GRADUATION PROJECT

Degree in Dentistry

Comparing the effectiveness of various tooth bleaching methods on enamel color improvement

Madrid, academic year 2024/2025

Identification number:101

ABSTRACT

Introduction: Tooth discoloration is becoming a common concern among the population, which significantly influences patients´ self-confidence and overall appearance. To overcome this issue, in-office, at-home, and combined bleaching methods are widely approached in aesthetic dentistry to improve enamel color. Employing the best method among the available treatments, clarifying their relative efficacy, durability, and sensitivity is essential. **Objectives:** The primary purpose of this study was to compare the effectiveness of in-office and at-home tooth bleaching on enamel color improvement. The secondary objective was to evaluate the efficacy of the combined bleaching technique compared to a single method. **Methods:** This systematic review was conducted based on our PICO question. Scientific databases such as PubMed and Medline were searched to identify the eligible studies. Twelve primary articles were conducted. Additionally, two recent systematic reviews were included for verification. ΔE values (color change), sensitivity, and relapse were among the key outcomes evaluated. **Results:** Both techniques revealed clinically significant whitening results. At-home bleaching showed slightly higher or equivalent ΔE values and superior long-term stability. While some studies reported lower sensitivity with at-home methods, overall sensitivity levels were similar. In-office techniques showed faster initial outcomes, but there was a higher chance of color relapse. The combined approach improved both short and long-term results. **Conclusions:** Although all three bleaching techniques are effective, the best option depends on the patient's requirements, treatment objectives, and risk of sensitivity. In-office procedures are best for quick results, at-home methods give long-lasting whitening, and mixed regimens provide balanced longevity and efficacy.

KEYWORDS

Odontology, In-office whitening, At-home whitening, Enamel color, Tooth color Improvement.

RESUMEN

Introducción: La decoloración dental es una preocupación estética creciente que afecta significativamente la autoestima de las personas y su percepción de salud bucal. Las técnicas de blanqueamiento en consultorio, en el hogar y combinadas se utilizan ampliamente en odontología estética para mejorar el color del esmalte. Seleccionar el método más adecuado requiere comprender sus niveles relativos de efectividad, duración de resultados y perfil de sensibilidad. **Objetivo:** El objetivo principal de esta revisión fue comparar la efectividad del blanqueamiento dental en consultorio y en el hogar en la mejora del color dental. Un objetivo secundario fue evaluar el **desempeño** de la técnica combinada en comparación con los métodos individuales. **Métodos:** Se realizó una revisión sistemática utilizando bases de datos como PubMed y Medline. Se seleccionaron doce estudios clínicos primarios junto con dos revisiones sistemáticas recientes. Los resultados evaluados incluyeron el cambio de color del esmalte (ΔE), la sensibilidad posterior al tratamiento y la durabilidad del efecto blanqueador. **Resultados:** Las tres técnicas mostraron mejoras clínicamente significativas. El blanqueamiento en el hogar presentó resultados iguales o ligeramente superiores en cuanto al cambio de color y mejor estabilidad a largo plazo. El tratamiento en consultorio ofreció resultados inmediatos, pero con mayor riesgo de recaída. La sensibilidad fue similar entre los métodos, aunque algunos estudios favorecieron el tratamiento en el hogar. Los protocolos combinados ofrecieron beneficios inmediatos y duraderos. **Conclusiones:** Cada método fue efectivo, pero la elección debe basarse en factores individuales como urgencia, riesgo de sensibilidad, objetivos estéticos, costo y adherencia del paciente.

PALABRAS CLAVE

Odontología, Blanqueamiento en consultorio, Blanqueamiento en el hogar, Color del esmalte, Mejora del color dental

Table of Contents

1. INTRODUCTION 1

1.1. Extrinsic Stains 1

1.2. Intrinsic Stains 1

1.3. Different Bleaching Techniques: 2

1.3.1. Vital Approach (External Bleaching): 2

1.3.1.1. In-office 2

1.3.1.2. At-home 2

1.3.1.3. Combined Technique 3

1.3.2. Non-vital Approach (Internal Bleaching): 4

1.3.2.1. Walking Technique: 4

1.3.2.2. Inside/Outside Technique: 4

1.4. Teeth discolored by tetracycline 5

2. OBJECTIVE 7

2.1. Primary objective 7

2.2. Secondary objective 7

3. MATERIALS AND METHODOS 7

4. RESULTS 11

5. DISCUSSION 19

5.1. Comparing the Effectiveness of In-Office and At-Home whitening methods and their stability over time 19

5.2. Combined bleaching approaches and long-term stability 20

5.3. Relapse and tooth whitening effects durability 20

5.4. Tooth sensitivity 21

5.5. Clinical Implications 21

6. CONCLUSION 21

7. SUSTAINABILITY 23

8. REFERENCES 24

1. INTRODUCTION

Nowadays, aesthetic dentistry has become increasingly important due to its influence on patients' smiles, confidence, social interactions, and overall satisfaction. Youngness, energy, and beauty are frequently linked to a healthy, brilliant smile, all of which can enhance social and professional relationships(1). Since tooth color plays a major role in creating a visually attractive and pleasing smile, discoloration may make someone less inclined to smile or interact with others. To address this concern, cosmetic and aesthetic dentistry offers numerous whitening techniques, providing a range of treatment options from at-home whitening kits to advanced in-office procedures that enhance the visual appeal of the smile and play a crucial role in enhancing patients' confidence(2).

To better understand tooth discoloration and its associated treatment, it is crucial to distinguish between the two main primary factors: Intrinsic and Extrinsic stains. Each of them, based on different factors, including aging, diet, and lifestyle choices, might require different treatment approaches(3).

1.1. Extrinsic Stains

covers the outer surface of the enamel; superficially stained, which is caused mostly by external factors (such as coffee, tea, tobacco, etc). This implies that depending on the extent of the discoloration, they may be treated with tartectomy or, as will be discussed below, with bleaching chemicals in cases of severe discoloration (3).

1.2. Intrinsic Stains

Compared to extrinsic discoloration, they are situated inside the tooth structure, primarily on the dentinal layer. It can be caused by two distinct factors, either local ones (such as age, root reabsorption, and pulp necrosis) or systemic (such as tetracycline, fluorosis, and the heritage factors) (3,4). Therefore, whitening procedures are frequently required since they originate in the deeper layers of tooth structure and are more challenging to treat (3).

The bleaching process involves varying concentrations of potent whitening agents such as Hydrogen Peroxide (HP), Carbamide Peroxide (CP), and Sodium Perborate. This procedure is assessed across three separate stages:

- Once the agents are applied, they spread into the tooth structure, meaning into the enamel and dentine layers (phase 1 -Diffusion) (5,6).

- Upon the penetration of these oxidizing agents into the tooth structure, they begin interacting with colored organic compounds, releasing reactive free radicals and changing and degrading those stained molecules (phase 2-Interaction) (5,6).
- Free radicals increase the color lightness and reduce chroma by reducing the tooth´s capacity of light reflection, resulting in a brighter and more natural tooth appearance (Phase 3- Surface Change and Color)(5,6).

1.3. Different Bleaching Techniques:

Among the selections of available methods, two predominant approaches stand out:

1.3.1. Vital Approach (External Bleaching):

It involves in-office dental whitening, the at-home method, and a combination of them, each with its pros and cons and differing factors (7,8).

1.3.1.1. In-office

The in-office bleaching approach has become popular among patients due to the rapid achievement of the desired result, performed under the supervision of professional dentists in a dental clinic by using various materials and equipment. Before application of this method, it is vital to follow considerations and protective measures such as isolation, desensitizing gel (using 5% Potassium Nitrate applied for 10 minutes), and soft tissue protection like lip and cheek retractors and gingival barriers (9). Accordingly, this method involves the use of high percentages of the previously mentioned materials, namely Hydrogen Peroxide(HP-typically ranging from 35% to 38%) and Carbamide Peroxide(CP- ranging from 30% to 35%), to produce a faster result (7,10).

Various activation methods, including heat, light, and lasers, are being carried out in the dental clinic to improve the quality of this approach and reduce the time efficiency, making it a time-effective solution for obtaining the desired outcome. It is highly desirable to note that a noticeable whitening impact can be achieved through one session within thirty to sixty minutes (1,7,11).

1.3.1.2. At-home

The At-home bleaching technique, also called At-home whitening or Tray-whitening technique, is a popular alternative technique for people looking for less intrusive whitening methods, achieved through a dentist-fabricated custom tray made of soft plastic material with a 2 mm thickness similar to the mouth guard (2). Filled typically with lower concentrates of Hydrogen

Peroxide (HP-3% to10%) and Carbamide Peroxide (CP- 10% to 20%), which is instructed the patients to take once or twice a day for thirty minutes to two hours each time or as an overnight application of eight to ten hours, the patients are monitored over a minimum of two weeks (two to five weeks) to assess the color change (7). Research shows that carbamide peroxide offers slightly greater whitening efficacy compared to hydrogen peroxide (12). Mild to moderate stains often respond well to this technique. However, severe discoloration may require a more concentrated approach (7).

1.3.1.3. Combined Technique

The combined approach of in-office dental bleaching and at-home one is characterized by a first in-office session associated with high HP concentration by following the protective protocols, including protective lips cream, gingival protection, and protective goggles, then the whitening gel is applied and repeated for four fifteen-minute cycles, in each cycle the new layer is added, and the previous one has removed in addition the surface of teeth is kept hydrated by the cotton rolls, once is finished the patients are instructed to follow the additional home protocols by using their custom trays filled with whitening gel (containing 10% to 16% Carbamide Peroxide) for a minimum of six hours each night over fourteen consecutive nights(13–15).

In the following table, one can see the comparisons of different whitening methods (In-office At-home and Combined) with regard to factors such as effectiveness, applied bleaching agents, and required time.

	At home	**In office**	**Combined**
Effectiveness	Less/takes longer(12)	Highly	Maximized/better than in-office application itself(13)
Procedure Time	Minimum 2 weeks, daily approach(7)	1-2 hours Single session(1,7,11)	1-2 hours (in office)followed by 2 weeks(at home)(9)
Bleaching agent percentage	HP 3 to10% CP 10 to20%(7).	HP 35-38% CP 30-35%(7,10)	In-office high percentage of HP 35% At-home CP 10 to16%(16)
Cost	Budget-friendly(17)	Expensive(18)	Initial in office cost, followed by the cost of at home products (13)
Convenience	Chairside approach	At-home procedure	Convenient, a mix of dental visits and home care
suitability	Ideal for people seeking more gradual and cost-effective outcomes(2)	Ideal for people seeking immediate, noticeable effects(12)	Ideal for people looking for a mix of convenience and efficacy(13)

Table 1. Comparative overview of At-Home, In-Office, and Combined teeth whitening methods.

1.3.2. Non-vital Approach (Internal Bleaching):

Non-vital tooth bleaching is a conservative technique used to treat discoloration in teeth that are no longer vital. This approach is specifically indicated in cases where intrinsic color alterations are present, as previously mentioned, such as:

- Pulp Necrosis: This can occur with or without hemorrhage (19).
- Incomplete Root canal treatment: (Intrinsic discoloration can result from endodontic treatments, as pulpal substances may infiltrate the surrounding dentinal tubules)(19). During the endodontic treatment, blood-derived elements like hemosiderin, hemine, hematin, and hematoidin, as well as their byproducts, can penetrate dentinal tubules. These iron-containing substances play a crucial role in contributing to intrinsic tooth discoloration after traumatic damage since they may associate with sulfides to produce dark pigments (19).
- Pulp tissue remnants are left over in the access opening (20).
- Substances that stain inside the tooth: Gutta Percha points (Alter light diffraction, which affects the optical properties of dentin) (19).

This technique is further categorized into two sub-methods: walking bleaching and inside-outside bleaching (21).

1.3.2.1. Walking Technique:

This method is used in root-canaled treated teeth using materials called sodium perborate, carbamide peroxide, and hydrogen peroxide (HP). Before beginning any procedure, it is important to apply protective precautions like isolation of teeth, eyes, etc. Upon finishing this step, a combination of bleaching agents, either hydrogen Peroxide and Sodium Perborate or a mixture of distilled water and Sodium Perborate, is inserted into the dental canal. Researchers defined that the latter mixture is more effective because it diminishes the possibility of side effects. Then, the access cavity is sealed with temporary material, and the patient is observed for two to seven days to assess the whitening effect. This process is carried out as much as needed until the desired color is achieved (22,23).

1.3.2.2. Inside/Outside Technique:

This dual method has some advantages over the previous technique, like reduced chair time and appointment, as the name suggests, targeting the inner and outer surfaces of the teeth and addressing tooth discoloration (20,24).

This approach is also generally used in root-canaled treated teeth with conditions such as severe discolorations due to pulpal trauma, retained pulp tissue, and severe discoloration that cannot be treated with external bleaching alone. Before starting the procedure, the target tooth is

completely isolated to prevent contamination from entering the pulp. Afterward, the root canal obturation material, meaning gutta-percha, is partially removed up to 1.5 mm below the cementoenamel junction (CEJ) (20,25).

The internal access cavity remains unsealed, allowing the patient to use the custom-fitted tray filled with whitening agent for overnight use, typically for five to six hours. The patient is monitored weekly by the dentist for color change without replacing the products inside the chamber. Ultimately, after three weeks, the whitening gel used inside the cavity is removed, which means the completion of the procedure is achieved (20,25).

1.4. Teeth discolored by tetracycline

Tetracyclines and their related compounds belong to the broad-spectrum antibiotics with bacteriostatic properties. They are active against microorganisms such as Gram-positive and Gram-negative bacteria. They are used in the treatment of infections such as those caused by Mycoplasma, Rickettsia, and Chlamydia (12,26).

The way to distinguish between unpigmented teeth and those with tetracycline stains is to view them in a dark room using ultraviolet light, which emits yellow fluorescence, indicating the deposited stained tooth, whereas the blue one demonstrates a healthy tooth. The Tetracycline dye has the ability to degrade under the influence of light, which can cause darker spots with age (13).

Its mode of action and subsequent adverse effects include the capacity to chelate calcium in the tooth tissue, which results in the development of a tetracycline-cal-calcium orthophosphate complex, and its integration as a fluorescent agent into calcifying tissues. When used, it integrates as a fluorescent agent into calcifying tissues. If it is used for a long time, it causes tooth discoloration (26). The extent of this discoloration is affected by the dosage, frequency, and duration of the treatment. Managing the aesthetics of teeth that are discolored by tetracycline can be difficult due to the wide range of staining intensity (12).

- Mild Staining (First-degree staining): Appears as a uniform yellow to greyish discoloration without banding and uniformly covers the teeth→usually responds well to the whitening treatment (12,26).
- Moderate staining (Second-degree staining): Characterized by yellow to dark grey discoloration→ It is responsive to bleaching (12,26).
- Severe staining (Third-degree staining): characterized by noticeable banding, particularly in the gingival third with a dark grey-blue appearance→partially responsive to bleaching /for optimal results, bonded restoration may be needed (12,26).

The At-home bleaching approach is effective for the first and second TETRACYCLINE discoloration degrees, applying 10 % CP for up to 6 months (12).

1.5. Dental fluorosis stain

Dental fluorosis is a prevalent type of intrinsic discoloration, causing stains ranging from yellow to brown and frequently raises cosmetic problems. When it comes to minimally invasive dentistry, several treatment options are up, including enamel microabrasion (MA), tooth bleaching, or a combination of both (27). In this technique, the surface of the enamel is removed using a paste, which usually has a thickness of about 18 to 200µm. The effectiveness of this method varies depending on the concentration of applied acid and the pressure. Since the enamel is thinned in this method, the chance of the underlying layer, which is dentine and typically yellowish in color, being visible increases. Therefore, a dual technique, a mixture of microabrasion and bleaching, is employed to address this issue as a standard method to penetrate the tooth structure and have a whitening effect simultaneously (27). Notably, research demonstrates that the whitening technique described above is more effective when performed at home rather than in a clinical setting. In-office bleaching generally relies on high concentrations of bleaching products; which can increase the risk of postoperative sensitivity and raise the likelihood of the agents reaching the pulp chamber, while at-home whitening typically utilizes lower concentrations, therefore minimizing these potential complications (27).

Justification:

Teeth whitening has become one of the most popular cosmetic treatments worldwide. It provides fast, non-invasive, and cost-effective results for improving the smile. It effectively lightens the tooth color without damaging its corresponding surface. A wide range of bleaching methods is available, from in-office treatments to home bleaching kits or even a combination of them. Each of these methods has different effectiveness, safety, and results (1).

Factors such as external or internal discoloration, age, and treatment costs influence the choice of treatment methods. For example, internal stains and surface discoloration of teeth may be caused by inherent or acquired factors. Some people inevitably experience internal tooth discoloration as they age. However, most people experience internal tooth discoloration due to acquired factors such as taking certain medications or trauma, or decay. Taking tetracycline at certain times of life and consuming too much fluoride can also lead to tooth discoloration, and depending on its stage (level of affectation), it can be treated by either external or internal whitening. Typically, severe discoloration cannot be treated with whitening and bleaching methods; therefore, the use of dental restorative methods such as veneers and composites is

recommended (3). During the bleaching process, the dentist uses hydrogen peroxide or carbamide peroxide, which are safe substances, as the active ingredient. These chemicals penetrate your teeth and remove both surface stains and deeper enamel discoloration (5,6).

Today, with advertising in the field of marketing for teeth whitening and achieving the best results in the shortest possible time, it draws the consumer's mind towards it without considering the side effects or safety standards, meaning that people are increasingly drawn to use over-the-counter and sometimes illegal options. Therefore, this study, which is based on valid and scientific evidence and conclusions, is necessary to make consumers aware of each of the available methods, their results, and potential adverse effects. Ultimately, it is the end user who, with a wide scope of scientific information, considering all possible aspects and results, and the current situation in relation to the degree of discoloration of their teeth and the available budget, with the advice of a dentist decides to follow the best method appropriate to their circumstances. Overall, this study is justified in terms of providing insights supporting the consumer´s decision-making regarding what whitening options to opt for. In addition, this study aims to yield a better understanding not only for the consumer but also for clinicians, enabling them to apply the best possible method for their patients.

2. OBJECTIVE

2.1. Primary objective

To evaluate and compare the effectiveness of two whitening techniques — the in-office method versus the at-home method — in enhancing enamel color.

2.2. Secondary objective

To evaluate the effectiveness of the combined bleaching technique compared to the single method in improving the color of enamel.

3. MATERIALS AND METHODOS

In accordance with the PICO framework below:

P	I	C	O
Population	Intervention	Comparison	Outcome
Adult human	In-office bleaching method	At-home whitening technique	The enamel color improvement

Table 2. Working table for formulating the research question.

The following research question was performed:

How does the effectiveness of in-office dental bleaching compare to at-home whitening methods in altering enamel color?

Eligibility of studies:

To conduct this systematic research, we resort to the methodology and bibliography to gather the most current and high-quality material based on analysis research, comprising the top scientific articles and journals published within the last 20 years via electronic databases such as PubMed and Medline. We included all randomized clinical trials, case-control, and cohort studies with any available books or documents. In contrast, other study kinds, such as meta-analyses and systematic reviews, were excluded. Our study included only adult human participants who were at least 18 years old, intending to evaluate and compare the effectiveness of two teeth whitening techniques: in-office and at-home bleaching. As previously stated, two primary databases were used for this research: Medline and PubMed. Both databases employed advanced search techniques to find the final articles that were relevant to the study's PICO question framework, as will be explained below:

For the PubMed database, the following keywords were utilized (Figure 1):

(((((tooth bleaching[MeSH Terms]) OR (agents, tooth bleaching[MeSH Terms])) OR ((tooth whitening[MeSH Terms]) OR (agents, tooth whitening[MeSH Terms]))) AND ((((enamel color) OR (tooth color)) OR (color change)) OR (enamel color alternation))) AND ((home bleaching) OR (home whitening))) AND ((office bleaching) OR (office whitening))

Figure 1. PubMed definitive search.

Likewise, in Medline, a similar approach was used to obtain the definitive research (Figure 2):

(tooth whitening or bleaching) AND (in office whitening or bleaching) AND (at home whitening or bleaching) AND (enamel color)

Figure 2. Medline definitive research.

Afterward, a preliminary search was employed, which yielded a total of 573 papers. Then, 31 duplications were removed by utilizing the Rayyan software, resulting in a total of 542 records. In the following step, they were screened by applying a filter to separate the Randomized clinical trials and eliminate the most systematic reviews, case series, cohort studies, and in vitro studies,

leaving a total of 47 articles sought for retrieval. Finally, by filtering only the full-text articles, 37 papers were deduced that subsequently were screened for their eligibility. To find suitable articles for this systematic review, a set of inclusion and exclusion criteria were applied (Figures 3 and 4).

Systematic reviews, in vitro studies and case reports
Children participants

Figure 3. Exclusion criteria.

Randomized clinical trials (RCT)
samples included adults
studies published Whitin 20 years
full text articles

Figure 4. Inclusion criteria.

We reviewed all conducted articles, so we manually discarded two more systematic reviews as well as three in vitro studies that had not been automatically filtered out previously. Additionally, one unrelated article, which had nothing to do with our topic, was removed. Lastly, twenty-three studies were excluded for not being in accordance with the PICO question.

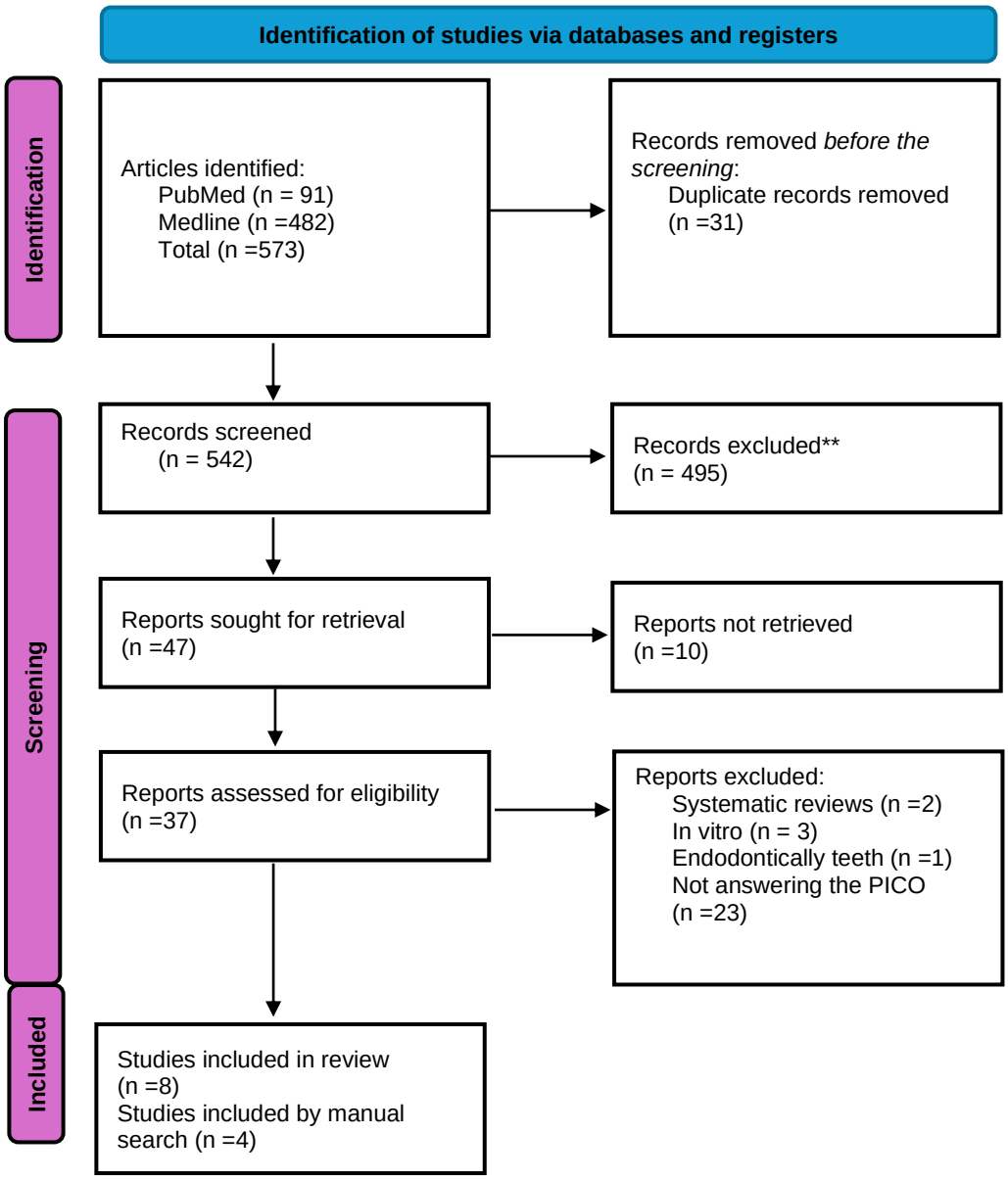

Figure 5. Prisma flow diagram illustrating the article selection process.

4. RESULTS

Year, Autor	Country	Study type	Sample	Intervention	Control	Outcome (enamel color)
Luca Giachetti et al. (28) 2010	Italy	Randomized clinical trial	N=17	In office bleaching (38% HP)	At home bleaching (10 % CP)	9 months follow-up, no significant difference was observed.
Ahmad Jum'a et al.(29) 2024	New Zealand	Randomized clinical trial	N=105	In office technique (37.5% HP)	At home bleaching technique (10% CP)	6 months follow-up demonstrates that the home bleaching has the most stable whitening effect compared to in in-office one. In-office approach has a faster initial effect, but has some percentage of relapse, not as effective as home whitening in the prolonged aspect.
Rafael Francisco Lia MONDELLI et al.(30) 2012	Brazil	Randomized clinical trial	N=48	In office bleaching with 2 different percentages (35% & 38% HP)	At home bleaching (15% CP)	No significant differences were observed between the two methods used, but still, we can state that all evaluation points (immediately after the treatment or even in the long-term run) in the at-home bleaching group have revealed statistically higher ΔE values compared to the in-office groups.

M Bizhang et al.(31) 2009	Germany	Randomized clinical trial	N=75	In office bleaching (15% HP)	Home bleaching products (10%CP)	In a 3-month follow-up, at-home bleaching demonstrates greater color change compared to the in-office method statistically. ΔE values from the baseline to immediately after treatment show a higher value for the home bleaching group than in-office one.
JB da Costa et al.(32) 2010	United States	Randomized, single-blind, split-mouth design clinical study.	N=20	In office bleaching (25% HP)	At home bleaching (10% CP)	Office whitening (OW) has a faster effect (Reaching the whitening level that at-home whitening (HW) would have achieved in five days). Patients in this study preferred home whitening over the in-office due to the comfort and lower cost.
R Zekonis et al.(33) 2003	Indianapolis	Randomized controlled clinical trial	N=19	In office bleaching (35% HP)	At home bleaching (10%CP)	This study reported that after 2 weeks of follow-up, the at-home approach demonstrated a higher ΔE value in comparison with the in-office, meaning that the patients, even though they had only completed one session of treatment, would require longer in-office treatment time to achieve the same value obtained with at home.

Jussara Karina Bernardon et al.(34) 2015	Brazil	Randomized controlled clinical trial	N=30	In office bleaching (35% HP)	At home bleaching (10%CP)	Based on this study, the in-office had a faster effect after just 2 sessions of treatment compared to at home, which needed at least 4 weeks to achieve a similar value and effect At the final evaluation, which took 6 weeks, both methods reached similar effect, but still in office still has a slight advantage
LIDIA YILENG TAY et al.(35) 2012	Brazil	Parallel, double-blind randomized clinical trial	N=60	In office bleaching (35% HP)	At home bleaching (16%CP)	Both techniques showed significant tooth whitening -No significant color rebound detected in 2 years for both Approaches -In general, both techniques reached a similar whitening effect
Jie Nie et al.(36) 2017	China	Randomized clinical trial	N=40	In office bleaching (38% HP)	At home bleaching (10%CP)	This study demonstrates that the home bleaching technique has a greater overall color change (ΔE value) than the office bleaching technique. Furthermore, this study has shown that not only is home bleaching more effective in changing tooth color, but it is also associated with greter patient comfort and satisfaction.

Marília Leao Goettems et al.(37) 2021	Brazil	Randomized controlled clinical trial	N=130	In office bleaching (35% HP)	At home bleaching (10%CP)	Using a Spectrophotometer to objectively measure the color change produced a bleaching effect at home that was superior to in-office whitening. With the use of the VITA Classical Shade Guide, no statistically significant changes were found.
B-j Zhong et al.(38) 2023	China	Randomized controlled clinical trial	N=45	In office bleaching (40% HP)	At home bleaching (10%CP)	Both studies showed a color improvement of the tooth bleaching regimens in both groups, with no significant difference between the office and home approach.
Sandrina Henn DONASSOLLO et al.(39) 2021	Brazil	Randomized controlled clinical trial	N=130	In office bleaching (35% HP)	At home bleaching (10%CP)	Prior to the bleaching treatment, both groups received 2% potassium nitrate applied for 10 minutes. The in-office group received a placebo at-home protocol, and at at-home group received a placebo in-office treatment. In-office bleaching was performed for 40 minutes per session and at home bleaching involved wearing a custom tray loaded with 10% CP for 2 hours daily over 14 days. No significant differences were found at the end of the treatment between the two groups, but it can be stated that in two weeks post-treatment, the at-home groups provided a slightly better effect, meaning in a short-term evaluation, the at-home groups are superior to the in-office groups.

Table 3. Summary of the evaluated primary studies comparing the effectiveness of in-office and at-home tooth whitening techniques

This systematic review resulted in a total of 12 articles with patients being assessed for their tooth color change in ΔE value.

ΔE definition: A quantitative measure of the difference in color between the baseline and final Examination.

Almost all the reviewed articles show that both methods of whitening lead to clinically significant tooth color change; however, some studies report that home-bleaching has slightly higher ΔE values and overall whitening results, compared to the in-office bleaching technique.

Zekonis et al. demonstrated that at-home whitening using 10% carbamide peroxide produced a more significant enamel color change than bleaching in an office with 35% hydrogen peroxide. In simpler terms, at-home methods led to a higher ΔE value at all evaluation measures (12 weeks of follow-up). Additionally, the performed survey of participants showed that 84% preferred the home approach over the in-office one, while 16% found no difference, and no subjects reported the in-office method having superior results(33).

Likewise, research by Bizhang et al. reported that statistically home bleaching technique with 10% Carbamide Peroxide with ΔE of 6.57 recorded had a greater color change compared to the in-office method using 15% Hydrogen Peroxide once per week for three consecutive weeks with a measured ΔE of 5.77 immediately after treatment. This is while in the 3-month follow-up, the registered ΔE values for both whitening techniques were 4.98 and 4.59, respectively. This indicates that both techniques were equally effective in achieving whitening results in the long term, with the at-home one statistically reaching a higher value straight after the treatment and keeping it there with less variation in three months(31).

In another study, Nie et al. assessed Chinese participants specifically and revealed that home bleaching with 10% carbamide Peroxide had greater overall color change than the in-office method using 38% Hydrogen Peroxide (with canines showing more pronounced changes than incisors). Their findings support that at-home whitening yielded higher ΔE values immediately, within 1 week, and 3 months of evaluation points. In total, this study concluded that for Chinese people, home bleaching was more effective in achieving lighter teeth and satisfaction with fewer sensitivity issues compared to in-office whitening (36).

According to Goettems et al., at-home whitening with 10% Carbamide Peroxide demonstrated a significantly greater impact on tooth color, achieving an ΔE value of 4.73 in comparison to tooth whitening in the office with 35% Hydrogen Peroxide. When assessed objectively (P= 0.033, indicating statistical significance), this approach showed measurable differences. However subjectively, by including personal bias from perception, no significant difference was evaluated, indicating that both treatments resulted in a similar whitening effect in a subjective manner(37).

Mondelli et al. evaluated five different groups of participants, four of whom underwent treatment with in-office bleaching products using 35% hydrogen Peroxide (with and without Hybrid light activation), while the last group received in- home bleaching with 15% Carbamide Peroxide. No significant differences were found within the in-office whitening groups, whether light activation was used or not. According to the comparison between home and in-office whitening procedures, it can be said that the home bleaching method maintained at all evaluating points (24 hours, 1 week and month, 6 months, 12 months, 18 months, and 24 months) higher ΔE values(whitening effect) than the in-office bleaching method(30).

In contrast, some studies have found no significant difference in the effectiveness of tooth color change between in-office and at-home whitening approaches.

Giachetti et al., in a nine-month follow-up, showed no discernible difference, neither statistically nor clinically, indicating that both methods produced comparable results(28).

Similarly, da Costa et al. concluded that although in-office bleaching using 25% Hydrogen Peroxide has shown faster and more immediate results than at-home whitening with 10% Carbamide Peroxide which implies that five consecutive days of at-home whitening treatment is equivalent to only one in-office session in terms of color change efficacy still over the long term (twenty days) the effectiveness of 10% carbamide peroxide is comparable to that of 25% of hydrogen peroxide. It is essential to highlight that the at-home approach was preferred by 74% of participants; they found it more convenient and cost-effective, and it was 100% recommended(32).

Zhong et al. and Jum'ah et al. are the only available articles that look at at-home bleaching using 10% Carbamide Peroxide and in-office technique with 40% Hydrogen Peroxide in Zhong´s study and 37.5% in Jum'ah´s, along with combinations of both techniques. In their study, Zhong et al. compared In-office followed by at-home bleaching for 7 days and vice versa**,** while Jum'ah´s study examined only in-office bleaching followed by at-home treatment for 7 days(29,38). Zhong et al. found that all bleaching regimens had a significant whitening effect ($P<0.05$), but comparing them together, no statistically significant differences were detected at any point, meaning all treatments were equally effective. It should be noted that the sequence of combined techniques did not affect overall whitening results(38).

In Jum'ah et al.´s study, all three bleaching methods greatly enhanced tooth color, but the combination procedure demonstrated superior short and medium-term outcomes than the in-office with 37.5% hydrogen Peroxide (which was the least effective in terms of lower whitening results and whitening relapse). Home bleaching with 10% Carbamide Peroxide provided slightly the same whitening as the combined technique, making it a useful substitute(29).

According to the study by Tay et al., even though the home bleaching approach with 16% Carbamide Peroxide produced higher ΔE values than in the office treatment with 35% Hydrogen Peroxide, the difference was not statistically significant (P value more than 0.51 in the first week and more than 0.47 in the second year). This suggests that, since there is no statistically significant difference, we cannot conclude that one method is superior to the other in terms of bleaching efficacy, so the whitening effects of both approaches were closely comparable in long-term evaluation (35).

Moreover, the paper published by Bernardon et al. reported a faster effect of in-office bleaching using 35% Hydrogen Peroxide (applied in two sessions) compared to the result of at-home bleaching with 10% Carbamide Peroxide within 2 weeks which these differences narrowed down after four sessions of office and four weeks of at-home treatments, (note that in this study the in-office whitening products done once a week which considered as 1 session in total 4 to 6 session was required since this study was evaluating the necessary treatment time to achieve the patient satisfaction) but still the in office had a slight advantage. At the final session/week of the treatment, both reached very similar levels, meaning 10% Carbamide Peroxide eventually caught up with 35% Hydrogen Peroxide, but took longer(34).

Lastly, the paper study done by Donassollo et al. reported that in the final stage of at-home and in-office groups (immediately after the treatment) with 10 % carbamide peroxide and 35% Hydrogen Peroxide, respectively, no significant differences (P=0.083) were discovered (objectively) in the short term. However, the long-term evaluation of this study, which was 2 weeks after the final treatment, reveals that at-home whitening reached a higher ΔE than the office groups (P=0.033). Regarding the subjective shade evaluation, no significant differences were detected in the shade guide unit changes (ΔSGU) between the groups(39).

Some of the examined papers have evaluated how well the whitening effects are maintained over time in both in-office and at-home procedures.

Jum'ah et al. assessed three different bleaching methods in the office (37.5% Hydrogen Peroxide), at home(10% Carbamide Peroxide), and in combination. They concluded that home bleaching (after 6 months ΔVS for all participants = 4.6), solely compared to in-office one (after 6 months ΔVS for all participants = 3.6) offers better color maintenance and stability; however, considering all three techniques, the combined groups provided the longest-lasting color stability (29).

Mondelli et al. discovered that home bleaching with 15% Carbamide Peroxide maintained a higher degree of whitening over time (after 24 months) in contrast to in-office bleaching with 35% Hydrogen Peroxide, which fades over time(30).

Likewise, Bizhang et al. showed that at-home whitening with 10% carbamide peroxide maintained better results than in-office with 15% Hydrogen Peroxide bleaching at the three-month mark(31).

In contrast, Tay et al. found that for both techniques, there was no discernible color recovery after two years of follow-up, meaning in both treatments(home whitening with 16% Carbamide Peroxide and in-office bleaching with 35% Hydrogen Peroxide), from 1 week to 2 years the color remained stable with minimal relapse(35).

The typical concern related to tooth whitening is postoperative sensitivity:

Research conducted by Zekonis et al., Giachetti et al., and Donassollo et al. showed that no significant differences were found between at-home bleaching and in-office bleaching in terms of tooth sensitivity(28,33). Donassollo et al. demonstrated that in-office bleaching initially causes more sensitivity (first day of the treatment), but this difference right after the first session narrowed down so that by two weeks of post-treatment, both groups showed similar tooth sensitivity levels. In other words, tooth sensitivity was similar and low between the two techniques (39).

Furthermore, Tay et al. defined two distinct terms

- The absolute risk of tooth sensitivity (ARTS) is the percentage of participants who experienced sensitivity at any point. ARTS shows no significant difference between in-office bleaching with 35% Hydrogen Peroxide and the at-home approach with 16% Carbamide Peroxide, so both regimens are equally likely to provide tooth sensitivity(35).
- The intensity of tooth sensitivity (ITS) refers to how strong the sensitivity was when it occurred. It was higher for in-office groups than the at-home ones. However, the issue was fully cured following the treatment, meaning no participants reported any tooth sensitivity after 2 years of follow-up(35).

Additionally, Goettems et al. demonstrated that participants who underwent in-office whitening were more susceptible to tooth sensitivity than at-home whitening. These differences were not statistically significant ($p = 0.106$), so it can be stated that tooth sensitivity is a common side effect regardless of the method used and does not differ significantly between them(37).

However, in the study done by Nie et al., it was explicitly stated that in-office whitening with 38% Hydrogen peroxide resulted in greater tooth sensitivity than the at-home approach using 10 % carbamide peroxide(36).

Similarly, Zhong et al. reveal that tooth sensitivity was significantly lower at home (10% Carbamide Peroxide) than in the office and combined regimens (with 40% Hydrogen Peroxide); therefore, the at-home method remains the preferred one for lower sensitivity and effectiveness(38).

Mondelli et al. support the finding of NIE et al. since they also reported that in-office bleaching groups with 35% Hydrogen Peroxide provide higher tooth sensitivity than at-home bleaching with 10% carbamide Peroxide. The highest sensitivity levels were recorded immediately following the treatment, but this returns to normal after a week(30).

5. DISCUSSION

Tooth whitening is a widely used aesthetic dental procedure aimed at enhancing enamel color to improve overall appearance. The present systematic review compares the effectiveness of various tooth-bleaching methods, including in-office, at-home, and combined techniques, based on twelve primary studies and two recent systematic reviews(18,40).

5.1. Comparing the Effectiveness of In-Office and At-Home whitening methods and their stability over time

This review evaluates several studies that assess in-office and at-home teeth whitening procedures, demonstrating that while both methods provide noticeable teeth whitening, their efficacy and recurrence rates vary.

Butera et al.´s systematic review assessed the effectiveness of in-office, at-home, and combined bleaching techniques, which demonstrated that all the approaches provide an effective whitening level(40)—the umbrella review by Aidos et al. Confirmed between in-office and at-home methods, the color change outcomes were comparable as well ($p = 0.95$, statistically insignificant)(18). Butera et al. demonstrated that the at-home method provides longer-lasting color retention than those who underwent the in-office one due to the greater duration and prolonged exposure of teeth to whitening agents(40). They also indicated that although office bleaching leads to an immediate result, it is linked to an increased risk of relapse, necessitating further maintenance treatments. The first claim supported by Butera and Aidos is aligned with our primary studies, indicating no statistically significant differences between in-office and at-home whitening treatments(28,29,32,34,35,38). For instance, this conclusion is supported by studies such as Bernardon et al. and Tay et al., who concluded that both whitening approaches

resulted in substantial whitening effects, with results being stable for up to two years(34,35). Similarly, a randomized clinical trial by Giachetti et al. revealed that at-home whitening (with CP) has comparable results to in-office bleaching (with HP) with insignificant variations in effectiveness(28). Likewise, the second statement, according to Butera et al.´s review, is consistent with the primary studies by Bizhang et al., Jum'ah et al., and Mondelli et al., who showed that at-home whitening offers better color stability in the long term(29–31). While by high-level evidence, the equivalency is suggested, it is noteworthy that some of our primary reviews suggested higher ΔE values in at-home whitening compared to in-office one. These results might not have achieved statistical significance at the meta-analytic level, but they do point to a useful benefit for at-home treatments in particular situations.

5.2. Combined bleaching approaches and long-term stability

Several studies evaluated the impact of the combined whitening technique wherein the patient initiates the treatment with office bleaching and completes it with at-home whitening using a personalized tray. Findings show that combined bleaching resulted in higher initial whitening and better color retention over six months. For instance, a randomized clinical control found that combined whitening had better ΔE maintenance over six months compared to the office or home methods alone. All these investigations are aligned with the recent systematic review by Butera et al., which showed the importance of the combined technique in maintaining long-lasting aesthetic effects by reporting reduced relapse rates in experiments employing it(40).

Despite the combined bleaching's apparent benefit, Aidos et al. came to the conclusion that no whitening method was inherently better(18). These contradictory results are probably caused by variations in the way patients react to bleaching agents and follow at-home instructions. Direct comparisons are further made more difficult by variances in study techniques, such as variations in bleaching agent concentration and application time.

5.3. Relapse and tooth whitening effects durability

Tooth color Relapse is a crucial factor to analyze and is defined as the loss of the tooth whitening effect in the long run. The reviewed papers consistently reported that at-home tooth bleaching has better color retention and stability than in-office tooth whitening in the long term, since the participants were instructed to apply the bleaching products (carbamide peroxide) periodically during an at-home technique(29–31). The systematic review by Butera et al. revealed that in-office tooth whitening treatments showed color regression within six months, while at-home one kept the results for up to a year (12 months)(40). However, Aidos et al. did not support these findings, noting that Carbamide peroxide-based at-home tooth whitening treatment exhibited

similar long-lasting whitening retention to Hydrogen Peroxide-based in-office treatment, meaning both techniques are similarly effective when considering overall longevity(18).

It seems that eating habits, especially the use of staining agents like tobacco and tea, have an impact on relapse rates. Several studies in this analysis indicated that the durability of results was greatly impacted by patient adherence to post-whitening dietary restrictions.

5.4. Tooth sensitivity

As it was stated before, postoperative sensitivity is one of the common side effects of dental bleaching.

Some of the primary reviewed studies demonstrated that the office technique is accompanied by higher tooth sensitivity due to the rapid penetration and higher connection of bleaching agents used (Hydrogen Peroxide 37%), in contrast, at-home whitening exhibited lower tooth sensitivity levels due to lower concentration over an extended period of time which are consistent with the systematic review by Butera et al., reported increased tooth sensitivity in an office and combined whitening groups(28,36,38,40). However, a number of other primary studies, plus the umbrella review by Aidos et al., found no statistically significant differences between any groups, indicating that tooth sensitivity might be a transient effect regardless of the whitening method applied(18,28,33,35,37,39). Interestingly, research has shown that adding desensitizing agents like fluoride and potassium nitrate to bleaching treatments significantly reduces TS without compromising whitening efficacy. This suggests that desensitizers could be incorporated into treatment plans to increase patient comfort without compromising effectiveness.

5.5. Clinical Implications

Considering the collective findings, there is not a single bleaching method that is always better. In-office tooth whitening offers an immediate aesthetic result, whereas the at-home approach provides a gradual effect but maintains the white color in the long run.

It appears that the combination of the two techniques mentioned above, which is named as combined technique, balances these advantages, yielding rapid tooth whitening and a long-lasting effect.

6. CONCLUSION

In this systematic review, we compare and analyze the effectiveness of mainly in-office and at-home tooth whitening methods and also dedicate a small part of our research to examining the differences between the previous two methods and the combined bleaching technique on tooth color improvement based on 12 primary studies and 2 recent systematic reviews.

All available findings confirm that all three whitening approaches can result in significant improvement in tooth color, however, with varying levels of stability, effectiveness, and patient comfort. At-home bleaching, typically using 10%-16 % carbamide peroxide, consistently revealed higher or equal ΔE values (tooth color improvement) in short and particularly over long-term follow-ups when compared solely to in-office tooth whitening. Several studies reported that patients who underwent at-home tooth bleaching accomplished more stable outcomes over time, along with lower replacement rates. This can be explained by the extended time of the bleaching agent in exposure to teeth, which allows deeper and more penetration without causing severe enamel alterations. Additionally, by reviewing the studies and conducting surveys it was revealed that patients prefer at-home methods due to greater convenience, lower cost, and lower reported sensitivity.

On the contrary, in-office bleaching, applying 35%-40% Hydrogen Peroxide, shows more immediate and instantaneous bleaching results, normally after one or two sessions of treatment. Therefore, this property makes an in-office approach appropriate for patients looking for quick aesthetic improvement, such as prior to a special event. However, the research indicates that they might have some degree of color regression in the long term in other words, the initial gain may not be as long-lasting. Above that, several studies found that in-office bleaching was associated with higher levels of tooth sensitivity, although these findings were not universal. This can be attributed to having a higher concentration of bleaching agents and shorter, more intense exposure time.

The combined technique, which is the combination of in-office followed by at-home whitening as a maintenance using a custom tray, was evaluated in some primary studies and demonstrated encouraging results in terms of color preservation and improvement.

This hybrid treatment appears to combine the advantages of both techniques, providing longer-lasting effectiveness with ongoing at-home and faster initial whitening outcomes with in-office application. Even though the outcomes differed depending on adherence and agent econcentration, systematic reviews conducted by Butera et al. demonstrated this method's potential to decrease color relapse and prolong the longevity of teeth whitening.

Post-treatment sensitivity is an important issue to consider when comparing both whitening treatments. Although sensitivity was a common side effect of all approaches, it was typically more severe within office one, though the effects were generally temporary. The most recent systematic reviews by Aidos et al. found no statistically significant differences in the prevalence of sensitivity between approaches.

In conclusion, the evidence suggests that there is no single whitening technique that is superior to the other ones meaning each method has its own unique benefits and drawbacks.

For instance, the. The at-home method offers gradual but more stable whitening results, whereas the in-office method produces immediate but less long-lasting outcomes, and a combination of methods can offer a well-rounded and all-encompassing long-term whitening plan. Therefore, the choice of the bleaching method should be tailored to the patients, considering their chief complaint, condition of enamel, risk of sensitivity in each individual, financial concerns, desired timeframe for the outcome, and patient compliance.

Future research and studies with larger sample sizes, longer follow-up times, and standardized methodology are needed to clarify the relative pros of each approach and improve the bleaching procedure

7. SUSTAINABILITY

This final project uses social, economic, and environmental perspectives to discuss sustainability.

In terms of society, it emphasizes patient-centered, scientifically proven methods of aesthetic dentistry. It puts an emphasis on patient pleasure, long-term satisfaction, and oral health by promoting safe and efficient teeth-whitening procedures. Furthermore, by advocating for at-home bleaching methods, the project reduces reliance on costly in-office treatments while increasing accessibility and financial affordability.

From an economic standpoint, the results favor less expensive whitening techniques that nevertheless meet high safety and efficacy standards. Long-term dental care is now more widely accessible thanks to this strategy, especially for populations who might find it difficult to afford the cost of conventional in-office interventions.

The study helps the environment by encouraging whitening effects that persist and lessen the need for repeated treatments. This reduces clinical waste, energy use, and material consumption, which attenuates the environmental impact of dental offices.

In the end, the project represents a dedication to moral, accountable, and environmentally friendly dental care. Taking into consideration social, economic, and environmental factors ensures that cosmetic dentistry benefits patients while also having a positive impact on society and the environment, which aligns with worldwide efforts for sustainable development.

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