, microabrasão e infiltração de resina, ou a sua combinação.

Assim, o objetivo desta revisão sistemática é fornecer uma visão geral das diferentes opções de tratamento restaurador disponíveis para a reabilitação de dentes com alterações cromáticas de etiologia intrínseca. Este estudo foi realizado de acordo com as diretrizes do Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). A pesquisa foi limitada aos idiomas Inglês e Português e a artigos publicados até março de 2024 que incluíam a avaliação estética do tratamento restaurador de dentes com alterações cromáticas. Foram incluídos quinze artigos. Foi realizado um questionário que teve como objetivo investigar os fatores que influenciam a eficácia do tratamento restaurador em dentes com alterações cromáticas.

Os resultados obtidos destacam uma relação significativa entre a aplicação combinada de opacificador e resina composta. Além disso, a literatura existente apoia o potencial das técnicas minimamente invasivas e resume como o substrato, a tonalidade, a espessura e o tempo de envelhecimento podem influenciar o sucesso do tratamento. Estes resultados mostram potencial na otimização de abordagens clínicas na gestão de alterações cromáticas. No entanto, são necessários mais estudos para definir orientações precisas nesta área, garantindo resultados ótimos para os pacientes.

### **III. Introduction**

The demand for dental aesthetics has been increasing exponentially. In contemporary dentistry, patients' needs are considered, addressing not only function but also dental aesthetic appearance.<sup>(1)</sup> Therefore, one of the main objectives of dental treatment is to mimic teeth and smile design as naturally and aesthetically as possible, based on individual characteristics and specific needs of each patient.<sup>(2)</sup>

#### **Color and Translucency**

Color is a phenomenon understood as a fundamental aesthetic parameter for the success of a restoration. The concept of color relates to a psychophysical response to the physical interaction of light energy with an object and the personal perception of an observer.<sup>(1)</sup> This variability plays an essential role in how light interacts with dental tissues, involving phenomena such as specular light transmission, specular reflection, diffuse light reflection, and absorption and dispersion of light.<sup>(3)(4)</sup>

In the domain of dental aesthetics, the analysis of translucency in dental materials is intricately tied to the perception of color, as both phenomena are significantly influenced by the interaction between light and dental tissues.<sup>(4)</sup> Translucency, as an intermediate state between total opacity and complete transparency, exhibits notable variation among individuals and even between teeth, thus contributing to the inherently subjective nature of its evaluation.<sup>(5)</sup> Collectively, these optical interactions impact the perception of color in dental restorations, highlighting the complexity and importance of understanding translucency in achieving aesthetically pleasing outcomes.<sup>(3)</sup>

#### **Teeth with chromatic alterations**

The chromatic alterations present variable clinical characteristics, depending on the location, composition, severity, and degree of adhesion to the enamel surface.<sup>(6)</sup> These should be known by the dentist for the formulation of a correct diagnosis.<sup>(7)</sup> The etiology of chromatic alteration can be determined by the location of dental pigmentation, such as extrinsic pigmentation, intrinsic pigmentation, or a combination of both.<sup>(8)</sup>

Extrinsic discoloration arises from the accumulation of chromogenic agents on the tooth surface or within the acquired pellicle.<sup>(9)</sup> This phenomenon is typically triggered by various factors, including the presence of bacteria within the dental biofilm and the consumption of pigmented foods or beverages. Additionally, indirect extrinsic pigmentation may occur due to chemical interactions between compounds such as chlorhexidine and iron salts.<sup>(7)</sup>

Intrinsic pigmentation results from alterations in the structural composition or thickness of dental hard tissues during tooth development.<sup>(10)</sup> This phenomenon occurs from the incorporation of chromogenic material, of endogenous or exogenous origin, into dental tissues.<sup>(8)</sup>



The causes of intrinsic tooth discoloration may arise at various stages of tooth eruption. It can occur during a pre-eruptive phase, impacting the formation and development of dental tissues, or during a post-eruptive phase, when agents originating from the pulp or tooth surface penetrate the hard tissues. Furthermore, within the pre-eruptive phase, pigmentation may manifest at different stages of odontogenesis: during odontogenesis due to alterations in the quality or quantity of tissues or through the incorporation of discoloring agents; or solely after odontogenesis. <sup>(7)(8)</sup>

The color of intrinsic tooth discoloration often reflects the nature of the underlying condition or cause. Therefore, by carefully evaluating the optical properties, improvements in diagnosis and treatment outcomes can be achieved.<sup>(9)</sup>

The following diagram (Table 1) aims to outline the factors associated with intrinsic chromatic alterations of dental tissues, commonly described in the literature. It enhances the understanding of the mechanisms underlying the discoloration process and the clinically observed colors.

**Table 1: Factors responsible for generalized and localized intrinsic discoloration of teeth**  
(8)(9)(10)(11)

Adapted from Manuel, S.T., Abhishek, P.T., & Kundabala, M. (2010).  
Etiology of tooth discoloration - a review. Nigerian Dental Journal.

**Factors responsible for generalized intrinsic discoloration of teeth**

|                         | Factors                                                                                                                                                                                                                                                            | Examples                                                                                         | Colors                                                     |               |
|-------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|------------------------------------------------------------|---------------|
| Pre-eruptive<br>causes  | <b><u>Disturbance of tooth germ</u></b><br>Disrupt of tooth development, leading to enamel hypomineralization or hypoplasia, due to changes in enamel mineralization and thickness.                                                                                | Infection (maternal or childhood)<br>Nutritional deficiency<br>Molar Incisor Hypomineralization  | White to yellow to brownish                                | Environmental |
|                         | <b><u>Metabolic disorders</u></b><br>Metabolic disorders disrupt normal metabolic processes, leading to abnormal accumulation and deposition of various substances within dental tissues.                                                                          | Hyperbilirubinemia<br>Alkaptonuria<br>Prophyria                                                  | Yellow - Green<br>Brown<br>Red/Purple to Brown             |               |
|                         | <b><u>Drug therapy</u></b> (maternal or childhood)<br>Some drugs such as minocycline and tetracycline, due to their specific chemical properties, form stable complexes with calcium ions in dental tissues during tooth development.                              | Ciprofloxacin<br>Minocycline<br>Tetracycline                                                     | Greenish<br>Blue - Green<br>Yellow, Brown, Blue or Gray    |               |
|                         | <b><u>Genetic disorders</u></b><br>These genetic disorders may affect either enamel, as in amelogenesis imperfecta, or dentin formation, as in dentinogenesis imperfecta and dentin dysplasias, and may occur in isolation or associated with systematic disorder. | Amelogenesis imperfecta<br>Dentinogenesis imperfecta<br>Dentin dysplasias<br>Epidermosis bullosa | Yellow - Brown<br>Blue - Brown<br>Yellow - Brown<br>Yellow |               |
|                         | <b><u>Endemic fluorosis</u></b><br>Marked by incorporation of excessive fluoride ions into hydroxyapatite crystals during enamel development.                                                                                                                      |                                                                                                  | Chalky white to Brown/Black                                |               |
| Post-eruptive<br>causes | <b><u>Dental conditions</u></b><br>Arises from the combined effects of secondary dentin deposition, stain accumulation, enamel thinning, and alterations in light transmission.                                                                                    | Ageing<br>Tooth wear                                                                             | Yellowish<br>Yellowish                                     | Hereditary    |

## Factors responsible for localized intrinsic discoloration of teeth

|                         | Factors                                                                                                                                                                                                                 | Examples                                                                    | Colors                                                           |
|-------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|------------------------------------------------------------------|
| Pre-eruptive<br>causes  | <b><u>Disturbance of tooth germ</u></b><br>Describe as hypoplastic lesions caused by trauma to a developing, unerupted tooth.                                                                                           | Turner's hypoplasia                                                         | White to yellow to brownish                                      |
|                         | <b><u>Pulpal causes</u></b><br>Associated with pulp tissue breakdown, by-product release, penetration into dentin, and alterations in dentin structure due to internal resorption or calcific metamorphosis.            | Pulpal trauma<br>Internal resorption<br>Calcific metamorphosis              | Pink – Grey/Brown<br>Pinkish<br>Yellowish - Brown                |
| Post-eruptive<br>causes | <b><u>Dental materials</u></b><br>Consequence of chemical reactions occurring at the interface between the dental material and dental tissues, leading to deposition of pigmented compounds within the tooth structure. | Amalgam<br>Composite/GIC<br>Intra canal medicaments<br>Obturating materials | Blue - Gray<br>Yellowish - Brown<br>Brownish - Gray<br>Dark gray |
|                         | <b><u>Dental conditions</u></b><br>As bacterial activity progresses and enamel demineralizes, the tooth structure alters the optical properties.                                                                        | Arrested carie                                                              | Dark brown to Black                                              |
|                         |                                                                                                                                                                                                                         |                                                                             |                                                                  |

In contrast to extrinsic pigmentations, intrinsic chromatic alterations cannot be eliminated without causing structural changes to the teeth. Addressing intrinsic discolorations typically requires more invasive procedures and may involve more expensive treatments to correct alterations in the internal tooth structure. <sup>(12)</sup>

### Management – Materials

For achieving optimal aesthetic outcomes, it becomes challenging to harmonize the color of the restorative material with the remaining dental structure and adjacent teeth. Alterations in the dental structures that constitute the coronal portion of the tooth, whether occurring during formation, development, or post-eruption, may lead to modifications in light transmission properties, consequently influencing the external appearance of the tooth. <sup>(13)</sup>

In response to the expressed aesthetic requirements, significant advancements have transpired over the past five decades concerning materials and devices utilized in Esthetic Dentistry. This advancement is geared towards replicating the natural characteristics inherent in teeth. <sup>(5)(14)</sup>

Conventional techniques for addressing changes in tooth color often involve the use of indirect restorations. Nevertheless, these methods present inherent limitations, such as the extensive nature of the procedures involved, the necessity

for significant reduction of tooth structure to achieve the desired aesthetic outcome, and the potential for subsequent tooth sensitivity. <sup>(8)</sup>

Due to their minimally invasive attributes, contemporary noninvasive treatments for addressing tooth discoloration include tooth-whitening, microabrasion, resin infiltration, or their combination. <sup>(15)(16)</sup> Dental bleaching may be regarded as a primary treatment option for addressing tooth discoloration. <sup>(6)</sup> Among the whitening agents currently employed are hydrogen peroxide (HP) and carbamide peroxide (CP), at concentrations ranging from 4% to 40%, in addition to sodium perborate (SP), either used independently or in conjunction with hydrogen peroxide. These agents may exhibit variations in concentration, composition, and instructions for use, depending on the specific technique employed. <sup>(17)</sup>

Resin infiltration and microabrasion have demonstrated efficacy in aesthetically enhancing white spots. <sup>(16)</sup> In resin micro-infiltration, acid etching is employed to open enamel prisms, facilitating resin infiltration to fill the porosities resulting from demineralization. Conversely, acid microabrasion chemically and mechanically removes enamel lesions of limited depth. <sup>(15)(18)</sup>

Despite its conservative approach, conservative techniques may not always yield optimal results. In such cases, alternative treatments such as resin composite restorations are recommended to achieve the desired outcome. This is primarily due to their ability to effectively conceal discolorations and their broad range of shades and translucency levels, enabling them to closely mimic natural teeth and provide satisfactory aesthetics. <sup>(18)</sup> Additionally, resin composite restorations require minimal or no substrate preparation and offer cost-effectiveness relative to indirect porcelain restorations. <sup>(19)</sup>

It's worth noting that direct resin composites have inherent limitations in their ability to provide opacity. <sup>(20)</sup> To mitigate this issue, opaquers have been developed specifically for use alongside restorative materials. Their principal function is to enhance the masking of underlying structures and minimize tissue reduction. <sup>(21)</sup>

## **Objectives**

In this sequence, the objectives of this study are:

- a) Addressing the different restorative treatment options available for the rehabilitation of teeth (vital or non-vital) with chromatic alterations of intrinsic etiology.
- b) Evaluating the influence of etiology and extension of teeth with chromatic alterations, the shade of resin composite and restorative treatment, through the administration of a survey at the Faculty of Dental Medicine of Porto University.

## IV. Materials and Methods

### i. Search Strategy

A systematic review was performed using electronic databases MEDLINE/PubMed and Elsevier/Scopus for obtaining the results, in order to identify publications about aesthetic evaluation of the restorative treatment of teeth with chromatic alterations, in the English or Portuguese language, between 2019 and 2024.

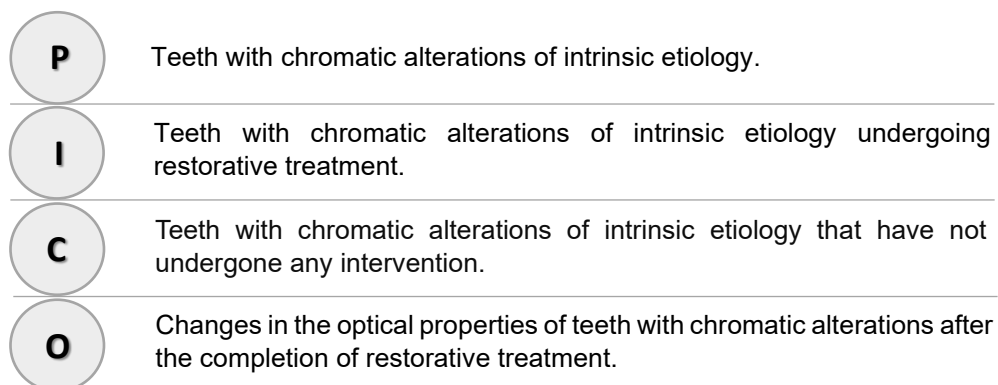
The subsequent keywords were employed in formulating the search terms delineated in Attachment 1, "Discolored tooth"; "Discolored background"; "Dark substrate"; "Dental stain"; "Fluorosis"; "Restoration"; "Resin"; "Whitening". The following inclusion and exclusion criteria were applied to all research databases.

**Table 2:** *Inclusion and exclusion criteria*

| Inclusion criteria                                                                                                                                                         | Exclusion criteria                                                                                                               |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| Studies including the assessment of aesthetics (color and/or translucency)                                                                                                 | Reviews, book chapters, theses, dissertations, and case reports                                                                  |
| Teeth with intrinsic chromatic alterations as the object of study                                                                                                          | Teeth with extrinsic chromatic alterations as the object of study (coffee or tea as discoloration agents)                        |
| Studies applying minimally invasive restorative treatment (bleaching, microabrasion, resin infiltration, composite resin restoration, or a combination of this treatments) | Studies in which the method of evaluating the optical properties of the restorative treatment does not involve spectrophotometry |

### ii. Research Question

This systematic review was conducted according to the guidelines of the PICO method, as presented in figure 1, through which the following research question was formulated: **"What are the effects of restorative treatment on the optical properties of teeth with chromatic alterations?"**



**Figure 1:** *PICO Method*

### iii. Criteria for Study Selection

Following the search strategy, titles and abstracts were read, applying the selection criteria. Duplicate studies between the research databases and within the same database were excluded. Eligible articles were independently read, and predefined data were extracted. Only full-text articles were selected.

For data extraction, articles were selected according to the previously mentioned inclusion and exclusion criteria. The composition of this systematic review is presented in Figure 2, following the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.

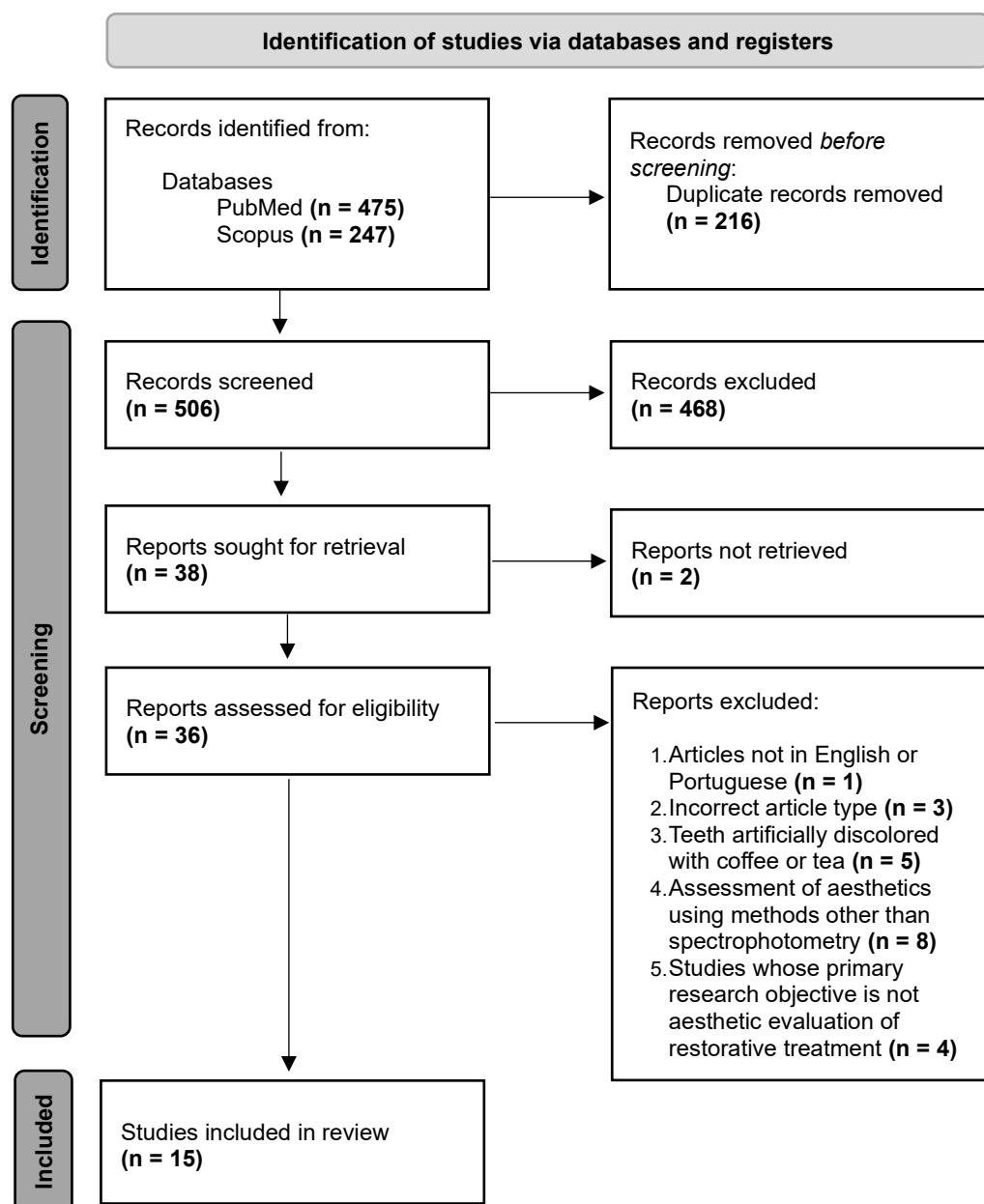


Figure 2: PRISMA Guidelines

#### **iv. Survey Methodology**

This investigation was undertaken with the purpose of exploring and implementing esthetic treatment solutions aligned with the principles of minimally invasive dentistry. The survey was conducted among students attending the Faculty of Dental Medicine of Porto University. This includes those registered in the curricular units of Conservative Dental Medicine Clinic II and Integrated Clinical Practice, as well as students pursuing specialization in Dentistry and Dental Aesthetics within the same faculty.

The research was centered around the administration of a questionnaire, provided in Attachment 2, which was structured to assess three key parameters: diagnostic proficiency in chromatic alterations, selection of dental materials, and aesthetic appraisal of the optical properties of restorative treatments according to FDI criteria – encompassing aspects such as color and translucency. The design was reviewed and approved by the Institutional Ethical Committee. Written informed consent and assent forms were obtained.

While the primary aim of the questionnaire is to solicit the viewpoints of students concerning the treatments they have administered, the subjects under investigation comprise patients presenting with one or more teeth manifesting chromatic alterations, who have sought the services of the university for the purpose of aesthetic treatment. Inclusion criteria comprised cooperative patients aged over 18 years, presenting with chromatic alterations in at least one tooth, attributed to pre-eruptive or post-eruptive factors, seeking services from the clinic of the faculty to address tooth appearance concerns. Exclusion criteria encompassed patients with indications for more invasive treatments such as prosthetic interventions or extractions, as well as those unwilling to participate in the study. A total of 30 patients underwent treatment.

The clinical evaluation pertains to the assessment conducted by dental students regarding the effectiveness of their dental restorations in teeth displaying chromatic alterations. To standardize responses, criteria endorsed by the FDI World Dental Federation, widely employed in numerous clinical investigations since 2007, were utilized. These criteria are delineated into three distinct groups, although only one was evaluated herein: the aesthetic parameters, comprising four criteria. Each criterion may be characterized by five scores, with three deemed acceptable and two deemed unacceptable (with one indicating repairable and another suggesting replacement).

A bivariate analysis was used to determine the association between the dependent (Masking ability) and independent variables (Etiology of Chromatic Alteration; Extension of Chromatic Alteration; Restorative Treatment; Shade of Resin Composite), using the chi-square test followed by the residual adjustment test. The significance level adopted was 5% ( $\alpha=0.05$ ). Statistical analysis was performed using an SPSS software program (SPSS Statistics 23.0.0, IBM Armonk, Chicago, IL, USA).

## V. Results

Based on the data obtained from the fifteen articles included for review, twelve are *in vitro* studies, one is a randomized clinical study, one represents an *in vivo* investigation, and one pertains to an *ex-vivo* study. Among the fifteen articles, five describe the masking efficacy of restorative materials, with two focusing on resin composite and three encompassing both resin composite and opaquers. Additionally, ten of the articles clarify the masking efficacy of bleaching techniques, with five exclusively addressing the efficacy of bleaching agents and the remaining five exploring potential associations with minimally invasive modalities such as resin infiltration, microabrasion, and violet LED light.

All articles are succinctly summarized, categorized by their treatment method (restoration or bleaching), and listed by the authors' names, as illustrated in Table 3.



**Table 3: Selected articles**

| Author/ Title                               | Type of Article | $\Delta E$ Color Differences                                 | Aim                                                                                                                                                       | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Risk of bias |
|---------------------------------------------|-----------------|--------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|
| <b>Barros et al. (2023)</b> <sup>(22)</sup> | <i>In Vitro</i> | $\Delta E_{00}$ (p) = 0.8<br>$\Delta E_{00}$ (a) = 1.8       | Evaluate the background and effect of surrounding colors on the color blending of a single-shade composite used in a thin layer.                          | The findings of this study indicate that there are no discernible aesthetic advantages associated with the utilization of single-shade composite material on a darker substrate. In such circumstances, it may be advisable to consider employing an opaquer with a similar color to the adjacent substrate.                                                                                                                                                                                                                              | Low          |
| <b>Lehr et al. (2022)</b> <sup>(23)</sup>   | <i>In Vitro</i> | $\Delta E_{00}$ (p) = 0.8<br>$\Delta E_{00}$ (a) = 1.8       | Evaluate the masking efficacy of opaques and resin composites when applied onto dental backgrounds exhibiting varying degrees of discoloration.           | This study demonstrates that the opaquer brand, thickness of the resin composite layer, and background shades exert significant influence on the masking ability. The most optimal combinations were observed with one or two coats of opaquer and a 1.0-mm-thickness resin composite layer for all backgrounds, excluding C4.                                                                                                                                                                                                            | Low          |
| <b>Lim et al. (2022)</b> <sup>(24)</sup>    | <i>In Vitro</i> | $\Delta E$ clinical acceptance < 2,7                         | Evaluate whether variations in both restorative material selection and thickness significantly impact the efficacy of masking dark and black backgrounds. | The analysis highlights significant differences in material efficacy for masking black backgrounds: pink opaquer, either independently or in conjunction with composite perform similarly, both significantly outperforming RMGI and opaque-shade composite resin. Notably, pink opaquer/resin composite displays the lowest mean TP value and stable material properties. Moreover, material thickness emerges as a significant factor in color masking, with a thickness of 2.0mm superior to 1.0mm across all tooth-colored materials. | Low          |
| <b>Morel et al. (2023)</b> <sup>(25)</sup>  | <i>In Vitro</i> | $\Delta E_{00}$ (p) = 0.8<br>$\Delta E_{00}$ (a) = 1.8       | Evaluate if the $\Delta E_{00}$ would be affected by the shade and opacity of resin composite layer combinations over darker or lighter substrates.       | This study elucidates the impact of different shades and opacities in monolayer, bilayer, and trilayer resin composite on masking darker substrates. Monolayer veneers with dentin opacity demonstrated the lowest TP values, whereas those in A1 shade with dentin opacity exhibited heightened $\Delta E_{00}$ values over darker tooth-colored substrates.                                                                                                                                                                             | Low          |
| <b>Perez et al. (2019)</b> <sup>(26)</sup>  | <i>In Vitro</i> | $\Delta E_{00} > 1.3 < 2.25$<br>$\Delta E_{ab} > 1.8 < 3.46$ | Evaluate the efficacy of the layering technique in masking a discolored background after one year of water aging.                                         | The multilayering technique, using the Z350XT resin composite system with the A1 shade, effectively masked a severely darkened substrate initially. However, after one year of water aging, only the one system remained stable, though lacking sufficient masking ability. This indicates that aging negatively impacts the masking capability.                                                                                                                                                                                          | Low          |

Treatment Method: Restoration (resin composite; opaquer)

|                                                      |                           |                                                                                                                  |                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                    |               |
|------------------------------------------------------|---------------------------|------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| <b>Bersezio <i>et al.</i> (2019)</b> <sup>(27)</sup> | Randomized Clinical Study | N/A                                                                                                              | Evaluate the efficacy of walking bleaching technique utilizing either 35%-HP or 37%-CP, administered across four weekly sessions.                      | The walking bleaching technique has exhibited significant efficacy, facilitating precise color matching with adjacent teeth, and ensuring sustained color maintenance at the one-year follow-up, with a slight rebound.                                                                                            | Some concerns |
| <b>Fagogeni <i>et al.</i> (2022)</b> <sup>(28)</sup> | <i>In Vitro</i>           | $\Delta E$ clinical acceptance < 3.3                                                                             | Evaluate tooth discoloration after endodontic procedures and the efficacy of subsequent whitening methods with 15%-CP.                                 | The whitening procedure merits consideration. However, it does not ensure a complete restoration to the original tooth color, particularly in cases involving the application of triple antibiotic paste.                                                                                                          | Low           |
| <b>Gaidarji <i>et al.</i> (2022)</b> <sup>(17)</sup> | <i>In Vitro</i>           | $\Delta E_{00}$ (p) = 0.8<br>$\Delta E_{00}$ (a) = 1.8<br>$\Delta E_{ab}$ (p) = 1.2<br>$\Delta E_{ab}$ (a) = 2.7 | Evaluate the effectiveness and stability of different bleaching techniques and bleaching agents on teeth stained by blood for a duration of one year.  | The color stability of the whitening produced by walking bleach (20%-SP), inside/outside (7.5%-HP) and in-office techniques (35%-HP) was maintained for 6 months. However, slight rebound was observed at the one-year follow-up, although the bleaching outcome remained in the range of excellent effectiveness. | Low           |
| <b>Saati <i>et al.</i> (2022)</b> <sup>(29)</sup>    | <i>In Vitro</i>           | N/A                                                                                                              | Evaluate the effects of different durations of home bleaching with 20%-CP on tooth discoloration induced by MTA                                        | The study underscores the efficacy of CP as an external bleaching agent when applied for 14 days to address discoloration induced by MTA. Moreover, it suggests that longer bleaching durations offer only slightly higher efficacy in tooth whitening.                                                            | Some concerns |
| <b>Saati <i>et al.</i> (2019)</b> <sup>(30)</sup>    | <i>In Vitro</i>           | $\Delta E$ clinical acceptance < 3.3                                                                             | Evaluate the effects of 35%-HP, SP and 20%-CP on tooth discoloration induced by MTA utilizing an external bleaching technique.                         | Results reveal that all tested bleaching agents effectively addressed the discoloration induced by MTA. Notably, HP exhibited superior effectiveness compared to other agents following the initial week. Additionally, it was determined that the disparity in efficacy between CP and SP was insignificant.      | Low           |
| <b>Dogra <i>et al.</i> (2020)</b> <sup>(31)</sup>    | <i>In Vivo</i>            | $\Delta E$ clinical acceptance < 3.7                                                                             | Evaluate the efficacy of resin infiltration treatment with DMG-Icon in inducing color change in non-pitted WLS present on teeth.                       | The application of resin infiltration using DMG Icon has demonstrated the capacity to improve the color of non-cavitated WLS. Furthermore, it is noteworthy that no cavitation transpired after etching, even in instances where the surface layer had been entirely eroded.                                       | High          |
| <b>Lee <i>et al.</i> (2020)</b> <sup>(32)</sup>      | <i>In Vitro</i>           | N/A                                                                                                              | Compare the efficacy of bleaching, resin infiltration, and microabrasion techniques in restoring the appearance of pre-existing WSL on tooth surfaces. | In terms of effectiveness, resin infiltration demonstrated the highest efficacy in concealing WSL, followed by bleaching and microabrasion methods. However, it is important to note that on severe lesions, resin infiltration proved insufficient to completely conceal the lesion.                              | Some concerns |

|                                                           |                      |                                                                                                                  |                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                         |               |
|-----------------------------------------------------------|----------------------|------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| <b>Marques <i>et al.</i> (2023)</b> <sup>(33)</sup>       | <i>In Vitro</i>      | $\Delta E_{00} (p) = 0.8$<br>$\Delta E_{00} (a) = 1.8$<br>$\Delta E_{ab} (p) = 1.2$<br>$\Delta E_{ab} (a) = 2.7$ | Evaluate the impact of tooth darkening severity on the efficacy of in-office bleaching protocols using violet LED light alone or combined with 37%-CP.                            | The study findings suggest that for bleaching naturally darkened teeth, the CP associated with the violet LED protocol is the most effective among all protocols tested, while the use of LED alone did not yield satisfactory results.                                                                 | Low           |
| <b>Shokouhinejad <i>et al.</i> (2022)</b> <sup>(34)</sup> | <i>Ex-vivo study</i> | $\Delta E$ clinical acceptance < 3.7                                                                             | Evaluate the efficacy of laser-assisted techniques (810nm Diode; 980nm Diode; Nd:YAG) with the conventional internal bleaching, for the correction of tooth discoloration by RET. | The present study demonstrated that there is no significant difference between photo-bleaching conducted by various lasers and conventional internal bleaching employing 35%-HP. Moreover, it was observed that the bleaching effects on the 12th day surpassed those of earlier sessions of bleaching. | Low           |
| <b>Silva <i>et al.</i> (2022)</b> <sup>(35)</sup>         | <i>In Vitro</i>      | N/A                                                                                                              | Evaluate the effectiveness of violet LED light as an alternative for bleaching traumatized deciduous teeth.                                                                       | The study demonstrates that violet LED light was not effective in bleaching primary incisors darkened by trauma after 8 sessions.                                                                                                                                                                       | Some concerns |

**Table 4:** Association Values (%) Between Masking Ability and Etiology of Chromatic Alteration; Extension of Chromatic Alteration; Restorative Treatment; Shade of Resin Composite

| Masking Ability                                       |                                        |                              |         |
|-------------------------------------------------------|----------------------------------------|------------------------------|---------|
|                                                       | Clinically Sufficient/<br>Unacceptable | Clinically<br>Excellent/Good | p-value |
| Etiology of Chromatic Alteration                      |                                        |                              |         |
| Dental Conditions                                     | 4 (23.5%)                              | 13 (76.5%)                   | 0.151   |
| Pulpal Causes                                         | 2 (100%)                               | -                            |         |
| Dental Materials                                      | 2 (28,6%)                              | 5 (71,4%)                    |         |
| Pre-eruptive Causes                                   | 2 (50.0%)                              | 2 (50.0%)                    |         |
| Extension of Chromatic Alteration                     |                                        |                              |         |
| Across the surface of enamel                          | 3 (60.0%)                              | 2 (40.0%)                    | 0.383   |
| Less than half the dentin surface                     | 5 (27.8%)                              | 13 (72.2%)                   |         |
| More than half the dentin surface                     | 2 (28.6%)                              | 5 (71.4%)                    |         |
| Restorative Treatment                                 |                                        |                              |         |
| Resin composite of dentin                             | 6 (42.9%)                              | 8 (57.1%)                    | 0.042   |
| Resin composite of dentin + Resin composite of enamel | 2 (100%)                               | -                            |         |
| Resin composite to dentin + Opaquer                   | -                                      | 8 (100%)                     |         |
| Resin Infiltration                                    | 1 (100%)                               | -                            |         |
| HP + Resin Infiltration                               | -                                      | 2 (100%)                     |         |
| HP                                                    | -                                      | 1 (100%)                     |         |
| CP + Resin composite to dentin + Opaquer              | -                                      | 1 (100%)                     |         |
| Microabrasion                                         | 1 (100%)                               | -                            |         |
| Shade of Resin Composite                              |                                        |                              |         |
| A1                                                    | 1 (100%)                               | -                            | 0.596   |
| A2                                                    | 3 (23.1%)                              | 10 (76.9%)                   |         |
| A3                                                    | 3 (37.5%)                              | 5 (62.5%)                    |         |
| A4                                                    | 1 (33,3%)                              | 2 (66,7%)                    |         |

The association values (%) between dependent and independent variables are shown in Table 4. There was a significant association between masking ability and restorative treatment ( $\chi^2 = 14,571$ ;  $p = 0.042$ ). The resin composite of dentin + opaquer was significantly associated with excellent/good masking ability.

In the sample, the factors *etiology in dental conditions*, *extension to less than half the dentin surface*, *restorative treatment with resin composite of dentin*, and *shade A2 of resin composite* are the most frequently occurring.

## VI. Discussion

The article selection process was based on obtaining findings suitable for clinical application. Given the development of a supplementary clinical questionnaire alongside the systematic review, known for its subjectivity, the chosen articles aimed to evaluate similar issues using objective methodologies, thus enabling the comparison of standardized outcomes derived from similar interventions. As a result, only articles utilizing spectrophotometry as their evaluation method were considered acceptable. Consistent with this methodology, case reports were intentionally excluded from the analysis owing to their reliance on isolated occurrences, thereby lacking the requisite statistical robustness for extrapolation to clinical contexts.

All articles featured in Table 3 encompass a quantitative evaluation of color variation. However, notable disparities exist in the clinical acceptance of color differences, that could potentially result in discrepancies when comparing findings across studies. Studies that do not reference the range of clinical acceptance regarding color variation were considered to have some concerns regarding the risk of bias.

As describe previously, tooth color assessment in dentistry involves a subjective process influenced by the characteristics of the light source, the properties of the object being observed (such as a tooth or dental restoration), and the perception of the observer.<sup>(1)</sup> In order to standardize this process, the Commission Internationale de l'Eclairage (CIE, International Commission on Illumination) has endorsed the utilization of the CIELAB color space. The CIELAB system provides a framework with three coordinates to represent colors: L\* (luminosity), a\* (red-green axis), and b\* (yellow-blue axis).

Utilizing this framework facilitates the quantification of chromatic disparities between two entities ( $\Delta E$ ). Essential to obtaining this metric is the establishment of both the perceptibility threshold, indicating the smallest detectable deviation perceptible to the human eye, and the acceptability threshold, which signifies the extent of color differentiation between teeth and aesthetic dental restorations considered unacceptable by a significant majority of individuals.<sup>(36)</sup>

The perceptibility and acceptability thresholds within the CIELAB ( $\Delta E_{ab}$ ) color space system have been established at 1.2 and 2.7, respectively. Subsequent enhancements in color difference equations have yielded the CIEDE2000 ( $\Delta E_{00}$ ) formula, which offers improved reliability. In this system, the thresholds for perceptibility and acceptability are refined to 0.8 and 1.8, respectively.<sup>(36)</sup> Numerous studies have sought to investigate these thresholds. Johnston and Kao identified a perceptibility threshold of 3.7  $\Delta E^*$  units, while Ruyter et al. determined that 3.3  $\Delta E^*$  units of color difference were deemed unacceptable by 50% of observers in their study utilizing sample pairs of dental composite resin.<sup>(37)(38)</sup>

### ***Treatment Method: Restoration***

Throughout the range of backgrounds examined, the most pronounced instances of unacceptable mismatches were consistently identified when comparing against the darker simulated substrates, characterized by its status as the darkest background under consideration (i.e., C4 and C4+), as evidenced in Lehr *et al.* and Morel *et al.* These findings align with previous research, reaffirming the notion that darker backgrounds with lower brightness values present formidable obstacles in achieving color harmony, underscoring the inherent difficulty in masking darker discolorations.<sup>(39)(40)</sup>

Furthermore, Lehr *et al.* have determined that optimal  $\Delta E$  outcomes consistently correlate with backgrounds exhibiting the highest luminosity levels among the tested samples. The authors concluded that darker backgrounds present increased difficulty in masking. In such scenarios, they recommend the use of opaque shades and thicker layers of resin composite to enhance masking capability.

The comprehensive understanding of the translucency and opacity characteristics inherent in resin composites assumes crucial importance within the realm of restorative dentistry.<sup>(41)</sup> These traits have a significant impact on how effective these materials are in concealing darker substrates. Indeed, translucency and opacity play very important roles in assessing a composite's capacity to seamlessly harmonize with surrounding tooth structures, thereby masking underlying discoloration or darker backgrounds.<sup>(42)</sup>

Barros MS *et al.* conducted a study elucidating the impact of the resin composite shade on the translucency adjustment potential (TAP) and color adjustment potential (CAP). Their findings indicate a significant influence of the resin composite shade on both TAP and CAP. Specifically, they observed that the shade A1 of a single shade composite exhibited the highest TAP when placed against a dark background, yet demonstrated the lowest CAP compared to shades A2 and A3 when similarly disposed.

Furthermore, Morel *et al.* corroborated these findings by demonstrating the effective opacifying effect of the dentin opacity layer. Their study concluded that for restorative procedures, selecting a resin composite with dentin opacity is preferable to selecting one with enamel opacity or body opacity when utilized on a darkened tooth-colored substrate.

Although previous studies have affirmed the effectiveness of shades A2 and A3 of composite resins, as well as opaque-shade composite resins, in masking discolored tooth structure in adult dentition, it is pertinent to note that this evidence primarily pertains to adult dentition.<sup>(39)(42)</sup> Additionally, Lim LJ's research reinforces this notion by asserting that shades A2 and A3 are not optimal choices for covering darker substrates in pediatric restoration conditions, which typically involve shallower cavities and a shade preference towards A1.

Minimally invasive dentistry promotes a conservative approach in esthetic treatments to preserve tooth structure. However, conservative preparations often

result in reduced composite layer thickness, leading to increased influence of the background on the final color of the restoration. Resin composites, due to their inherent optical characteristics, have limited masking capacity, with effectiveness directly linked to the thickness of composite layers. <sup>(43)</sup>

Prior research consistently highlights the relationship between enhanced masking efficacy and greater resin composite layer thickness, suggesting that thicknesses below 1 mm are insufficient for adequately masking dark substrates. <sup>(41)(42)(44)</sup> This assertion finds support in studies such as those by Lehr RM *et al.* and Perez BG *et al.*, who demonstrated that reductions in resin composite thickness to 0.5 mm fall below the threshold for effective masking ability. Additionally, Lim LJ *et al.* identified superior masking ability with a thickness of 2.0 mm compared to 1.0 mm.

Moreover, Morel LL *et al.* have emphasized the advantages of multilayer composite resin veneers over traditional monolayer techniques. These advantages stem from the optimized optical properties achieved through strategic layer combinations incorporating various shades and opacities.

In the anterior region, where preparation thickness is limited, the creation of space for layering multiple shades may necessitate additional dental tissue reduction. <sup>(43)</sup> Hence, to mitigate excessive tooth preparation, it is recommended to employ a combination of opaquer and resin composite application. Opaquers are favored for their high opacification ability, allowing for their use in thin coats <sup>(23)</sup>. However, it should be noted that merely covering a dark substrate with an opaque resin does not guarantee an esthetic restoration, as highlighted by Barros MS *et al.*

Furthermore, Lim LJ *et al.* demonstrate the efficacy of pink opaquer, either alone or in combination with resin composite, in masking dark to black backgrounds. This resin-based composite, available in a pink universal shade, assists in counteracting unpredictable color and neutralizing grey tones beneath the restoration, thereby enhancing color value.

In clinical terms, the application of opaquers serves to introduce depth within the restoration, thereby replicating the necessary high values in the tooth's medium third. However, achieving this effect poses challenges, as operators may encounter difficulty in precisely controlling thickness despite being able to select shade and opaquer manufacturer according to preference. Consequently, it can be inferred that the application process lacks a prescribed method or order to attain maximum efficacy in masking dark backgrounds. <sup>(43)</sup>

Despite the ongoing advancements in resin composites, the masking of discolored substrates remains a significant challenge for clinicians. This challenge stems from the observation that restorative systems providing multiple layering options do not consistently guarantee clinically acceptable and enduring outcomes. <sup>(26)</sup>

### ***Treatment Method: Bleaching***

Various techniques have been utilized by researchers to address tooth discoloration, including internal, external, or combined approaches <sup>(45)(46)</sup>. Internal bleaching investigations were conducted by Berzesio *et al.* in an *in vivo* setting and by Fagogeni *et al.* through *in vitro* assessment. Additionally, external bleaching was examined in two *in vitro* studies (Saati *et al.*<sup>29</sup>; Saati *et al.*<sup>30</sup>). A singular study comparing both internal and external bleaching techniques was conducted by Gaidarji *et al.*

Findings from internal bleaching techniques demonstrated consistent outcomes across different bleaching agents and concentrations. Berzesio *et al.* reported notable efficacy for 35%-HP and 37%-CP, while Fagogeni *et al.* achieved comparable results with only 15%-CP. Discrepancies in outcomes regarding CP concentrations may be attributed to variations in evaluation periods. Berzesio *et al.* conducted evaluations over the course of one year, in contrast to Fagogeni *et al.* four-week assessment. Furthermore, Gaidarji *et al.* showcased the effectiveness of 20%-SP in internally bleaching non-vital teeth.

Both external bleaching treatments exhibited considerable efficacy and stability, with consistent alterations in tooth coloration. Saati *et al.*<sup>30</sup> exclusively reported a higher efficacy for 35%-HP compared to 20%-CP or SP. Studies conducted on primary teeth support these findings, suggesting that HP exhibits greater effectiveness compared to CP. <sup>(46)</sup> However, certain studies did not observe a significant disparity in the efficacy of these bleaching agents. The authors suggested that the differing outcomes might be due to the longer follow-up period, as HP efficacy decreases over time, eventually matching CP. <sup>(47)</sup>

The primary disparities among the studies may be attributed to variables affecting their efficacy, including a) the concentration of the active compound, b) application duration, and c) treatment duration <sup>(30)</sup>. Optimal selection should consider factors such as the longevity of the whitening effect. Evidence from studies by Shokouhinejad *et al.* and Saati *et al.*<sup>30</sup> supports the sufficiency of 12 to 14 days for achieving tooth bleaching, but a minor rebound effect should be anticipated.

Given the resistance of certain intracoronal discolorations to bleaching, particularly those induced by metals, and the demonstrated efficacy of various techniques and bleaching agents, the successful application of any technique is achievable. However, prospective longitudinal clinical trials are imperative to elucidate the enduring side effects, risks, and sustainability of treatment outcomes.

Hydrogen peroxide, the primary active ingredient in most bleaching materials, can be applied directly or synthesized through chemical reactions with carbamide peroxide or sodium perborate <sup>(27)</sup>. However, the use of high concentrations of peroxide has been linked to adverse effects, including gingival irritation, dentin sensitivity, and irreversible pulp damage <sup>(49)</sup>.



In certain circumstances, especially with immature teeth, it may be advisable to use less potent yet safer bleaching agents like carbamide peroxide or sodium perborate due to their specific molecular structures and minimal tissue-damaging potential <sup>(30)</sup>. Chemical bleaching agents raise safety concerns and ongoing discussions regarding their safety. However, alternatives like resin infiltration or microabrasion aim to minimize side effects while achieving successful color changes. <sup>(50)</sup>

In the literature, two less invasive techniques for bleaching enamel defects have been described: resin infiltration and microabrasion. Studies have undertaken comparisons regarding the efficacy of resin infiltration technique against microabrasion for the management of WSL. The findings indicate that neither microabrasion nor resin infiltration technique achieves complete eradication of white spot lesions. However, resin infiltration demonstrates a higher efficacy when compared to microabrasion. <sup>(51)</sup> Lee *et al.* attributed this finding to the similar translucency of enamel and resin, suggesting that resin infiltration yields better treatment outcomes. It's also plausible that microabrasion removes the surface layer, exposing a deeper and potentially more prominent portion of the white spot lesion in some cases.

In line with previous research, Lee *et al.* demonstrated that resin infiltration is highly effective for some lesions but less so for deeper lesions where infiltration fails to mask the lesion adequately. In cases of severe lesions, there may be only minimal improvement, and the white spot lesion remains visible after treatment. <sup>(52)(53)</sup>

In the past few years, considerable attention has been directed towards exploring the potential of violet LED light as an alternative to traditional bleaching methods. Studies have elucidated that its mechanism operates without triggering chemical reactions, thereby establishing it as a less intrusive approach with minimized risks of adverse effects. <sup>(54)</sup> However, research findings have highlighted the incapacity of violet LED light to achieve bleaching outcomes comparable in intensity to those obtained with hydrogen peroxide and carbamide peroxide. <sup>(55)(56)</sup> Marques *et al.*, Shokouhinejad *et al.*, and Silva *et al.*, consistently demonstrates that the isolated application of violet LED light fails to yield satisfactory results.

Marques *et al.* further support these findings by emphasizing that while violet LED light alone exhibits limited efficacy in the bleaching process, its combination with bleaching agents enhances the optimization of peroxide chemical dissociation, thereby strengthening the efficacy of bleaching treatments.

### ***Clinical questionnaire***

The survey aimed to simulate aesthetic treatment solutions aligned with the concept of minimally invasive dentistry. In this study, the tested hypothesis was partially supported, as the efficacy of masking dental imperfections was found to be influenced by the choice of restorative treatment. However, factors such as the etiology, extent of chromatic tooth alteration, and shade of resin composite

did not significantly affect the masking ability. Nevertheless, it was confirmed that the restorative treatment effectively masked the majority of observed chromatic tooth alterations.

When evaluating the aesthetic components of color and translucency, operators noted that restorative treatments consistently achieved clinically acceptable outcomes, often rated as excellent or good, particularly when utilizing a combination of opaquer and resin composite of dentin. While direct comparisons with other studies are challenging due to variations in materials, specimens, techniques, and methodologies, these findings align with previous research.

Despite the availability of opaquers in the dental market, few dental students are familiar with their properties, and an even smaller fraction comprehend their efficacy in masking color irregularities. Consequently, the prevalent preference for selecting resin composite of resin may be justified, although it may not consistently yield clinically satisfactory results.

Other investigated factors did not demonstrate a significant influence on the aesthetic outcome. However, understanding the etiology and extent of chromatic alterations remains essential for guiding the selection of optimal restorative materials. Additionally, identifying the most frequently occurring factors, as elucidated in this investigation, is crucial for clinical decision-making.

Limitations of this study include operator inexperience, incomplete control over material thickness, and the inherent subjectivity of classifying aesthetic outcomes using visual scales rather than quantitative evaluations. Furthermore, the absence of photographs of treated teeth may have limited readers' ability to appreciate reported outcomes. Additionally, this study did not assess the effects of restorative treatment on surface roughness properties and mineral content of enamel and dentin, factors known to influence clinical decisions and long-term treatment outcomes.

It is important to acknowledge that the sample size in this study was limited to 30 teeth, potentially compromising the statistical robustness of our findings. We recommend that future research efforts employ larger sample sizes to corroborate and validate our reported outcomes.

## **VII. Conclusion**

In conclusion, this systematic review highlights the complexities involved in substrate masking and underscores the importance of selecting appropriate materials and techniques to achieve optimal outcomes in restorative treatment. To achieve effective masking ability with direct restorations, clinicians should consider utilizing resin composite shades such as A2, A3, or dentin opacity. Additionally, maintaining a resin composite thickness below 1mm, combined with an opaquer underneath, can yield excellent results.

Furthermore, alternative techniques such as internal and external bleaching show promise, however requiring further research to determine the optimal bleaching agent concentration and application duration. Alternative masking techniques, including resin infiltration, microabrasion, or the combined application of violet LED light and whitening, offer viable options, with resin infiltration emerging as the most successful method.

In the developed study despite factors like etiology, extension and resin composite shade not significantly affect masking ability, restorative treatments consistently achieved clinically acceptable outcomes, particularly with a combination of opaquer and dentin resin composite. Overall, further studies are warranted in this area to enhance clinicians' ability to address chromatic alterations effectively and provide patients with aesthetically pleasing and enduring restorative procedures.

## VIII. References

- 1) Joiner A. Tooth colour: a review of the literature. *J Dent.* 2004;32(Suppl 1):3-12. doi: 10.1016/j.jdent.2003.10.013. PMID: 14738829.
- 2) Blatz MB, Chiche G, Bahat O, Roblee R, Coachman C, Heymann HO. Evolution of Aesthetic Dentistry. *J Dent Res.* 2019 Nov;98(12):1294-1304. doi: 10.1177/0022034519875450. PMID: 31633462.
- 3) Ten Bosch JJ, Coops JC. Tooth color and reflectance as related to light scattering and enamel hardness. *J Dent Res.* 1995;74:374-380.
- 4) Ragain JC Jr, Johnston WM. Accuracy of Kubelka-Munk reflectance theory applied to human dentin and enamel. *J Dent Res.* 2001 Feb;80(2):449-52. doi: 10.1177/00220345010800020901. PMID: 11332530.
- 5) Kim JH, Lee YK, Powers JM. Influence of a series of organic and chemical substances on the translucency of resin composites. *J Biomed Mater Res B Appl Biomater.* 2006;77:21-27.
- 6) Plotino G, Buono L, Grande NM, Pameijer CH, Somma F. Nonvital tooth bleaching: a review of the literature and clinical procedures. *J Endod.* 2008 Apr;34(4):394-407. doi: 10.1016/j.joen.2007.12.020. Epub 2008 Feb 15. PMID: 18358884.
- 7) Manuel ST, Abhishek P, Kundabala M. Etiology of tooth discoloration - a review. *Nigerian Dental Journal.* 2010;18(2):56-63. <https://doi.org/10.61172/ndj.v18i2.143>
- 8) Hattab FN, Qudeimat MA, al-Rimawi HS. Dental discoloration: an overview. *J Esthet Dent.* 1999;11(6):291-310. doi: 10.1111/j.1708-8240.1999.tb00413.x. PMID: 10825865
- 9) Baharvand, Maryam. (2014). Colors in tooth discoloration: A new classification and literature review. *International Journal of Clinical Dentistry.* 7. 17-27.
- 10) Sulieman, M. (2005). An Overview of Tooth Discoloration: Extrinsic, Intrinsic and Internalized Stains. *Dental update.* 32. 463-4, 466. 10.12968/denu.2005.32.8.463.
- 11) Aishuwariya, T. & Selvanayagam, Delphine Priscilla. (2021). Decision Analysis On Discolored Tooth Management. *International Journal of Dentistry and Oral Science.* 8. 2839-2843. 10.19070/2377-8075-21000554.
- 12) Melo, N.S.F. & Silva, Regina & Lima, Antonio. Green teeth resulting from neonatal hyperbilirubinemia: Report of a case. (2015). *Pediatrica Polska.* 90. 155-160. 10.1016/j.pepo.2014.12.004.
- 13) Watts A, Addy M. Tooth discolouration and staining: a review of the literature. *Br Dent J.* 2001 Mar 24;190(6):309-16. doi: 10.1038/sj.bdj.4800959. PMID: 11325156.
- 14) Bayne SC, Ferracane JL, Marshall GW, Marshall SJ, van Noort R. The Evolution of Dental Materials over the Past Century: Silver and Gold to Tooth Color and Beyond. *J Dent Res.* 2019 Mar;98(3):257-265. doi: 10.1177/0022034518822808. PMID: 30784370
- 15) Paris S, Meyer-Lueckel H. Masking of labial enamel white spot lesions by resin infiltration – a clinical report. *Quintessence Int.* 2009 Oct;40(9):713-718.
- 16) Sundfeld RH, Rahal V, Croll TP, De Alexandre RS, Briso AL. Enamel microabrasion followed by dental bleaching for patients after orthodontic treatment – case reports. *J Esthet Restor Dent.* 2007; 19:71-77.

- 17) Gaidarji B, Perez BG, Ruiz-López J, Pérez MM, Durand LB. Effectiveness and color stability of bleaching techniques on blood-stained teeth: An in vitro study. *J Esthet Restor Dent*. 2022 Mar;34(2):342-350. doi: 10.1111/jerd.12850. Epub 2021 Dec 3. PMID: 34859941.
- 18) Croll TP. Enamel microabrasion: observations after 10 years. *J Am Dent Assoc*. 1997 Apr;128 Suppl:45S-50S. doi: 10.14219/jada.archive.1997.0424. PMID: 9120146.
- 19) Kamishima N, Ikeda T, & Sano H (2005) Color and translucency of resin composites for layering techniques *Dental Materials* 24(3) 428-432
- 20) Gupta S, Tandan M, & Sodhi PS (2011) Improving esthetics of discoloured teeth using opaquers under direct composite resin veneers *Heal Talk III*(03) 8-9.
- 21) McInnes-Ledoux PM, Zinck JH, Weinberg R. The effectiveness of opaquer and color-modifier materials: a laboratory study. *J Am Dent Assoc*. 1987 Feb;114(2):205-9. doi: 10.14219/jada.archive.1987.0009. PMID: 3469269.
- 22) Barros MS, Silva PFD, Santana MLC, Bragança RMF, Faria-E-Silva AL. Background and surrounding colors affect the color blending of a single-shade composite. *Braz Oral Res*. 2023 Apr 28;37:e035. doi: 10.1590/1807-3107bor-2023.vol37.0035. PMID: 37132724.
- 23) Lehr RM, Perez BG, Gaidarji B, Dalmolin A, Durand LB. Masking Ability of the Combined Application of Opaquers and Resin Composite on Discolored Backgrounds. *Oper Dent*. 2022 Mar 1;47(2):225-235. doi: 10.2341/20-304-L. PMID: 35584333.
- 24) Lim LJ, Chen JW, Su JM, Goodacre B. Comparison of the Masking Ability and Translucency of Different Tooth-Colored Restorative Materials. *Pediatr Dent*. 2022 Mar 15;44(2):130-135. PMID: 35484775.
- 25) Morel LL, de Holanda GA, Perroni AP, de Moraes RR, Boscatto N. Effect of shade and opacity on color differences and translucency of resin composite veneers over lighter and darker substrates. *Odontology*. 2024 Apr;112(2):355-363. doi: 10.1007/s10266-023-00842-9. Epub 2023 Aug 17. PMID: 37589926.
- 26) Perez BG, Miotti LL, Susin AH, Durand LB. The Use of Composite Layering Technique to Mask a Discolored Background: Color Analysis of Masking Ability After Aging-Part II. *Oper Dent*. 2019 Sep/Oct;44(5):488-498. doi: 10.2341/18-016-L. Epub 2019 Jan 23. PMID: 30673369.
- 27) Bersezio C, Ledezma P, Estay J, Mayer C, Rivera O, Fernández E. Color Regression and Maintenance Effect of Intracoronal Whitening on the Quality of Life: RCT-A One-year Follow-up Study. *Oper Dent*. 2019 Jan/Feb;44(1):24-33. doi: 10.2341/17-288-C. Epub 2018 Jul 30. PMID: 30059269.
- 28) Fagogeni I, Metlerska J, Falgowski T, Górski M, Lipski M, Nowicka A. Effectiveness of Teeth Whitening after Regenerative Endodontics Procedures: An In Vitro Study. *J Clin Med*. 2022 Nov 28;11(23):7016. doi: 10.3390/jcm11237016. PMID: 36498591; PMCID: PMC9738840.
- 29) Saati K, Chitsazha R, Firouzi N, Tour Savadkouhi S, Firouzi N. Effect of Different Durations of Home Bleaching on Tooth Discoloration Caused by Mineral Trioxide Aggregate: An In Vitro Study. *J Res Dent Maxillofac Sci* 2023; 8 (1) :11-17
- 30) Saati K, Sheikhi S, Esnaashari E, Valizadeh S. The Effects of Three Bleaching Agents on Tooth Discoloration Caused by Mineral Trioxide Aggregate. *Iran Endod J*. 2019 Fall;14(4):253-258. doi: 10.22037/iej.v14i4.23071. PMID: 36794102; PMCID: PMC9923412.

- 31) Dogra S, Goyal V, Gupta A, Joshi S, Kataria V, Saini J, Nagpal M, Narula P. Spectrophotometric Evaluation of Color Change in Tooth Enamel Defects Using Resin Infiltrate: An In Vivo Study. *Int J Clin Pediatr Dent.* 2020 Mar-Apr;13(2):150-154. doi: 10.5005/jp-journals-10005-1727. PMID: 32742092; PMCID: PMC7366758.
- 32) Lee J, Okoye LO, Lima PP, Gakunga PT, Amaechi BT. Investigation of the esthetic outcomes of white spot lesion treatments. *Niger J Clin Pract.* 2020 Sep;23(9):1312-1317. doi: 10.4103/njcp.njcp\_119\_20. PMID: 32913173.
- 33) Marques JV, Carlos NR, Turssi CP, França FMG, Vieira Junior WF, Basting RT. Effectiveness of changing the color of darker teeth is potentiated by association with violet LED light. *Photodiagnosis Photodyn Ther.* 2023 Dec;44:103794. doi: 10.1016/j.pdpdt.2023.103794. Epub 2023 Sep 10. PMID: 37699468.
- 34) Shokouhinejad N, Khoshkhounejad M, Hamidzadeh F. Evaluation of the Effectiveness of Laser-Assisted Bleaching of the Teeth Discolored due to Regenerative Endodontic Treatment. *Int J Dent.* 2022 Jul 6;2022:3589609. doi: 10.1155/2022/3589609. PMID: 35847349; PMCID: PMC9279097.
- 35) Da Silva AGA, Baioni JC, de Oliveira J, Sendyk WR, Kimura JS, Tanaka MH, Scatolin RS. Evaluation of the efficacy of the use of violet LED light in the bleaching of damaged primary incisors darkened by trauma. *Photodiagnosis Photodyn Ther.* 2023 Mar;41:103239. doi: 10.1016/j.pdpdt.2022.103239. Epub 2022 Dec 16. PMID: 36535599.
- 36) Commission Internationale de l'Eclairage (CIE), Recommendations on uniform color spaces, color-difference equations, and psychometric color terms. Supplement No. 2 of publication CIE No. 15 (E-1.3.1). Paris: Bureau Central de la CIE, 1978.
- 37) Johnston WM, Kao EC. Assessments of appearance match by visual observation and clinical colourimetry. *Journal of Dental Research* 1989;68:819–22.
- 38) Ruyter IE, Nilner K, Moller B. Color stability of dental composite resin materials for crown and bridge veneers. *Dental Materials* 1987;3:246–51.
- 39) Gupta S, Tandan M, & Sodhi PS (2011) Improving esthetics of discoloured teeth using opaques under direct composite resin veneers *Heal Talk III*(03) 8-9.
- 40) Kim SJ, Son HH, Cho BH, Lee IB, Um CM. Translucency and masking ability of various opaque-shade composite resins. *J Dent.* 2009 Feb;37(2):102-7. doi: 10.1016/j.jdent.2008.10.002. Epub 2008 Nov 22. PMID: 19028004.
- 41) Miotti LL, Santos IS, Nicoloso GF, Pozzobon RT, Susin AH, Durand LB. The Use of Resin Composite Layering Technique to Mask Discolored Background: A CIELAB/CIEDE2000 Analysis. *Oper Dent.* 2017 Mar/Apr;42(2):165-174. doi: 10.2341/15-368-L. Epub 2016 Nov 1. PMID: 27802121.
- 42) Ryan EA, Tam LE, McComb D. Comparative translucency of esthetic composite resin restorative materials. *J Can Dent Assoc.* 2010;76:a84. PMID: 20719098.
- 43) An JS, Son HH, Qadeer S, Ju SW, Ahn JS. The influence of a continuous increase in thickness of opaque-shade composite resin on masking ability and translucency. *Acta Odontol Scand.* 2013 Jan;71(1):120-9. doi: 10.3109/00016357.2011.654250. Epub 2012 Jan 30. PMID: 22283436.
- 44) Spaveras A, Vjero O, Anagnostou M, & Antoniadou M (2015) Masking the discolored enamel surface with opaques before direct composite veneering *Journal of Dentistry, Oral Disorders & Therapy* 3(3) 01-08.

- 45) Vichi A, Fraioli A, Davidson CL, & Ferrari M (2007) Influence of thickness on color in multi-layering technique *Dental Materials* 23(12) 1584-1589.
- 46) De-Jesus-Soares, A.; Prado, M.; Nagata, J.Y.; Pini, N.I.P.; Cardoso, R.A.; Vargas-Neto, J.; Figueiredo de Almeida Gomes, B.P.; Lima, D.A.N. Internal bleaching after pulp revascularization using two intracanal medicaments: A case report. *Int. J. Clin. Dent.* 2018, 11, 127–135
- 47) Antov, H.; Duggal, M.S.; Nazzal, H. Management of discolouration following revitalization endodontic procedures: A case series. *Int. Endod. J.* 2019, 52, 1660–1670.
- 48) Burrows S. A review of the efficacy of tooth bleaching. *Dent Update.* 2009;36(9):537-51.
- 49) Giachetti L, Bertini F, Bambi C, Nieri M, Russo DS. A randomized clinical trial comparing at-home and in-office tooth whitening techniques: a nine-month follow-up. *J Am Dent Assoc.* 2010;141(11):1357-64.
- 50) Basting R.T., Amaral F.L., França F.M., Florio ´ F.M. Clinical comparative study of the effectiveness of and tooth sensitivity to 10% and 20% carbamide peroxide home-use and 35% and 38% hydrogen peroxide in-office bleaching materials containing desensitizing agents. *Oper. Dent.* 2012 Sep-Oct; 37 (5):464–73. doi:10.2341/11-337-C.
- 51) M. Behl, A.K. Patnana, V. Khanna, K. Chaudhry, Evaluation of three different bleaching agents in permanent and primary teeth: an in vitro study, *Int. J. Clin. Pediatr. Dent.* 13 (2020) 130–135, <https://doi.org/10.5005/jp-journals-10005-1721>
- 52) Son J-H, Hur B, Kim H-C, et al. Management of white spots: resin infiltration technique and microabrasion. *J Korean Acad Cons Dent* 2011;36(1):66–71. DOI: 10.5395/JKACD.2011.36.1.66.
- 53) Kim S, Kim EY, Jeong TS, Kim JW. The evaluation of resin infiltration for masking labial enamel white spot lesions. *Int J Paediatr Dent* 2011;21:241-8. 15.
- 54) Torres C, Borges A, Torres L. Effect of caries infiltration technique and fluoride therapy on the colour masking of white spot lesions. *J Dent* 2011;39:202-7.
- 55) Lago ADN, Ferreira WDR, Furtado GS. Dental bleaching with the use of violet light only: Reality or Future? *Photodiagnosis Photodyn Ther.* 2017 Mar;17:124-126. doi: 10.1016/j.pdpdt.2016.11.014. Epub 2016 Nov 27. PMID: 27902926
- 56) de Almeida ENM, Silva AM, Besegato JF, de Sousa Gomes Costa JL, Manzoli TM, de Andrade MF, Kuga MC. Effectiveness and color stability of non-vital dental bleaching photoactivated by violet LED on blood-stained teeth. *Photodiagnosis Photodyn Ther.* 2023 Jun;42:103329. doi: 10.1016/j.pdpdt.2023.103329. Epub 2023 Feb 8. PMID: 36758735.
- 57) Santos AECGD, Bussadori SK, Pinto MM, Pantano Junior DA, Brugnera A Jr, Zanin FAA, Rodrigues MFSD, Motta LJ, Horliana ACRT. Evaluation of in-office tooth whitening treatment with violet LED: protocol for a randomised controlled clinical trial. *BMJ Open.* 2018 Sep 4;8(9):e021414. doi: 10.1136/bmjopen-2017-021414. PMID: 30181185; PMCID: PMC6129043.

## IX. Attachments

### Attachment 1

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |            |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| <b>PubMed</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | <b>247</b> |
| ("Discolored tooth" OR "Discolored teeth" OR "Discoloured tooth" OR "discoloured teeth" OR "tooth discoloration" OR "teeth discoloration" OR "dental discoloration" OR "discolored background" OR "discolored backgrounds" OR "tooth stain" OR "teeth stain" OR "dental stain" OR "fluorosis stains" OR "dark tooth" OR "dark teeth" OR "dark substrate" OR "dark substrates" OR "dark discoloration" OR "dark stain" OR "dark background" OR "tooth-colored" OR "background color") AND ("restoration" OR "restorations" OR "resin" OR "composite" OR "composites" OR "resins" OR "bleach" OR "bleaching" OR "whitening" OR "resin infiltration" OR "microabrasion" OR "opaquer") NOT "review" NOT "case report"                                                                                                           |            |
| <b>Scopus</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | <b>476</b> |
| TITLE-ABS-KEY ( ( "Discolored tooth" OR "Discolored teeth" OR "Discoloured tooth" OR "discoloured teeth" OR "tooth discoloration" OR "teeth discoloration" OR "dental discoloration" OR "discolored background" OR "discolored backgrounds" OR "tooth stain" OR "teeth stain" OR "dental stain" OR "fluorosis stains" OR "dark tooth" OR "dark teeth" OR "dark substrate" OR "dark substrates" OR "dark discoloration" OR "dark stain" OR "dark background" OR "tooth-colored" OR "background color") AND ( "restoration" OR "restorations" OR "resin" OR "composite" OR "composites" OR "resins" OR "bleach" OR "bleaching" OR "whitening" OR "resin infiltration" OR "microabrasion" OR "opaquer" ) ) AND PUBYEAR > 2018 AND PUBYEAR < 2025 AND ( LIMIT-TO ( DOCTYPE , "ar" ) ) AND ( LIMIT-TO ( LANGUAGE , "English" ) ) |            |



## Attachment 2



FACULDADE DE  
MEDICINA DENTÁRIA  
UNIVERSIDADE DO PORTO

This questionnaire constitutes a means of study for the investigation to be developed regarding 'The aesthetic approach of restorative treatment of teeth with chromatic alterations,' being of interest within the scope of a research project in the course "Monografia/Relatório de estágio" of the Integrated Master's Degree in Dentistry at the Faculty of Dental Medicine of Porto University.

Tooth \_\_\_\_\_

Color of classical VITA scale \_\_\_\_\_

You should mark with ☒ the option you consider most appropriate.

### 1. Diagnosis

#### Etiology - Intrinsic Chromatic Alteration

- ☐ **Dental conditions** (Arrested carie; Aging; Tooth wear)
- ☐ **Pulpal causes** (Pulpal trauma; Internal resorption; Calcific metamorphosis)
- ☐ **Dental materials** (Amalgam; Composite/GIC; Intra canal medicaments; Obturating materials)
- ☐ **Pre-eruptive causes** (Molar Incisor Hypomineralization; Hyperbilirubinemia; Alkaptonuria; Minocycline; Tetracycline; Amelogenesis imperfecta; Dentinogenesis imperfecta; Dentin dysplasias, etc)

#### Extension

- ☐ The chromatic alteration extends across the surface of enamel
- ☐ The chromatic alteration extends to less than half the dentin surface
- ☐ The chromatic alteration extends to more than half the dentin surface

You should mark with ☒ the option you consider most appropriate.

### 2. Restorative Treatment

| Bleaching      |                    |                            |                             |                           | Direct Restoration |                           |                           |
|----------------|--------------------|----------------------------|-----------------------------|---------------------------|--------------------|---------------------------|---------------------------|
| Micro-abrasion | Resin infiltration | Oxidant: Hydrogen Peroxide | Oxidant: Carbamide Peroxide | Oxidant: Sodium Perborate | Opaker             | Resin composite of dentin | Resin composite of enamel |
|                |                    |                            |                             |                           |                    |                           |                           |

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You should mark with ☒ the option you consider most appropriate.

**3. Evaluation of esthetic optical proprieties of restorative treatment according to the FDI criteria  
– color and translucency**

|                                     | Clinically acceptable                                        |                  |                                                              | Clinically unacceptable                                        |                                         |
|-------------------------------------|--------------------------------------------------------------|------------------|--------------------------------------------------------------|----------------------------------------------------------------|-----------------------------------------|
|                                     | Clinically excellent                                         | Clinically good  | Clinically satisfactory/sufficient                           | Clinically unsatisfactory (but reparable)                      | Clinically poor (replaceable necessary) |
| <b>Color match and translucency</b> | Good color match, no difference in shade and/or translucency | Minor deviations | Distinct deviation but acceptable, does not affect esthetics | (Localized) clinical deviation that can be corrected by repair | Unacceptable; replacement necessary     |

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