Review Article

Post-Obturation Tooth Discoloration: A Scoping Review of Endodontic Sealer Choices for Aesthetic Success

Raghad A. Alhashimi[1*], George Cosmin Gafita[2], Dinesh Martin[3]

1 College of Dentistry University of Baghdad, Baghdad, Iraq
2 Glendair Dental Practice, Limes Avenue, Alfreton, DE55 7DW, United Kingdom
3 Smiles By Martin, GF2 Emerald Plaza, 11 EMR St Augustine, Trinidad and Tobago
*Corresponding author: raghadalhashimi@codental.uobaghdad.edu.iq

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Abstract: Background: Post obturation discoloration, is an undesirable outcome of endodontic treatment and is particularly burdensome on clinicians managing anterior teeth. Objectives: This review examines the discoloration potential of a plethora of historical and currently used endodontic sealers with the aim of providing clinicians with a guide on material selection, with the most minimal esthetic impact. Method: A PICO framework was employed to identify relevant data, focusing on discoloration associated with different sealers. A literature search was conducted across PubMed, ScienceDirect, and Google Scholar. Relevant studies published between January 2000 and January 2024 were selected based on pre-defined inclusion and exclusion criteria. The findings revealed that most of the included studies were *ex vivo* and *in vitro*, with limited *in vivo* evidence available. Insufficient long-term follow-up was noted and direct comparisons between the various sealer brands was limited. Conclusion: Zinc oxide-based sealers should be avoided by the clinician in areas of high esthetic concern. The strict confinement of the sealers to the canal space, is the best strategy to minimize discoloration. There is a need for improved materials, and more robust long-term studies to generate evidence-based guidelines as it relates to sealers.

Keywords: Endodontic sealer, Tooth discoloration, Endodontic treatment, post-obturation discoloration.

Introduction

Endodontic sealers encompass a variety of materials, used particularly in non-surgical root canal treatments (NSRCT). They facilitate the fixation and bonding of gutta-percha points to the canal walls and seal any voids present due to internal canal wall irregularities**.** More specifically, sealers fill voids, seal apical, accessory, and lateral canals, enhance the bonding between the gutta percha and canal walls effectively sealing and entombing residual microbes and preventing their escape. They are typically applied as a thin paste that serves as both a lubricant and luting agent during obturation with a core material allowing fixation to the canal wall [(1)]. The long-term success of NSRCT is directly dependent on correct sealer choice. Their significant role in clinical dentistry is underscored by the enduring research into their formulations and delivery methods. Different sealers offer unique properties and performance that can profoundly influence treatment outcomes [(2)].

The evolution of sealers, akin to other advancements in dentistry, has resulted in a wide array of products, each with unique chemical compositions, advantages, and marketing strategies targeted at dental professionals. However, a well-recognized issue is the potential for post-obturation discoloration, which is of particular importance in anterior teeth. This discoloration, which presents as a dark grey or brownish hue (Figure 1), can manifest immediately or progressively over time, causing significant aesthetic concerns for patients [(3)]. Historically, full coverage restorations or other indirect and direct restoration methods were employed to mask this discoloration [(4)]. With the contemporary shift towards minimally invasive and

ultra-conservative dentistry, avoiding discoloration at the onset is preferable. Anterior teeth generally undergo non-axial loading, reducing the necessity for crowns, especially important in endodontic treatment cases as a result trauma and those with minimal access preparations [5]. Indirect restorations, regardless of how minimal the preparations, are a more destructive means of achieving an esthetic outcome compared to preventing discoloration. Although various internal and external bleaching agents are available to address discoloration, avoiding additional procedures is desirable from both a financial and ethical perspective [6]. Therefore, it is crucial to consider the discoloration potential of endodontic sealers to ensure optimal aesthetic outcomes in endodontic treatments.

Figure 1: Representative images of post obturation tooth discoloration resulted from endodontic sealers.

The ideal endodontic sealer should effectively prevent microbial ingress and reinfection of the three dimensional root canal system, exhibit antimicrobial activity without cytotoxicity or inflammatory responses, be radiopaque, dimensionally stable, color stable, insoluble in tissue fluids, bacteriostatic, biocompatible, and easily removable to facilitate retreatment [7]. A wide range of sealers are commercially available for dental practitioners (Table 1) with varying level of undesirable tooth discoloration which was rarely investigated. Therefore, this review was designed to address this issue commonly associated with post obturation of endodontically-treated teeth.

Table 1: Classification of endodontic sealers according to their composition

Sealer Type	Properties
Zinc oxide-eugenol	Biocompatible, antibacterial (due to eugenol), high pH prevents bacterial growth. High solubility limits long-term effectiveness.
Calcium hydroxide	Antimicrobial stimulates hard tissue formation, high pH effective against microorganisms. Highly soluble and weak dentin adhesion leads to microleakage.
Glass ionomer	Fluoride release prevents secondary caries, bonds well to dentin, good biocompatibility. Brittleness and moisture sensitivity limit use.
Bioceramics	Bioactive, promotes healing, highly biocompatible, dimensionally stable, intrinsic antibacterial properties (high pH). Expensive and handling challenges.
Fatty acid based	Less toxic than eugenol and widely used as ligands for chelate sealers, in conjunction with zinc oxide
Tricalcium silicate	Favorable sealing ability, low microleakage, promotes healing and tissue regeneration. Lowest relative microleakage among sealers.
Epoxy resin	Excellent adhesion to dentin, low solubility, durable, minimizes microleakage. Can irritate periapical tissues and exhibit polymerization shrinkage.
Methacrylate resin	Strong adhesion, good handling properties. Biocompatibility concerns and difficult to remove during retreatment.

Materials and Methods

Research question

A PICO model was utilized to formulate the research question "What endodontic sealants result in the lowest chance of post obturation staining in teeth as compared to natural tooth?".

Where:

P	Problem	Post obturation endodontic staining anterior teeth
I	Intervention	Various endodontic sealants
C	Comparator	The color of a natural tooth
O	Outcome	Clinical recommendation

Literature Search

A comprehensive search was carried out using PubMed, ScienceDirect, and Google Scholar including the following MeSH (Medical Subject Heading) based terms: 'endodontic sealers' OR 'root canal sealers' AND 'tooth discoloration' OR 'post obturation discoloration' OR 'endodontic staining obturation' OR 'tooth color' AND 'endodontic treatment'. The search process was repeated in which the word "sealer" was substituted with

"ZOE" Sealer, Zinc Oxide Eugenol Sealer, Calcium Hydroxide Sealer, Silicone Sealer, Resin Sealer, Bioceramic Sealer, Fatty Acid Sealer, Glass Ionomer Sealer, GIC Sealer".

Eligibility Criteria

To ensure relevance, our inclusion criteria focused on studies of non-surgical root canal therapy performed on human anterior and posterior teeth. We restricted our search to peer-reviewed journal articles published in English between January 2000 and January 2024. Conversely, studies were excluded if they involved animal teeth or if they used materials like MTA or other similar biomaterials (including Biodentine) when used as regenerative or reparative agents within the tooth, especially those that would not typically enter the root canal chamber..

Data management

After finishing the initial search, the articles were imported to EndNote (version 20). The titles of the articles were first screen by two authors (RAA and GCG) followed by abstract reading to filter the articles according to eligibility criteria. The resulted entries went through full-text reading by the same authors to select the eligible articles for final analysis. A flowchart was prepared based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The key information relevant to the research question were recorded and summarized by a third author (DM).

Results

A total of 161 search results were obtained when the 3 databases were combined. After filtering process, only 22 papers (Figure 2) were included in the final literature review [8-29]. Most of the articles were *ex vivo* studies [10] [14] [15] [20-23] [25] [29] on extracted teeth, mostly posterior molars and premolars (n=8) and *in vitro* experiments [9] [11-13] [16-19] [24] [26-28] (n=12) with only one cross-sectional study [5] (Table 2). The decision to include all teeth was made after a preliminary search revealed little data on anterior teeth only.

Multiple investigations have determined that zinc-oxide eugenol (ZOE) sealers are associated with substantial short- and long-term discoloration, in contrast to resin-based sealers, which demonstrate a reduced likelihood of inducing discoloration [10] [14] [20] [22] [27]. However, other papers noted that discoloration varied among resin sealers, with some brands causing more than ZOE or other resin options [24, 26]. Whereas another paper, resin based, Non-ZOE and ZOE based showed similar discoloration [12]. Severe discoloration was noted with ROTH 811 and Pulpisad with darkening noticeable as early as one week and persisting for up to 3 years [10] [21]. The Resin-based sealers AH26 and AH Plus demonstrated varying magnitudes of discoloration. AH Plus appears to cause less discoloration compared to other resin sealers,

especially AH26 [18] [24]. The methacrylate resin, Epiphany SE performed better than alternatives, with minimal color changes noted over the course of the studies [16] [22].

Bioceramic and calcium silicate-based sealers, overall demonstrated a reduced potential for discoloration, with a measure of variability existing based on brand and study design. For instance, Bioroot RCS and TotalFill BC Sealer showed minimal discoloration at the cervical and incisal thirds of anterior teeth [29]. EndoCem did not cause dentine staining as with ProRoot and Angelus MTA [23]. Bismuth oxide appears to contribute to staining when contaminated with Sodium Hypochlorite, as was evident in the studies using Gray Mineral Trioxide Aggregate (GMTA) and White Mineral Trioxide Aggregate (WMTA) [17]. Calcium hydroxide-based sealers revealed variability, though lower discoloration potentials when compared to ZOE and Bioceramic materials [19]. The data is contraindicated by one paper that demonstrates evolving darkening when compared to AH Plus [13]. Glass ionomer and Silicone-based sealers revealed limited available evidence data was available on these categories from the lack of use and inclusion in several studies. However, silicone based sealers have shown reduced discoloration potential [8].

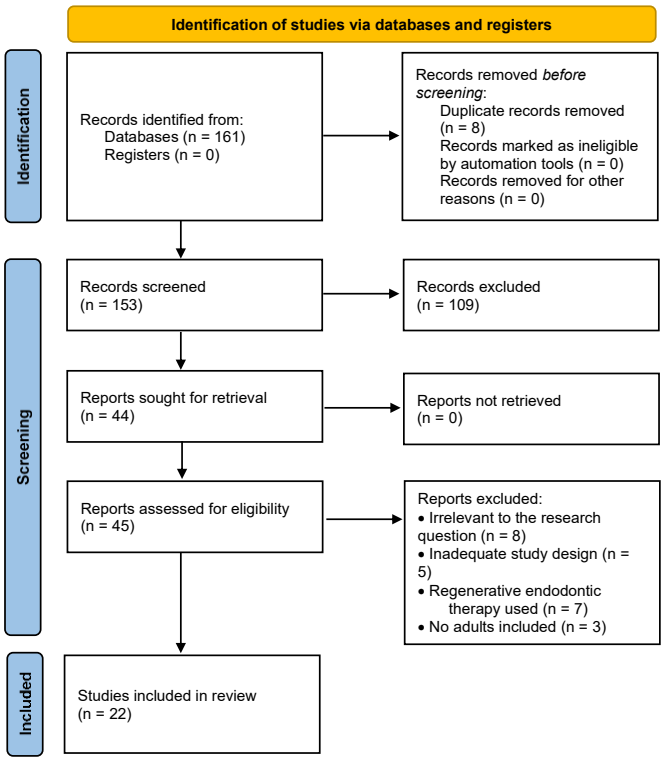

Figure 2: PRISMA flowchart of the study

Research indicates that calcium silicate sealers appear to induce minimal discoloration, but existing studies are limited in number and lack long-term follow-up data [23]. One study found no discernible difference in discoloration between AH26 (epoxy resin-based) and Epiphany (methacrylate resin-based), yet this comparison could have been strengthened by including a wider array of resin-based sealers [18]. The bioceramic sealers consistently demonstrated the greatest discoloration, while resin-based sealers presented the least [9]. Calcium hydroxide sealers generally exhibited favorable staining profiles compared to other materials, with specific positive outcomes reported for Apexit, Resinoseal, and Apexit+ [11] [19]. Furthermore, AH Plus showed less discoloration than the bioceramic sealer Totalfill in a comparative analysis [9]. A separate study on AH26 and Epiphany found no discoloration differences, though specific color parameters like saturation and brightness were not assessed [18]. Notably, when the smear layer was preserved, no significant discoloration was observed over six months (at 0, 1, 3, and 6 months) among MTA Fillapex (salicylate), AH Plus (epoxy resin), and Iroot SP (MTA/bioceramic) [13]. Some studies found no significant difference in discoloration among certain calcium hydroxide sealers. AH Plus does not have any silver salts in its composition as it was made to replace AH26 and ultimately to try and reduce its post-op discoloration potential. It is usually considered the 'gold standard' when compared with other

sealers [13]. It is also marketed as having a lower tendency for discoloration, and lower formaldehyde release. However, one study reported that AH Plus and Endofill caused the most significant discoloration, followed by Apexit and MTA Fillapex [16]. Color changes in most of the studies was assessed by using spectrophotometry technique [8-17] [19-24] [26] [29], while the rest of the studies used digital image analysis [18] [25] [27] [28] and one study included polarized transmission light microscopy [16].

Table 2: Summary of studies included for analysis

Author (year)	Design, settings	Sealers used	Time frame	Assay	Outcomes
Llena, Herrero [29] (2023)	*Ex vivo*, 40 maxillary incisors	AH Plus, Bioroot RCS, TotalFill BC, and gutta-percha only (negative control)	1, 6 months, 2, and 3 years	Spectrophotometry	All groups presented some degree of discoloration. Calcium silicate-based cements (Bioroot RCS and TotalFill BC Sealer) produced acceptable levels of discoloration
Bosenbecker, Barbon [8] (2020)	Cross-sectional study (n=70)	AH Plus, EndoFill, FillCanal, MTA Fillapex	N/A	Spectrophotometry	ZOE and MTA-based sealers caused significant staining.
Alotaibi, Altuwaijri [9] (2019)	*In vitro*, 30 incisors	TotalFill, Apexit+, AH Plus	1 week, 1, 3 months	Spectrophotometry	TotalFill showed the highest discoloration; AH Plus the least.
Ekici, Ekici [10] (2019)	*Ex vivo*, 60 incisors	Pulpispad, AH26, MTA Fillapex, EndoREZ	1 month, 1, 3 years	Spectrophotometry	Pulpispad (ZOE) showed the most discoloration; EndoREZ had the least discoloration at 3 years.
Chahande, Patil [11] (2017)	*In vitro*, 40 premolars	Apexit+, ResinoSeal, Blood Control	10, 17, 24 days	Spectrophotometry	ResinSeal produced greater discoloration than Apexit+.
Zarei, Javidi [12] (2017)	*In vitro*, 60 incisors	AH26, Pulpdent, NZOE	0, 24h, 72h, 1 week, 1 month	Spectrophotometry	AH26 caused discoloration due to silver ions; NZOE showed similar discoloration.
Forghani, Gharechahi [13] (2016)	*In vitro*, 60 premolars	MTA Fillapex, AH Plus, iRoot SP	1, 3, 6 months	Spectrophotometry	AH Plus initially caused more discoloration, but MTA Fillapex exceeded it after 3 months.
Gürel, Kivanç [14] (2016)	*Ex vivo*, 56 incisors	Pulpispad, AH26, MTA Fillapex, EndoRez	4 weeks	Spectrophotometry	All sealers caused discoloration, but Pulpispad caused the most. EndoREZ showed the best bleaching response.
Shokouhinejad, Nekoofar [15] (2016)	*Ex vivo*, 104 single-rooted teeth, smear layer removed	ProRoot MTA, OrthoMTA, Biodentine, ERRM	N/A	Spectrophotometry	Biodentine and ERRM showed less discoloration than OrthoMTA.
Suciu, Ionescu [16] (2016)	*In vitro*, polarized light microscopy	AH Plus, EndoFill, Apexit, MTA Fillapex	1 week, 3 months	Spectrophotometry and polarized transmitted light microscopy	AH Plus and EndoFill caused the highest discoloration.
Kohli, Yamaguchi [17] (2015)	*In vitro*, 80 teeth	EndoSequence, BioDentine, WMTA, GMTA, AH PLUS, TAP	0, 1 week, 1, 2, 6 months	Spectrophotometry	GMTA, WMTA, and TAP caused significant discoloration.
Shahrami, Zaree [18] (2015)	*In vitro*, 40 incisors	AH26, Epiphany	3, 6, 12 months	Digital image analysis	No major difference in discoloration between AH26 and Epiphany.
El Sayed and Etemadi [19] (2013)	*In vitro*, 50 premolars, smear layer removed	AH Plus, Apexit+, Sultan	3, 7, 10, 17 days	Spectrophotometry	Apexit+ had the least discoloration; Sultan (ZOE) caused moderate discoloration.
Ioannidis, Beltes [20] (2013)	*Ex vivo*, 80 third mandibular molars, smear layer present	Roth 811, AH26, GUTTAFLOW, Epiphany SE	1 week, 1, 3, 6 months	Spectrophotometry	Roth 811 caused fast and severe discoloration, even at 1 week; GUTTAFLOW and Epiphany showed minimal discoloration.
Ioannidis, Mistakidis [21] (2013)	*Ex vivo*, 45 third molars	Fillapex, Roth 811	1 week, 1, 3 months	Spectrophotometry	Roth 811 caused severe discoloration; Fillapex

					resulted in minimal alteration.
Ioannidis, Beltes [22] (2013)	*Ex vivo*, 80 mandibular molars, smear layer not removed	Roth 811 (ZOE), AH26 (epoxy resin), GUTTAFLOW (silicone), Epiphany SE (resin)	N/A	Spectrophotometry	Roth 811 caused severe discoloration; GUTTAFLOW and Epiphany SE showed the least risk.
Jang, Kang [23] (2013)	*Ex vivo*, 32 incisors	MTA, ProRoot, Angelus, Endocem	1, 2, 4, 8, 12 weeks	Spectrophotometry	ProRoot and Angelus caused discoloration; Endocem did not affect dentin surface.
Meincke, Prado [24] (2013)	*In vitro*, 40 teeth	AH Plus, EndoFill, Endomethasone N, Sealer 26	6 months	Spectrophotometry	Sealer 26 and Endomethasone N caused the highest discoloration.
Thomson, Athanassiadis [25] (2012)	*Ex vivo* study on various medicaments	AH26, AH Plus	N/A	Digital image analysis	AH26 caused greater darkening compared to other sealers.
Zare Jahromi, Navabi [26] (2011)	*In vitro*, 50 maxillary central incisors	AH26, ZOE	4 months	Spectrophotometry	AH26 caused greyish discoloration; ZOE produced light red-orange discoloration.
Partovi, Al-Havvaz [27] (2006)	*In vitro*, 45 premolars	AH26, EndoFill, Tubliseal, ZOE	3, 6, 9 months	Digital image analysis	ZOE and EndoFill caused the greatest discoloration.
Parsons, Walton [28] (2001)	*In vitro*, 50 single-rooted premolars	AH26, Kerr Pulp Canal Sealer, Roths 801, SealApex	1, 3, 9, 12 months	Digital image analysis	All sealers caused discoloration, with AH26 and Kerr Pulp Canal Sealer showing increased discoloration over time.

ZOE: zinc oxide eugenol, MTA: mineral trioxide aggregate, GMTA; Gray Mineral Trioxide Aggregate, WMTA: White Mineral Trioxide Aggregate

Discussion

Despite the wide array of dental sealers available, there's a notable lack of studies assessing their potential to discolor teeth. To fully grasp the existing data, it's helpful to review the historical composition of these materials. Zinc oxide-based sealers, introduced in 1973, include products like Tubli Seal and Roth 811. When mixed, zinc oxide (ZnO) and eugenol in these sealers create an amorphous gel with a rigid matrix. Notably, some formulations contain silver, which contributes to tooth darkening [30]. However, ZOE sealers have been widely successful, primarily due to their antimicrobial activity. To address concerns about eugenol's cytotoxicity, fatty acid-based sealers like Nogenol were later developed [31]. Research suggests that eugenol oxidation and the presence of silver are the main culprits behind discoloration [26] [28]. Specifically, eugenol in ZOE sealers bonds with ZnO and oxidizes, progressively darkening the tooth and contributing to higher discoloration rates observed with Endofill and other ZOE-based sealers.

Calcium hydroxide-based (salicylate-based) sealers are highly alkaline and antimicrobial, making them otherwise excellent. Their water solubility, however, necessitates their incorporation into a matrix. Common examples are SealApex, Apexit, and MTA FillApex. Although MTA FillApex contains 15% MTA powder, it is mainly resin and is mistakenly categorized as an "MTA sealer"; it should remain classified as a calcium hydroxide-based sealer [32]. Glass ionomer sealers, created by mixing silicate glass powder with polyacrylic acid, are challenging to remove and not widely adopted. Products like KT-308 from GC and Ketac Endo exist, but it is notable that no relevant studies were found for them, despite historical evidence of their good apical sealing.

Resin sealers can be classified as either epoxy products, or methacrylate products. The epoxy products (AH26, and AH Plus) were invented in 1938. AH26 releases formaldehyde and subsequently was replaced with AH Plus for safety reasons. Multiple studies have concluded about the discoloration potential of these sealers, especially AH26. A spectrophotometric study concluded that AH26 produced more discoloration that AH Plus and a ZOE sealer [24]. The Methacrylate Products include EndoREZ (2nd

generation), RealSeal, Resilon/Ephiphany (3rd generation), Super Bond RC Seal, Hybrid Root Seal (4th generation). They first appeared in the 1970s, and continue to be in widespread use [33]. Authors did not retrieve enough studies about the Silicone based sealers such as GuttaFlow, GuttaFlow2 and RoekoSeal which limited stating concrete conclusions in this systematic review.

Tricalcium silicate sealers, also known as bioceramic sealers, emerged in 1993, offering excellent physical and biological characteristics. Popular products in this category are ProRoot MTA, MTA, MTA FillApex, Endo CPM, and Biodentine. However, labeling them solely as "bioceramic sealers" oversimplifies their classification, as numerous dental materials fit the "bioceramic" description. A significant point to remember is that contact with substances like sodium hypochlorite can lead to tooth color changes.

Many calcium silicate cements have a high potential for staining teeth, as observed in studies using bovine teeth. Because of this, you should avoid using them in anterior (front) teeth [34]. Interestingly, replacing bismuth oxide with zirconium oxide powder in these cements can reduce the risk of discoloration. However, some sealers like GMTA, WMTA Angelus, Gray and White Proroot MTA, and Ortho MTA are still highly likely to cause discoloration after a root canal procedure [34]. Most studies on this topic used bovine teeth and fall outside the scope of this review. Even so, one review, primarily on bovine teeth, concluded that more research is needed to fully assess discoloration, as the findings were inconclusive [34]. A critical concern is how these materials react with sodium hypochlorite, a common and highly effective irrigant used in endodontic treatment. Materials containing bismuth oxide can cause discoloration when they come into contact with sodium hypochlorite. This is a particular concern for MTA Fillapex and other sealers that contain bismuth oxide [35]. However, internal bleaching has proven effective in treating discoloration caused by MTA Fillapex and AH-26 sealers [14].

Color Analysis

During this literature review, several methods of analysing colour differences were identified. Spectrophotometers, and Photoshop image analysis were the most common. Spectrophotometers have been introduced in dentistry for quantitative tooth colour measurements [36] [37. Instrumental measurements, including dental colorimeters and spectrophotometers, often incorporate the Commission International de I'Eclairage's (CIE) L*a*b* system. The total colour difference between two objects is expressed numerically, by their Euclidean distance, in ΔE values [38]. While a spectrophotometer is more reliable, it is not readily available to all assessors. A SLR camera as a colour measuring device may be considered suitable when used with CS5.1 (Adobe Photoshop) [39]. Because of the inter-variability of the 2 methods used between studies, the results should be interpreted with caution.

General Trends

The varying conclusions across papers on discoloration likely stem from their randomized and often inaproperiate study designs. We could not find any studies that met our criteria for glass ionomer sealers. These sealers are not currently used extensively in dental practice worldwide, perhaps due to the difficulty of their removal, preventing us from offering a definitive conclusion on their performance. This review clearly shows that the risk of discoloration differs considerably between various materials and brands.

Research on dental sealer discoloration lacks crucial elements like randomized or blinded trials that directly compare widely used sealers. The studies also vary significantly in their observation periods, sometimes spanning mere days, with only one study extending to a three-year follow-up [10]. To draw meaningful comparisons, standardized evaluation methods are clearly needed. Several papers attempted to assess staining by applying material solely to the tooth's coronal (crown) aspect, even though it's generally accepted that this practice should be avoided. Additionally, some clinicians removed the smear layer before material application, while others did not. While this difference might influence how the material penetrates and bonds, its effect on discoloration remains unclear and needs future research. Finally, very few newer sealers have been evaluated, meaning most available data is primarily historical.

Concluding remarks and recommendations

When choosing a sealer for anterior teeth, preventing post-obturation discoloration is a major concern. Our review highlights a significant issue in current research: studies often deliberately contaminate the crown, which is counterproductive. Future lab studies should be more precise, focusing only on the root canal, taking immediate measurements, and simulating oral conditions with aqueous storage. We found that significant discoloration occurs immediately after obturation, especially if the smear layer is removed—a step that was never justified in the studies. While removing this layer seems to worsen discoloration, more research is needed to definitively confirm this effect and guide clinical practice.

The current empirical data is demonstrably insufficient. Methodological compromises, including heterogeneous measurement standards and, critically, a pervasive absence of long-term follow-up or comprehensive sampling of sealer typologies and brands, characterize the majority of extant studies. The exclusive reliance on *ex vivo* models, while ethically justifiable in certain contexts, renders the generalizability of findings questionable, particularly given the dearth of in vivo observational or historical cohort investigations. Furthermore, apparent discontinuities and variabilities between sealer brands of ostensibly similar composition underscore the imperative for more exhaustive comparative analyses. Collectively, the existing dataset is largely anecdotal and necessitates more rigorous, longitudinal experimental designs. An additional limitation is the temporal lag in the literature, with a significant proportion of studies employing materials that are no longer standard in contemporary endodontic or general dental practice. These cumulative design deficiencies preclude the derivation of unambiguous conclusions.

- A major issue is the lack of clear reporting on how discoloration is measured and by whom.
- While digital photography and spectrophotometers are commonly used, with the latter offering more quantitative results, we still need more data to compare these two methods. In addition, relying on visual examination, even by a trained observer, is not advised
- Many studies fail to report immediate post-obturation measurements, which are crucial for establishing a baseline for comparison.
- Data on actual discoloration within the root canal is limited. Instead, many studies deliberately contaminate the tooth surface or crown, which seems counterproductive given that avoiding coronal contamination is known to be vital for preventing discoloration.
- Other variables that often go unaddressed or are inconsistent across studies include how teeth are stored during experiments (e.g., in water or other conditions)
- Variety of control groups used, ranging from distilled water to amalgam or sometimes no controls at all.
- Most existing studies rely on extracted teeth, and their follow-up periods vary significantly, limiting how well these findings apply to real-world clinical situations.
- Lack of studies investigating newer dental materials, making it impossible to draw conclusions about their discoloration potential.

Despite these flaws, the reviewed studies do support the following recommendations for dental practitioners:

1) Avoid using Roth 811, a discontinued material.
2) Confine obturation material strictly to the canal space to prevent external discoloration.
3) Exercise caution when using calcium silicate-based and resin sealers, as they can contribute to discoloration.
4) Remove any sealer remnants from the pulp chamber before placing the final restoration.
5) Awareness should be considered for the variability in discoloration even with resin sealers, despite their empirical appearance of being the least likely material to cause discoloration.

Ultimately, understanding the causes of discoloration and implementing preventive strategies are essential for dentists aiming to improve patient satisfaction and treatment outcomes. As research

continues to advance, we can expect to see more innovative materials and techniques that enhance both the effectiveness and aesthetic results of endodontic treatment.

Conflict of interest

The authors have no conflicts of interest to declare.

Author contributions

All authors contribute to literature search, writing the first draft, reviewed the results and approved the final version of the manuscript to be published.

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NA

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تغير لون الأسنان بعد حشوة الجذر: مراجعة شاملة لاختيارات مانع التسرب اللبية لتحقيق النجاح الجمالي

رغد عبدالرزاق الهاشمي, جورج كوزمين جافيتا, دينيش مارتن

المستخلص:

الخلفية: تغير اللون بعد الحشو هو نتيجة غير مرغوب فيها للعلاج اللبي ويشكل عبئًا كبيرًا بشكل خاص على جمالية الأسنان الأمامية. الأهداف: تدرس هذه المراجعة إمكانية تغير اللون لعدد كبير من مانعات التسرب اللبي التاريخية والمستخدمة حاليًا بهدف تزويد الأطباء بدليل حول اختيار المواد بأقل تأثير سلبي على جمالية الاسنان. الطريقة: تم استخدام إطار PICO لتحديد البيانات ذات الصلة، مع التركيز على تغير اللون المرتبط بمانعات التسرب المختلفة. تم إكمال البحث في الأدبيات باستخدام PubMed وScienceDirect و Google Scholar تم النظر في الدراسات ذات الصلة من يناير 2000 إلى يناير 2024 باستخدام معايير الإدراج والاستبعاد. النتائج: كانت غالبية الدراسات خارج الجسم الحي وفي المختبر مع أدلة محدودة في الجسم الحي. لوحظ عدم كفاية المتابعة طويلة الأمد وكانت المقارنات المباشرة بين العلامات التجارية المختلفة لمانعات التسرب محدودة. الاستنتاج: يجب على الطبيب تجنب مانعات التسرب القائمة على أكسيد الزنك في المناطق ذات الاهتمام الجمالي العالي. إن حصر المواد المانعة للتسرب بشكل صارم في حيز القناة هو أفضل استراتيجية لتقليل تغير اللون. وهناك حاجة إلى مواد محسنة ودراسات طويلة الأمد أكثر قوة لوضع إرشادات قائمة على الأدلة فيما يتعلق بالمواد المانعة للتسرب.