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# Prevention and Management of Tooth Discolouration of Endodontic Origin (DEO): A State-of-the-Art Review

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## ABSTRACT

**Background:** Tooth discolouration of endodontic origin (DEO) refers to an undesirable change in tooth colour arising from the pulp space as a result of reactive physiological processes, pathological processes or endodontic procedures and materials. As DEO frequently affects teeth in the aesthetic zone, it may substantially impair self-esteem and oral health-related quality of life, making its prevention and minimally invasive management clinically important.

**Objectives:** This state-of-the-art review summarizes current knowledge on the aetiology, diagnosis, prevention and management of DEO. Emphasis is placed on the colour stability of contemporary endodontic materials, preventive clinical protocols, case selection, bleaching techniques, regulatory aspects of bleaching agents, safety considerations and possible complications. Restorative treatment options are also discussed for situations in which bleaching is ineffective, contraindicated or insufficient to achieve an acceptable aesthetic outcome.

**Method:** Given the broad scope of the review and the anticipated heterogeneity of the available evidence, a narrative review study type was adopted. A targeted literature search was conducted in PubMed from database inception to April 2026 using relevant keywords related to the DEO topic. The search was supplemented by screening the reference lists of identified articles and key reviews.

**Results:** Prevention should focus on preserving pulp vitality whenever possible, selecting materials with a low discolouration potential, performing meticulous endodontic procedures and providing a durable coronal seal. When treatment is required, bleaching should be considered the first-line option whenever clinically appropriate. Restorative intervention should be reserved for cases in which bleaching is contraindicated, unsuccessful or insufficient to achieve an acceptable aesthetic outcome. Selection and use of bleaching agents must comply with applicable local regulatory requirements.

**Conclusion:** By integrating current evidence, clinical experience and regulatory considerations, this review provides a contemporary basis for clinical decision-making and supports the forthcoming position statement of the European Society of Endodontology on prevention and management of DEO.

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## 1 | Introduction

Tooth discolouration of endodontic origin (DEO) denotes an undesirable change in tooth colour arising from within the root canal or pulp chamber. It may result from reactive physiological processes (e.g., pulp-canal obliteration, tertiary dentine formation) or pathological events (e.g., trauma-related haemorrhage, pulp necrosis, intracoronal resorption). In addition, endodontic interventions—such as pulp capping, pulpotomy, revitalization, as well as intracanal dressings and root-canal fillings—can cause visible discolouration particularly when materials lack adequate colour stability or react chemically with surrounding tissues, blood or irrigating solutions (Ahmed and Abbott 2012; Krastl et al. 2013; Kahler and Rossi-Fedele 2016; Bosenbecker et al. 2020).

DEO usually affects only one or a few teeth, and may substantially impair aesthetics, self-esteem and oral health-related quality of life particularly when the aesthetic zone is involved (Bersezio et al. 2017, 2018; Bonafe et al. 2021). Because affected teeth are often structurally sound and functional, conservative management is both clinically and ethically preferable. Unlike the bleaching of an otherwise healthy dentition for purely cosmetic enhancement, the management of DEO addresses a localized pathological or treatment-related alteration in tooth appearance and should therefore be regarded as a medically indicated therapeutic intervention aimed at restoring the original clinical appearance in a minimally invasive manner. Nonetheless, current approaches to the prevention and management of DEO, as well as the selection of materials and techniques, remain highly variable. Contemporary endodontic materials differ considerably in their discolouration potential, and new material formulations continue to enter the market.

Regulations governing bleaching procedures vary worldwide. The European Union (EU) and the United Kingdom (UK) apply similar restrictions, which differ notably from the regulatory frameworks in many other regions. These differences, together with misconceptions regarding the risks and indications of bleaching, have contributed to the underuse of this minimally invasive treatment in favour of prosthetic restorations. In view of the international readership of the *International Endodontic Journal*, this review considers the available evidence on treatment approaches and bleaching agents from a global perspective, while acknowledging that the clinical use of specific products must comply with local regulatory frameworks.

A comprehensive review by Kahler provided an important and detailed overview of the management of discoloured teeth, including vital and non-vital teeth, bleaching strategies, prosthodontic considerations, safety issues and regulatory aspects (Kahler 2022). Since its publication, further information has become available. The present state-of-the-art review builds on this existing knowledge and updates it with more recent evidence and clinical considerations. In contrast to broader reviews on tooth discolouration in general, this article focuses specifically on DEO and does not address discolouration of non-endodontic origin. Likewise, discolouration associated with different pathological tooth resorptions is not addressed, as its management requires fundamentally different therapeutic approaches (Patel et al. 2023).

A targeted literature search was conducted in PubMed from database inception to April 2026. Search terms included combinations of 'tooth discolouration' or 'tooth discoloration' with 'endodontic', 'root canal treatment', 'intracoronal bleaching', 'internal bleaching', 'non-vital bleaching', 'walking bleach', 'vital bleaching', 'external bleaching', 'pulp canal obliteration', 'transient apical breakdown', 'hydraulic calcium silicate cement', 'bioceramic sealer', 'minimally invasive access cavity', 'cervical root resorption' and 'restorative treatment'. Boolean operators ('AND' and 'OR') were used to combine terms as appropriate. The reference lists of relevant articles and key reviews were screened to identify additional publications. Relevant textbook chapters, position statements, regulatory documents and product-composition data were also considered where appropriate. Publications were selected if they addressed the aetiology, diagnosis, prevention or management of DEO. Laboratory studies were included when they provided relevant evidence on material-related discolouration, chemical interactions or bleaching mechanisms.

Given the broad scope of the review and the heterogeneity of the available evidence, the aim was to provide a clinically oriented narrative synthesis rather than to answer a narrowly defined research question. Consequently, no formal systematic-review protocol, risk-of-bias assessment or meta-analysis was undertaken. By integrating current evidence, clinical experience and regulatory considerations, this review provides a contemporary basis for clinical decision-making and supports the forthcoming European Society of Endodontology Position Statement on the prevention and management of DEO.

## 2 | Aetiology, Classification and Diagnosis of DEO

Tooth discolouration originating from the pulp tissue, the root canal system or from interventions used to manage diseases of the pulp is intrinsic in nature. DEO can be classified as physiological, pathological or iatrogenic. Before treatment is initiated, an accurate diagnosis and a discussion of the patient's aesthetic expectations are essential (Kahler 2022). The diagnostic process should include a history of dental trauma, caries, orthodontic treatment, previous endodontic or restorative procedures, and the onset and progression of the colour change. Clinical examination should assess the colour, distribution and severity of the discolouration, ideally supported by standardized clinical photographs from both the labial and palatal/lingual aspects, as discolouration may be more apparent from the oral aspect. Pulp sensibility, where appropriate, percussion response, periodontal probing, mobility and the quality of existing restorations should also be assessed. Periapical radiographs are required to evaluate pulp canal obliteration, root canal fillings, periapical status and possible resorptive defects. Cone-beam computed tomography should be reserved for selected cases in which conventional radiographs are inconclusive and the additional information obtained would influence the diagnosis, patient management or treatment. Careful differential diagnosis distinguishes DEO from discolouration of non-endodontic origin,



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including extrinsic staining, caries, restoration-related discolouration and developmental defects.

## 2.1 | Physiological or Pathological Causes for DEO

### 2.1.1 | Trauma-Related Intrapulpal Haemorrhage (Transient Pink Discolouration)

Teeth that have sustained a traumatic event, often a luxation injury, may sustain an associated intrapulpal haemorrhage. The blood components diffuse into the dentinal tubules and cause initial pinkish discolouration (Figure 1) (Plotino et al. 2008). Pulp necrosis may develop subsequently, but this is not inevitable. Teeth that retain pulp vitality may show only transient discolouration and subsequently return to their normal colour (Andreasen and Kahler 2015). If the pulp survives the trauma and recovers, enzymes can haemolyse the extravasated erythrocytes and the tooth recovers to an improved colour within a few months (Andreasen 1989; Heithersay and Hirsch 1993; Marin et al. 1997).

### 2.1.2 | Trauma-Related Transient Apical Breakdown (Transient Grey/Brown Discolouration)

Transient apical breakdown (TAB) of the root tip may be seen after moderate luxation injuries, especially extrusive or lateral luxations. It is initially associated with widening of the periodontal ligament space apically, ranging up to a pronounced apical radiolucency, an ischemic but not infected pulp and a grey or brown discolouration (Andreasen 1986; Tsukiboshi et al. 2024). This process has been described as being followed by apical resorption with enlargement of the apical foramen and subsequent revascularization of the pulp. The ischaemic tissue may then be replaced by vital tissue, often accompanied by a return to normal pulp sensibility responses, while the transient discolouration usually improves spontaneously within 6–12 months (Tsukiboshi et al. 2024).

### 2.1.3 | Pulp Necrosis (Grey/Brown Discolouration)

Pulp necrosis caused by trauma or caries typically leads to discolouration. Haemolysis of erythrocytes releases iron into the pulp space and dentinal tubules (Marin et al. 1997). Interactions between blood, bacterial by-products and degrading proteins of necrotic pulp tissue can cause grey, black or brown discolourations (Figures 2 and 3) (Watts and Addy 2001; Plotino et al. 2008; Ahmed and Abbott 2012; Setzer 2020). In cases of sterile necrosis, discolouration results from the haemoglobin and associated haematin molecules (Marin et al. 1997). Iron release is less likely without infection, as this process is facilitated by bacterial interactions (Plotino et al. 2008). Moreover, the loss of vascular supply prevents the delivery of enzymes capable of degrading and haemolysing erythrocytes, allowing residual blood components to persist within the dentinal tubules and contribute to discolouration.

### 2.1.4 | Pulp Canal Obliteration (Yellow and Yellow-Brown Discolouration)

Pulp canal obliteration (PCO), also referred to as calcific metamorphosis, may result in yellow to yellow-brown discolouration of the affected tooth (Jacobsen and Kerekes 1977; Robertson et al. 1996; Setzer 2020).



**FIGURE 1** | Discolouration of right central incisor shortly after subluxation. No clinical symptoms and positive sensibility test. No intervention needed but monitoring.

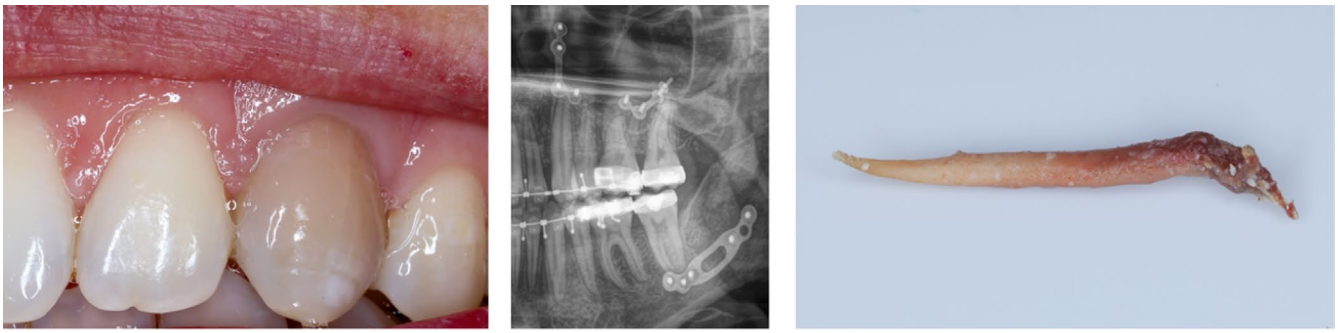


**FIGURE 2** | Grey discolouration of the maxillary left canine due to pulp necrosis following damage to the neurovascular supply during orthognathic surgery. The extirpated pulp tissue shows a necrotic appearance without evidence of vascularisation.



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Luxation injuries constitute the main predisposing factor because they may damage the neurovascular supply of the pulp. PCO represents a successful but dysregulated healing response involving accelerated hard-tissue deposition within the pulp space, including secondary and reparative dentine formation and tubular sclerosis. These structural changes probably contribute to a darker and more yellowish tooth colour (Watts and Addy 2001; Setzer 2020).

The exact mechanism underlying the yellow discolouration associated with PCO remains unclear. The prevailing explanation attributes the yellow appearance to reduced translucency caused by an increased thickness of dental hard tissue beneath the enamel as mineralised tissue fills the pulp space (Patterson and Mitchell 1965; Bastos and Cortes 2018). However, this explanation may not fully account for the clinical observations. Following luxation injuries, obliteration may progress to complete PCO within the first 5 years after trauma, whereas visible crown discolouration appears to be uncommon during this early period despite radiographic evidence of PCO (Andreasen et al. 1987). This indicates that radiographic obliteration and clinically visible yellow discolouration do not necessarily develop in parallel (Figure 3).

Discolouration typically develops gradually after the onset of PCO and may intensify over time (Figure 4). In most instances of pulp canal obliteration, the affected teeth are considered vital despite a lack of response to pulp sensibility tests. However, if apical periodontitis develops, root canal treatment is indicated (Robertson et al. 1996; McCabe and Dummer 2012).

## 2.2 | Iatrogenic Causes for DEO

### 2.2.1 | Orthodontic Transient Apical Breakdown Transient (Grey Discolouration)

High orthodontic forces may cause transient tooth discolouration resembling that observed after luxation injuries (Baik et al. 2017). In one study, colour resolved in 33% of cases after a median follow-up of 23 months, while individual case reports have documented resolution within 6 months (Gonzalez et al. 2014; Baik et al. 2017; Zhu 2023).

### 2.2.2 | Pulp Tissue Remnants After Endodontic Treatment (Mostly Grey Discolouration)

Pulp extirpation may leave blood products and tissue remnants within the pulp space (Plotino et al. 2008). Furthermore, if the pulp is sedated with a medicament instead of completely debriding the canal, the presence of the retained lacerated pulp vessels and the constituents of the medicament could cause discolouration of the crown (Figure 5).

### 2.2.3 | Root Canal Irrigants and Root Canal Medication (Mostly Grey/Brown Discolouration)

The root canal irrigants most frequently used to reduce the microbial load include 1%–5.25% sodium hypochlorite (NaOCl) and 0.2%–2% chlorhexidine digluconate (CHX) which are not in themselves associated with tooth discolouration (Dettwiler

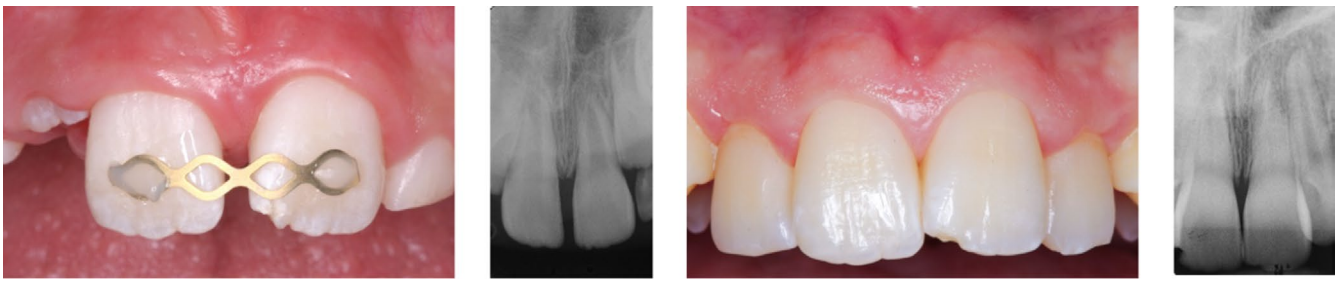


**FIGURE 3** | Pulp canal obliteration 4.5 years after subluxation of both maxillary central incisors, without visible crown discolouration at this stage.



**FIGURE 4** | Yellow discolouration of teeth 12 and 11 associated with pulp canal obliteration and rather brown discolouration of tooth 21 associated with pulp necrosis in a 27-year-old patient 19 years after luxation injuries.



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**FIGURE 5** | Discolouration of a tooth associated with insufficient endodontic access cavity preparation and residual tissue remnants in the region of the pulp horns.

et al. 2016). For smear layer removal, 10%–17% ethylene diamine tetracetic acid (EDTA) or 10%–50% citric acid have been recommended (Zehnder et al. 2005). Continuous chelation can also be achieved by adding etidronic acid to the sodium hypochlorite solution (Deari et al. 2019). None of these chelating agents cause tooth discolouration when in contact with dentine. However, irrigants used in sequence can interact and form coloured precipitates. Interaction of CHX with NaOCl leads to the formation of an orange-brown precipitate. The precipitate is formed by the reaction of the chloride in NaOCl with the guanine group in CHX (Basrani et al. 2007). The formation of para-chloroaniline is controversial (Nocca et al. 2017), and it is likely that it is formed but not released in solution (Orhan et al. 2016); however, it contaminates the dentine and adheres to the canal walls causing tooth discolouration (Souza et al. 2013).

The main intracanal medicament used in the treatment of permanent teeth is calcium hydroxide. Calcium hydroxide itself has not been associated with colour changes; however, the inclusion of certain radiopacifiers, particularly bismuth-based compounds, in calcium hydroxide pastes may result in staining (Lenherr et al. 2012).

Antibiotic-corticosteroid pastes recommended after severe luxation injuries, especially avulsion (Krastl et al. 2021), differ considerably in their discolouration potential. There is strong evidence that Ledermix, which contains demethylchlortetracycline, may cause significant tooth discolouration (Day et al. 2019); whereas alternative products that use clindamycin instead of the tetracycline component appear to be more colour stable (Dettwiler et al. 2016).

Antibiotic pastes, which have historically been widely used in revitalization procedures as alternative intracanal dressings because of their pronounced antimicrobial activity, are also associated with severe tooth discolouration, particularly when used as triple antibiotic pastes containing minocycline (Galler et al. 2022). However, replacing minocycline with other antibiotics, such as cefuroxim or clindamycin, does not eliminate the risk completely and even double antibiotic pastes without minocycline may still cause pronounced discolouration (Lenherr et al. 2012; Dettwiler et al. 2016; Badi et al. 2026).

### 2.2.4 | Root Canal Filling Materials (Mostly Grey/Brown Discolouration)

Root canal filling materials include solid cones, sealers and materials of higher viscosity used to block the communication between the root canal and the periodontal ligament space in immature teeth with open apices. The discolouration potential of root canal filling materials has been investigated in numerous in vitro studies during the past four decades using a wide range of materials and methodological approaches (Ahmed and Abbott 2012; Krastl et al. 2013). In brief, root canal filling materials may cause varying degrees of tooth discolouration, with the extent of staining depending on the specific material, the time elapsed and the location of residual material within the pulp chamber (Figures 6 and 7).



**FIGURE 6** | Exposed roots during crown lengthening showing the difference in colour between root canal filled teeth 12 and 11 with an unknown material and vital teeth.

Regardless of the chemistry, pronounced discolouration has particularly been associated with materials containing bismuth-based components, especially bismuth oxide included as a radiopacifier (Figure 7). A review of the literature on root canal sealers identified the chemistries of the classic sealers used in root canal therapy (Prashanth 2017), and bismuth-based products are shown to be present in most of the formulations. Table 1 provides an overview of different chemistries of sealers associated with discoloration and their composition.

The newer sealers, particularly the hydraulic calcium silicate sealers, include alternative inert radiopacifies such as zirconium oxide and exhibit satisfactory colour stability (Lenherr et al. 2012; Thomson et al. 2012; Camilleri et al. 2022). A market survey published in 2023 demonstrated considerable variation in the chemistry of sealers marketed as bioceramic or hydraulic calcium silicate–based materials. A major limitation was the lack of detailed information provided by manufacturers regarding both composition and the quantity of individual components (Cardinali and Camilleri 2023). Therefore, generalization across this material group should be made with caution. The bismuth oxide and its associated links



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**FIGURE 7** | Severe discolouration of the right maxillary central incisor associated with an inadequate root canal filling with an unknown, presumably bismuth-containing, root filling material which extends above the cement-enamel junction.

**TABLE 1** | Composition of root filling materials associated with discolouration.

| Material name | Active component | Radiopacifier | Additives |
|---|---|---|---|
| Grossman formulation | Zinc oxide | Bismuth subcarbonate | Hydrogenated rosin, hydrous alumina, sodium borate, eugenol |
| Endomethasone | Zinc oxide | Bismuth subnitrate | Dexamethasone, hydrocortisone, thymol iodide, paraformaldehyde |
| N2 | Zinc oxide | Bismuth subcarbonate, bismuth subnitrate, titanium dioxide | Lead tetroxide, paraformaldehyde, phenyl mercuric borate, eugenol, cleum rosea, cleaum lavandular |
| AH 26 | Methanamine, epoxy resin | Bismuth oxide, silver/ titanium dioxide | Calcium hydroxide |
| Riebler | Zinc oxide | Barium sulphate | Formaldehyde, sulfuric acid, ammonia, glycerine, phenol |
| Pulp canal sealer | Zinc oxide | Barium sulphate, bismuth subcarbonate | Eugenol, staybelite resin, sodium borate |
| Endofill | Thymol iodide | | Eugenol, polyoxymethylene, hydrocortisone acetate, dexamethasone acetate |
| Tubliseal | Zinc oxide | Barium sulphate | Eugenol, corn starch, mineral oil, thymol iodide |
| Cavizol | Zinc oxide | | Zinc sulfate, glycerol acetate, polyvinyl acetate, calcium sulphate |

*Note:* The data has been collated from Prashanth (2017).

to tooth discolouration are the main shortcoming of the use of hydraulic cements for various endodontic applications. To this end, the updated classification of hydraulic cement used in dentistry classifies these materials as bismuth-containing or free of bismuth (Camilleri 2026).

In general, attributing discolouration to a specific sealer class would be an oversimplification, as the staining potential appears to be more closely related to individual additives and radiopacifying chemistries than to the basic sealer matrix itself. For example, among resin-based sealers (Komabayashi et al. 2020), AH 26 was associated with visible discolouration, whereas the successor product AH Plus seemed to exhibit satisfactory colour stability, an effect that has been attributed primarily to the replacement of bismuth oxide with zirconium oxide as the radiopacifier (Lenherr et al. 2012; Thomson et al. 2012; Kohli et al. 2015). The bismuth oxide in AH 26 interacted with the formaldehyde released by the epoxy resin leading to a dark precipitate (Marciano et al. 2015).

#### 2.2.5 | Cements Used in Vital Pulp Treatment/ Revitalization (Mostly Grey Discolouration)

Vital pulp treatment (direct pulp capping or pulpotomy) has historically used calcium hydroxide. However, current international



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guidelines primarily recommend hydraulic calcium silicate–based cements (HCSCs) as capping materials for vital pulp treatment of traumatically exposed pulps (Krastl et al. 2021) and, in particular, after carious pulp exposure (Duncan et al. 2019; AAE 2021). The discolouration potential of these materials has been investigated extensively in in vitro studies. A review demonstrated considerable differences in discolouration potential within this material group (Mozynska et al. 2017). Bismuth oxide is present in a number of HCSCs (such as Pro Root MTA) and has been linked to severe tooth discolouration in all formulations. Interactions of bismuth oxide with tooth structure (Marciano et al. 2014), blood (Guimaraes et al. 2015) and sodium hypochlorite (Camilleri 2014) showed a distinct change in colour in the bismuth oxide from yellow to dark brown/black with an associated change in colour of the material and the adjacent tooth structure. The bismuth oxide changes phase, and the dark colour is caused by the formation of δ-bismuth oxide (Camilleri et al. 2026).

All HCSCs regardless of the presence of bismuth oxide seem to exhibit clinically perceptible colour changes in contact with sodium hypochlorite and chlorhexidine. Chlorhexidine appears to cause more pronounced discolouration than sodium hypochlorite, and the extent of staining also varies between individual products. (Keskin et al. 2015; Usta and Keskin 2024).

Although clinical data are scarce, and a comprehensive review (Fasoulas et al. 2023) identified only 4 clinical studies that reported tooth discolouration associated with vital pulp therapy (Taha and Khazali 2017; Awawdeh et al. 2018; Parinyaprom et al. 2018; Uesrichai et al. 2019), the available comparative evidence suggests that MTA has a substantially higher discolouration potential than a fast-setting HCSC with an alternative radiopacifier. These clinical findings are in line with the in vitro evidence.

As the same class of HCSCs is also recommended as barrier materials in revitalization procedures, the implications for tooth discolouration are similar. However, in these cases, the discolouration is more likely to affect the cervical region of the tooth.

Irrespective of the intrinsic discolouration potential of the HCSCs used, it should be acknowledged that in both vital pulp treatment and revitalization procedures the material is placed in direct contact with vascularized tissue or blood. The presence of blood alone may therefore influence subsequent tooth colour (Lenherr et al. 2012; Shokouhinejad et al. 2016).

## 3 | Prevention of DEO

Although treatment strategies for discoloured teeth are available, they are often challenging, may be partially invasive and do not necessarily guarantee long-term aesthetic success. Preventing DEO wherever possible is therefore an important clinical goal.

Throughout endodontic treatment, clinicians can reduce the risk of discolouration by selecting conservative treatment strategies and colour-stable materials, cleaning dentine meticulously and providing a durable coronal seal (Ahmed and Abbott 2012; Ahmed et al. 2022).

Maintaining pulp vitality whenever possible reduces the need for intracanal procedures and, consequently, the risk of coronal staining. Although vital pulp treatment can also result in some degree of discolouration, this is often material-dependent and may be easier to manage than the more severe discolouration that can result from unsatisfactory root canal treatment.

For vital pulp treatment, clinicians should avoid bismuth-containing biomaterials and select alternatives with more colour-stable radiopacifiers. Similarly, in revitalization procedures, calcium hydroxide should replace discolouring antibiotic pastes as the intracanal medicament whenever clinically appropriate, and HCSCs with low discolouration potential should be selected for the coronal barrier (Kahler and Rossi-Fedele 2016; Kahler 2022).

In teeth with pulp necrosis, prevention of DEO depends largely on meticulous removal of all pulp tissue remnants, thorough cleaning of the root canal and access cavity, and strict control of the location of intracanal materials.

The access cavity should provide sufficient access to permit complete removal of necrotic tissue, particularly from the pulp horns, where retained remnants may contribute to subsequent discolouration (Plotino et al. 2008; Ahmed and Abbott 2012; Ahmed et al. 2022; Kahler 2022). This consideration may be particularly relevant to ultraconservative access cavities. In an ex vivo study, these cavities were associated with significantly more root-filling material remaining in the pulp chamber after cleaning than traditional access cavities, providing a plausible pathway for subsequent staining (Silva et al. 2020). However, minimally invasive access preparation does not necessarily compromise colour stability: when the pulp chamber was meticulously cleaned under an operating microscope using alcohol and ultrasonic tips, no difference in colour stability was observed between minimally invasive and conventional access cavities (Silva-Sousa et al. 2024). Thus, the potential discolouration risk appears to depend less on access-cavity design alone than on whether the design permits adequate visualization, removal of tissue and filling-material remnants, and thorough cleaning of the pulp chamber.

In addition to adequate access and meticulous cleaning, prevention requires careful selection and placement of intracanal materials. Medicaments with known staining potential should be avoided whenever suitable alternatives are available. If their use is necessary, they should be confined to the radicular portion of the canal system, below the gingival level, and any remnants should be thoroughly removed from the pulp chamber. Sealing the coronal dentinal tubules with a bonding agent before placement of the medicament may be an additional strategy to reduce the risk of discolouration (Shokouhinejad et al. 2018, 2019).

To reduce the likelihood of chemical interactions between different irrigants, or between irrigants and other endodontic materials, that may result in discolouration, intermediate rinsing with saline is advisable (Krishnamurthy and Sudhakaran 2010). Irrigant activation may further enhance the cleaning effect and facilitate removal of any precipitates



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formed (Guneser et al. 2017). Root canal filling materials should not be left in the pulp chamber. Particularly in aesthetically relevant teeth, root canal filling material should be removed below the CEJ or, where appropriate, below the gingival level in order to reduce the risk of visible coronal staining (Kahler 2022).

Another essential preventive measure is careful cleaning of the access cavity after root canal filling. Remains of necrotic tissue, medicament, sealer, gutta-percha or restorative material within the pulp chamber can all contribute to later discolouration. Clinicians should therefore clean the pulp chamber thoroughly, ideally under magnification and adequate illumination, while preserving sound tooth structure. Epoxy resin-based sealers are hydrophobic and poorly soluble in aqueous cleaning solutions; consequently, cleaning with water/air spray alone is largely ineffective, whereas scrubbing the access cavity with an ethanol-saturated microbrush reduced the sealer-covered area by 93% in vitro (Bodere et al. 2022). Furthermore, clinical evidence indicates that air abrasion of the access cavity reduces the occurrence of discolouration (Zizka et al. 2021). Finally, a well-sealed adhesive composite restoration is crucial, as coronal leakage may permit recontamination of the root canal system and also increase the risk of future discolouration.

## 4 | Clinical Management of DEO in Root-Filled and Revitalized Teeth

Intracoronal bleaching also referred to as internal bleaching, is generally recommended as the method of choice for managing discolouration in adequately root-filled teeth and can be performed either in-office using high-concentration bleaching agents or, more commonly, by employing the walking bleach technique, which is considered the standard approach (Attin et al. 2003; Plotino et al. 2008; Ahmed et al. 2022; Kahler 2022). In this procedure, a hydrogen peroxide–releasing agent is placed within the coronal pulp chamber, sealed and left in place for several days, allowing it to diffuse into the discoloured dentine. The reactive molecules break down the long-chained, dark-coloured chromophore compounds and cleave their double bonds into smaller, less pigmented and more diffusible molecules (Dahl and Pallesen 2003).

A simultaneous external tray bleaching of the discoloured tooth during the intracoronal procedure (inside–outside *closed* technique) may accelerate the bleaching effect but adds cost and complexity and is therefore not required in most cases. The inside–outside open technique, in which the access cavity is left open to allow the patient to replenish the bleaching agent, has been described as an alternative approach and allows motivated patients to titrate the colour improvement (Carrillo et al. 1998; Sulieman 2008; Leith et al. 2009). From an endodontic perspective, however, this approach is not ideal because, during home bleaching, the root canal filling is protected only by the cervical barrier, creating a risk of bacterial contamination of the dentine and root canal system (Ahmed et al. 2022; Kahler 2022). In settings where regulatory restrictions limit the use of bleaching agents to lower concentrations with reduced efficacy, however, this approach may be necessary to facilitate effective bleaching.

### 4.1 | Pulp Chamber Preparation for Intracoronal Bleaching

The access cavity should be carefully prepared under rubber dam isolation, with complete removal of any remaining restorative material, root filling material or necrotic pulp tissue, particularly from the pulp horns. Incomplete cleaning—especially on the labial wall of the pulp chamber—can markedly reduce bleaching efficacy by preventing direct contact between the bleaching agent and the discoloured dentine (Attin et al. 2003; Ahmed and Abbott 2012). Magnification and optimal illumination facilitate precise cleaning while helping to preserve sound tooth structure (Kahler 2022). The fluorescence-aided identification technique (FIT) provides a non-invasive adjunct for distinguishing composite remnants from natural tooth tissue during cleaning of the access cavity (Magni et al. 2022). Discoloured dentine should not be routinely removed, because bleaching aims to improve tooth colour while preserving sound tooth structure (Attin et al. 2003).

### 4.2 | Cervical Sealing

After cleaning the pulp chamber, the root canal filling should be reduced to provide space for a protective cervical seal approximately 2 mm thick (Figure 8). This barrier prevents apical leakage of the bleaching agent along the root filling and protects the periradicular tissues (Rotstein, Zyskind, et al. 1992; de Oliveira et al. 2003). Traditionally, the cemento-enamel junction (CEJ) has served as the reference for positioning the seal, and the coronal surface of the barrier should follow the CEJ contour as closely as clinically feasible. However, in cases of gingival recession or root exposure, the CEJ no longer coincides with the visible crown margin. In such cases, the barrier should follow the gingival contour, with its most coronal aspect positioned

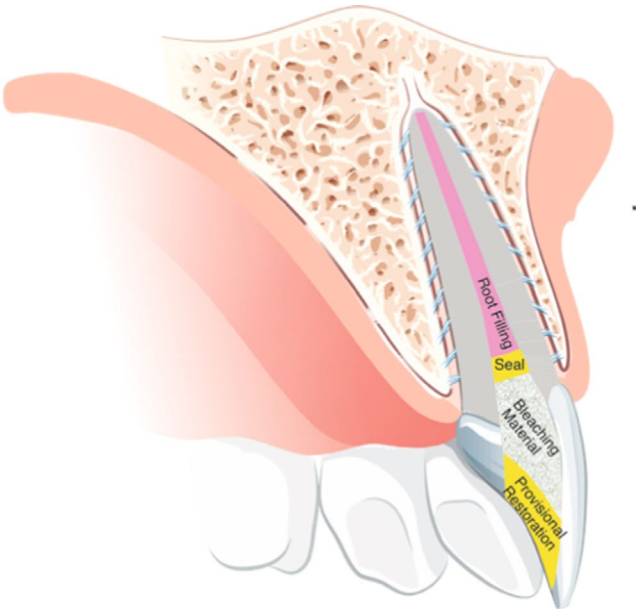



**FIGURE 8** | Schematic illustration of the recommended intracoronal bleaching cavity and cervical barrier. The cervical barrier should follow the CEJ contour as closely as clinically feasible and end just below the level of the labial gingival margin to allow effective bleaching.



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slightly below the labial gingival margin. A barrier positioned too coronally may leave unbleached dentine in the cervical area and result in an uneven shade. Conversely, positioning the barrier too apically may bring the bleaching agent into close contact with the periodontal tissues and increase the risk of external cervical resorption. Ideally, the barrier should follow the epithelial attachment to provide both aesthetic and biological protection (Ahmed et al. 2022; Kahler 2022). Various materials have been proposed for the cervical seal, including Cavit, IRM, glass-ionomer or zinc phosphate cements, hydraulic calcium-silicate cements (Plotino et al. 2008; Ahmed et al. 2022). Although their sealing performance varies, all can provide a sufficient short-term intracoronal barrier when properly placed. Self-adhesive flowable composites may represent another practical alternative (Traviglia et al. 2019).

In cases where the walking bleach technique is applied to teeth that have undergone successful revitalization, the pre-existing HCSC coronal plug—originally placed as part of the regenerative procedure—should be partially reduced to permit adequate bleaching of the entire crown. Depending on the situation, an additional cervical seal may be required. The final coronal barrier should ideally be positioned slightly below the gingival margin, while maintaining at least 2 mm of material thickness (from intracanal barrier and/or cervical seal) to protect the underlying vital or newly formed tissue.

Before placing the bleaching agent, ultrasonic tips, ethanol-soaked foam pellets or microbrushes or air abrasion may provide a final cleaning step. Dentine etching remains controversial. Most earlier studies found no clear improvement in bleaching efficacy when the smear layer was removed (Casey et al. 1989; Horn et al. 1998), whereas more recent data suggest that pre-treatment with phosphoric acid may enhance the bleaching effect (Deny et al. 2026). However, acid etching may also increase dentine permeability and hydrogen peroxide diffusion (Camps et al. 2010), potentially affecting the periodontium adversely (Fuss et al. 1989). Therefore, the available evidence does not support routine smear-layer removal (Attin et al. 2003; Ahmed et al. 2022).

### 4.3 | Bleaching Agents and Regulatory Considerations in the EU and UK

Reactive oxygen-releasing agents used for intracoronal bleaching include hydrogen peroxide, carbamide peroxide, sodium perborate and sodium percarbonate. These agents are available as either granules or gels. Selection should balance efficacy and safety while accounting for the regulatory framework applicable in the jurisdiction where treatment takes place. From a practical perspective, granules in aqueous suspension are often easier to place within the access cavity than gel-type materials and provide a more stable base for adaptation and sealing of the temporary restoration (Mayer et al. 2024).

The $H_2O_2$ equivalent allows comparison of the theoretical oxidation potential of different oxygen-releasing agents. However, it does not fully predict clinical performance because the bleaching effect also depends on pH, solubility, release kinetics and interactions with dental hard tissues (Mayer et al. 2024).

Sodium perborate granules in aqueous suspension (approximately 21% $H_2O_2$ equivalent) (Mayer et al. 2024) have historically been the most extensively investigated and clinically established agent for this indication and have shown a favourable safety profile compared with high-concentration hydrogen peroxide-based materials. However, the EU classifies perboric acid and its salts, including sodium perborate, as Category 1B reproductive toxicants. Consequently, the REACH Regulation 1907/2006 has prohibited their use in cosmetics in the EU since May 2023 (European_Parliament_and_Council 2006). Although this restriction does not specifically target dental use, it effectively precludes the use of sodium perborate for intracoronal bleaching within the EU. However, this is not a worldwide ban, as the regulatory status of sodium perborate differs across jurisdictions.

As alternative bleaching agents, both granular materials in aqueous suspension and gel-type preparations may be used for internal bleaching with the walking bleach technique. Granular bleaching agents include sodium percarbonate (approximately 27% $H_2O_2$ equivalent) and carbamide peroxide (approximately 35% $H_2O_2$ equivalent) (Mayer et al. 2024). Compared with sodium perborate, substantially less evidence is available for these materials. In vitro and ex vivo studies have demonstrated clinically relevant bleaching effects with sodium percarbonate, although its efficacy appears to be lower than that of sodium perborate under comparable conditions (Mayer et al. 2024). Gel-type agents contain either carbamide peroxide or hydrogen peroxide and are available in different concentrations up to 35% hydrogen peroxiden (Lim et al. 2004; Frank et al. 2022). In an aqueous environment, carbamide peroxide dissociates into hydrogen peroxide and urea. Consequently, its hydrogen peroxide equivalent corresponds to approximately one third of its nominal concentration (Plotino et al. 2008; Mayer et al. 2024).

The EU and UK impose additional restrictions on the maximum hydrogen peroxide concentration in bleaching products. Under Council Directive 2011/84/EU concerning cosmetic products, freely available oral products are limited to $\leq$0.1% hydrogen peroxide present or released, a concentration that is clinically ineffective for the management of DEO. Bleaching products containing more than 0.1% and up to 6% hydrogen peroxide may only be sold to dental practitioners, with first use by a dental practitioner or under direct supervision (European_Union_Council 2011).

Thus, the maximum permitted concentration for cosmetic tooth whitening in the EU is 6% hydrogen peroxide. Commercially available 16% carbamide peroxide gels for cosmetic tooth whitening are intended to remain within this limit. For individuals under 18 years of age, the Directive does not permit the use of products containing or releasing more than 0.1% hydrogen peroxide for cosmetic tooth whitening, even by dental professionals (European_Union_Council 2011). As a consequence, cosmetic bleaching of teeth affected by DEO would effectively not be possible in children at the permitted concentration of 0.1% hydrogen peroxide.

Because DEO is not regarded as a cosmetic indication but as a medically indicated therapeutic intervention, and because Council Directive 2011/84/EU addresses cosmetic products



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outside a medical indication, the legal situation is not entirely straightforward and has given rise to differing interpretations across the EU. In addition, in some countries of the EU, bleaching gels containing up to 35% hydrogen peroxide are marketed for medical tooth whitening as part of an internal bleaching approach.

In the UK, the General Dental Council has stated that concentrations exceeding 6% of hydrogen peroxide present or released in oral products, including tooth-whitening or bleaching products, remain prohibited unless wholly for the purpose of the treatment or prevention of disease. The same position statement also notes that, in persons under 18 years of age, products containing $>0.1\%$ and $\leq 6\%$ hydrogen peroxide may be used where such use is intended wholly for the purpose of treating or preventing disease (General_Dental_Council 2016). This regulatory ambiguity is of particular clinical and ethical relevance in children and adolescents with DEO, because the alternative treatment options are more destructive to tooth tissues. It should also be acknowledged that, in other parts of the world, higher concentrations of hydrogen peroxide are used without equivalent regulatory restriction. A recent review based on 40 studies including 1042 patients concluded that bleaching procedures are safe in children and adolescents (Lopes et al. 2025). The American Academy of Paediatric Dentistry supports appropriately selected bleaching procedures that have been shown to be safe and effective for children and adolescents (American_Academy_of_Pediatric_Dentistry 2025).

Bleaching procedures should also be deferred during pregnancy, as recommended by the American Dental Association and the American Academy of Paediatric Dentistry, because evidence regarding foetal safety is limited (Ahmed et al. 2022; Amer 2023).

Taken together, these regulatory and safety considerations highlight the need for clinicians to remain compliant with the regulatory framework applicable in their own jurisdiction at all times, as regulations may differ between countries and may change over time.

### 4.4 | Application of the Bleaching Agent and Temporary Restoration

The bleaching agent is placed into the pulp chamber and positioned obliquely against the labial wall to maximize the effect on visible crown areas while leaving space for a 2–3 mm layer of temporary restoration. Granular agents in aqueous suspension can be applied with an amalgam carrier or a spatula, whereas gel-type agents are usually delivered with the provided syringe and application tip.

Conventional temporary hydraulic materials such as Cavit can provide a short-term seal over the bleaching agent when firmly packed into the access cavity to a thickness of at least 2 mm (Hosoya et al. 2000).

Gel-type bleaching agents, however, do not provide a stable base for adequate condensation of the temporary material. In such cases, a small foam pellet can separate the bleaching gel from the temporary restoration (Traviglia et al. 2019).

In general, flowable composite materials used in combination with a dental adhesive provide better stability and sealing (Kahler 2022), but they require greater procedural care to ensure adequate bonding to clean cavity margins. Self-adhesive flowable composites may at first glance represent a straightforward alternative for reducing technique sensitivity, but their bond strength and sealing ability are considerably inferior (Delgado et al. 2025).

### 4.5 | Duration and Replacement

A treatment cycle generally lasts 3–7 days, depending on the concentration and $H_2O_2$ equivalent of the bleaching agent and the severity of the discolouration. Further cycles with fresh bleaching agent may be performed until the desired shade change is achieved, usually after 2–4 cycles. Patients should assess the colour change daily and report marked or rapid whitening (Kahler 2022). Highly concentrated bleaching agents may induce pronounced whitening within only a few days, increasing the risk of over-bleaching, especially in teeth with limited residual hard-tissue thickness.

If bleaching does not produce a satisfactory effect, the cause requires careful reassessment. Residual restorative material, particularly on the labial wall of the access cavity, may prevent contact between the bleaching agent and the discoloured tooth structure and thereby limit its efficacy. Discolouration caused by metallic ions may also respond less favourably to bleaching (Brown 1965).

### 4.6 | Definitive Restoration

After successful intracoronal bleaching, the access cavity should be definitively restored with an adhesive resin composite (Figure 9). Residual peroxide and free oxygen can temporarily compromise polymerization and bond strength (Cavalli et al. 2001; Shinohara et al. 2001, 2004, 2005). Therefore, an interval of 1–3 weeks before placement of the final restoration is preferable, with a calcium hydroxide dressing placed during this period (Kahler 2022). Although in vitro evidence suggests



**FIGURE 9** | Intracoronal bleaching of discoloured central incisors with subsequent composite restorations.



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that immediate restoration may be feasible, the available findings remain limited and method-dependent (Arcari et al. 2007). Antioxidant pretreatment, for example with 10% ascorbic acid (Olmedo et al. 2021), and gentle surface refreshing of enamel and dentine may help optimize adhesion when earlier definitive restoration is intended. A well-sealed and durable final restoration prevents contamination of the root canal system and reduces the risk of recurrent discolouration.

## 5 | Clinical Management of DEO in Calcified Teeth

Crown discolouration of anterior teeth due to pulp canal obliteration is a frequent late consequence of dental trauma. These teeth are often intact and caries-free but may gradually develop a yellowish discolouration over time. In the absence of signs of apical pathology, endodontic intervention is not indicated (Amir et al. 2001; McCabe and Dummer 2012). Although intracoronal bleaching of obliterated teeth with preparation of a deep access cavity with placement of a cervical barrier has been described (Pedorella et al. 2000), such approaches are invasive and should be considered critically because they require removal of sound tooth structure and may introduce root canal contamination. External bleaching therefore represents the first-line treatment (Ahmed et al. 2022).

### 5.1 | External Bleaching

In general, bleaching of teeth with DEO associated with pulp canal obliteration may be less reliable, because the darkening results from reduced translucency and a more pronounced dentine appearance rather than staining by iron-related compounds (Setzer 2020).

These teeth often respond more slowly and therefore require an effective but conservative protocol. Treatment options include both in-office and home bleaching (Kwon 2011).

In-office bleaching with high-concentration hydrogen peroxide gels may improve tooth shade. Treatment usually comprises 20-min cycles, with no more than three applications per visit, and requires strict gingival protection using light-cured barriers. However, a single visit rarely achieves an ideal colour match. Light activation does not appear to improve the colour change, regardless of the concentration of the bleaching agent (Maran et al. 2018).

In contrast, single-tooth tray home bleaching is generally considered the preferred approach (Chong 1993; Greenwall 2007; Amato and Krastl 2012). Custom trays should include a reservoir that is limited to the affected tooth in order to avoid unintentional bleaching of adjacent teeth (Figure 10). Patients typically wear the tray with a 10%–20% carbamide peroxide gel for a few hours each day. Visible improvement may occur within the first week; however, patients may need to continue treatment for several weeks depending on the severity of the discolouration and the concentration of the bleaching agent. Longer daily wear or an extended treatment period may compensate for a lower gel concentration (Ahmed et al. 2022). Combining in-office treatment with single-tooth tray home bleaching may accelerate the response (Park et al. 2023). If bleaching alone does not achieve the desired aesthetic outcome, restorative options may be considered (see below).

## 6 | Treatment Success, Colour Stability and Retreatment

Studies using various bleaching agents and clinical protocols generally report either an excellent colour match or clinically significant improvement after intracoronal bleaching (Brown 1965; Holmstrup et al. 1988; Anitua et al. 1990; Waterhouse and Nunn 1996; Abbott and Heah 2009; Amato et al. 2018).

Short-term outcomes are favourable, with success rates during the first year often approaching 95%–100%, depending on the criteria used to define success (Kahler 2022).

Long-term colour stability, however, is less predictable, and no bleaching protocol can guarantee a stable result. After a follow-up of 1–8 years, Friedman et al. found that 50% of teeth matched the adjacent teeth, 29% showed some discolouration but remained acceptable to the patient, and 21% required further treatment; most failures occurred between 2 and 8 years after bleaching (Friedman et al. 1988). At 16 years after a combined in-office and walking bleach protocol using sodium perborate and hydrogen peroxide, Amato et al. reported favourable colour stability in 22 of 35 evaluable cases (62.9%), whereas 13 cases (37.1%) showed marked relapse of two or more shade units (Amato et al. 2006). In a subsequent 25-year follow-up study, the same group reported an 85% success rate after a combined in-office and walking bleach protocol using 10% carbamide peroxide, again defining success as a colour mismatch of less than two shades compared with adjacent teeth (Amato et al. 2018).



**FIGURE 10** | Single-tooth tray home bleaching of a tooth with pulp canal obliteration.



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In general, many patients appear to accept some degree of colour regression. The patient's aesthetic expectations largely determine whether the outcome remains acceptable and whether further intervention is necessary. If colour relapse after initially successful intracoronal bleaching results in an aesthetically unacceptable outcome, repeat internal bleaching may be considered. However, re-entry poses a risk because removal of a well-bonded definitive composite restoration is technically demanding and may unintentionally remove sound tooth structure. Magnification, careful technique and sufficient treatment time help preserve dentine and minimize iatrogenic damage during re-intervention (Ahmed et al. 2022).

Evidence regarding tray bleaching of calcified teeth remains limited. Case reports describe successful outcomes, but long-term colour-stability data are lacking (Chong 1993; Amato and Krastl 2012; Park et al. 2023). Colour relapse is likely to occur over time and may become apparent as early as 1–3 years after bleaching (Park et al. 2023). In such cases, renewed bleaching using the original tray may represent a simple and practical option.

## 7 | Risk Assessment and Complications

### 7.1 | Cervical Root Resorption

Intracoronal bleaching is generally considered to be safe and less destructive to tooth structure than porcelain veneers or crowns (Dahl et al. 2019; Newton and Hayes 2020; Kahler 2022). Nevertheless, external cervical root resorption has historically been described as a serious complication of bleaching with peroxide-containing agents (Harrington and Natkin 1979; Lado et al. 1983; Cvek and Lindvall 1985). Reported rates of external cervical resorption after intracoronal bleaching without a cervical barrier ranged from 6% to 8% in cases treated with 35% hydrogen peroxide and from 18% to 25% when hydrogen peroxide was heat-activated (Friedman et al. 1988; Heithersay et al. 1994; Friedman 1997). By contrast, no cases of resorption were reported when sodium perborate was applied over a zinc oxyphosphate cement barrier placed to protect the cervical region (Amato et al. 2006).

The mechanism proposed for initiation of the resorptive process is the diffusion of hydrogen peroxide through dentinal tubules into the cervical region of the tooth, particularly in areas lacking cementum (Kopp 1973; Rotstein et al. 1991; Neuvald and Consolaro 2000). It has been suggested that hydrogen peroxide and free oxygen radicals reaching the periodontal tissues (Wang and Hume 1988; Newton and Hayes 2020) may trigger resorption (Dahlstrom et al. 1997). These oxidants appear to be more active when heat is applied (Harrington and Natkin 1979; Freccia et al. 1982; Madison and Walton 1990) and heat may additionally promote denaturation of dentine matrix proteins (Lado et al. 1983).

However, cervical resorption diagnosed after bleaching does not necessarily establish a causal relationship. In anterior teeth, trauma is the most common reason for both endodontic treatment and subsequent discolouration requiring bleaching (Amato et al. 2006; Abbott and Heah 2009). Consequently, whether trauma or bleaching represents the principal predisposing factor often remains unclear. In a study of 337 teeth with external cervical resorption, Mavridou et al. identified bleaching as the sole predisposing factor in only 1% of cases (Mavridou et al. 2017).

Overall, the available evidence suggests that the risk for cervical resorption is particularly low when low-concentration bleaching agents are used, heat activation is avoided and a cervical barrier is placed over the root canal filling (Amato et al. 2018; Kahler 2022).

### 7.2 | Structural Enamel and Dentine Damage

Numerous laboratory studies have reported changes in the microhardness and morphology of dental hard tissues following exposure to bleaching agents (Murchison et al. 1992; Rotstein, Lehr, and Gedalia 1992; Tong et al. 1993; Zalkind et al. 1996; Bitter 1998; Lopes et al. 2002; White et al. 2002; Chng et al. 2005; Zanolla et al. 2017; Grazioli et al. 2018). Available evidence suggests that peroxide components may alter the ratio of organic to inorganic constituents within these tissues (Powell and Bales 1991; Tong et al. 1993; Lewinstein et al. 1994). These morphological changes are concentration-dependent as 35% carbamide peroxide changed the inorganic composition of the enamel, whereas lower concentrations of 10%–16% had no effect on enamel composition (Oltu and Gurgan 2000). The clinical significance of these changes in enamel constituents and surface structure is not well understood. Moreover, this issue is of greater relevance to external bleaching (Kahler 2022).

### 7.3 | Fracture Risk

The effect of intracoronal bleaching on fracture resistance remains controversial. Most studies report no significant reduction in fracture resistance after intracoronal bleaching (Bonfante et al. 2006; Azevedo et al. 2011; Uzunoglu et al. 2018), whereas one study reported that all bleaching protocols reduced fracture resistance in bovine teeth (Leonardo et al. 2014).

Fracture-risk assessment should also consider the aetiology of DEO because teeth discoloured following trauma may already have cracks or structural defects that increase their inherent susceptibility to fracture independently of bleaching. Irrespective of the bleaching protocol, structural weakening may occur if excessive cervical dentine is unintentionally removed during access cavity preparation or if severely discoloured dentine is deliberately removed. Such tissue sacrifice should therefore be avoided whenever possible. On the other hand, in view of the current trend toward smaller access cavities to reduce fracture risk, it is noteworthy that tooth shade was re-established more easily by intracoronal bleaching with traditional access cavities than with contracted endodontic access cavities (Marchesan et al. 2018).

### 7.4 | Gingival Irritation

Gingival irritation primarily concerns external bleaching, and its severity depends on the concentration of the bleaching agent (Bruzell et al. 2013). In intracoronal bleaching, routine



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application of a rubber dam prevents contact of the bleaching agent with the oral soft tissues (Heithersay et al. 1994). If necessary, block-out materials may be used to improve sealing of the rubber dam and provide additional protection for the gingival tissues (Rotstein 2019; Setzer 2020).

## 8 | Restorative Options for Discoloured Teeth

Restorative treatment may be necessary when non-vital bleaching is contraindicated or unsuccessful, or when bleaching alone cannot achieve a satisfactory aesthetic outcome. In such cases, progressively more invasive restorative options may be considered, including direct composite veneers, indirect ceramic veneers and full-coverage crowns (Kahler 2022; Aljanahi et al. 2025). Each of these restorative modalities has specific indications, advantages and limitations.

### 8.1 | Direct Composite Veneers

Direct composite veneers represent a conservative and versatile option for masking discoloured anterior teeth (Figure 11) (Felippe et al. 2003; Dietschi 2008; Yanikian et al. 2019; Fahl and Ritter 2020).

Compared with indirect ceramic veneers, direct composite veneers offer several advantages, including lower cost, shorter treatment time, ease of repair and modification, and the ability to complete the restoration in a single clinical session. Especially in younger patients, direct composite veneers are preferred over indirect ceramic veneers because tooth position and gingival margins may change during growth and development.

Although composite veneers are commonly perceived to require less aggressive tooth preparation than ceramic veneers, this assumption is only valid when the underlying tooth structure is not significantly discoloured. In severely discoloured teeth, 1.0–1.5 mm of space is usually needed for composite layering, and additional incisal reduction of about 2 mm may be required to achieve proper aesthetic integration (Felippe et al. 2003; Yanikian et al. 2019; Fahl and Ritter 2020). A silicone index based on a diagnostic wax-up can help control the preparation depth and ensure sufficient restorative space.

Small-particle hybrid composite resins are most commonly used (Dietschi 2008; Ferracane 2011; Gresnigt et al. 2012; Dietschi et al. 2019; Fahl and Ritter 2020). Careful shade analysis of adjacent teeth is essential. In cases of severe discolouration, an opaquer may be needed after adhesive bonding to neutralize the dark substrate, followed by dentine and enamel composite layers. Additional tints or translucent shades may be used to reproduce natural optical effects (Felippe et al. 2003; Yanikian et al. 2019; Fahl and Ritter 2020). Aesthetic success depends not only on colour masking but also on accurate morphology, surface texture and surface gloss (Dietschi 2008; Fahl and Ritter 2020).

Clinical studies evaluating direct composite veneers with 10-year follow-up have reported annual failure rates of about 5%–10% (Coelho-de-Souza et al. 2015; van de Sande et al. 2019; Mazzetti et al. 2022). Outcomes appear less favourable in non-vital than in vital teeth, reflecting the greater aesthetic challenges when restoring endodontically treated anterior teeth (Coelho-de-Souza et al. 2015).

### 8.2 | Indirect Ceramic Veneers

Indirect ceramic veneers are a valuable option when patients seek a more durable restoration with superior aesthetic potential (Figure 12). (Peumans et al. 2004; Gurel et al. 2012; Gresnigt et al. 2019; Rinke et al. 2020; Mazzetti et al. 2022). As with direct composite veneers, tooth preparation must provide sufficient space to mask the underlying discolouration while reproducing the optical properties of adjacent teeth (Magne and Belser 2021a; Clavijo 2024a).

To improve masking and avoid visible transition zones between the restoration and the natural tooth structure, the cervical margin is often placed slightly subgingivally. As a general guide, approximately 0.3 mm of ceramic thickness is required for each shade change (Sulikowski and Yoshida 2001; Coachman et al. 2014; Gurrea and Bruguera 2016; Clavijo 2024b).

Feldspathic ceramics are generally considered the material of choice for the highest aesthetic demands as they allow excellent control of translucency and colour in thin layers (Calgaro et al. 2014; Magne and Belser 2021b; Clavijo 2024a) and enable selective intrinsic masking (Magne et al. 2010; Chu and Mieleszko 2014; Schlichting et al. 2015). However, they are technique-sensitive, require a highly skilled ceramist and are less suitable in cases with increased occlusal loading (Faus-Matoses et al. 2020).

Lithium-disilicate glass-ceramics ($LiSi_2$) are another commonly used option and may be fabricated by pressing or CAD-CAM. They are available in different translucencies and may be layered to improve aesthetics (Magne and Belser 2021a; Clavijo 2024b). However, masking a dark substrate with $LiSi_2$

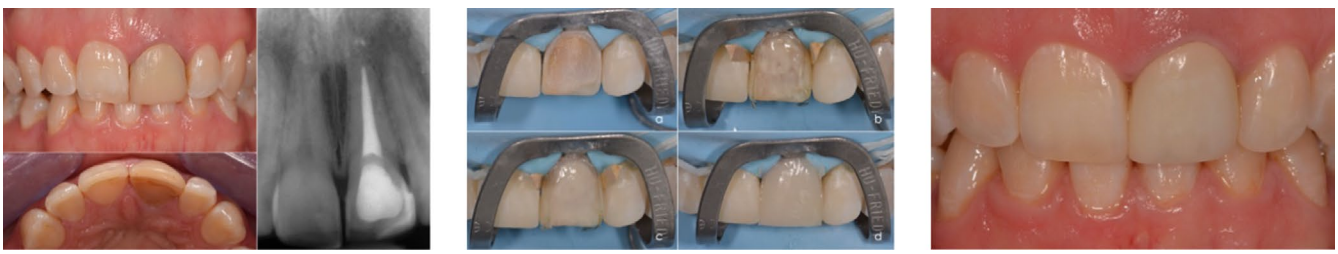


**FIGURE 11** | Management of DEO with direct composite restoration.



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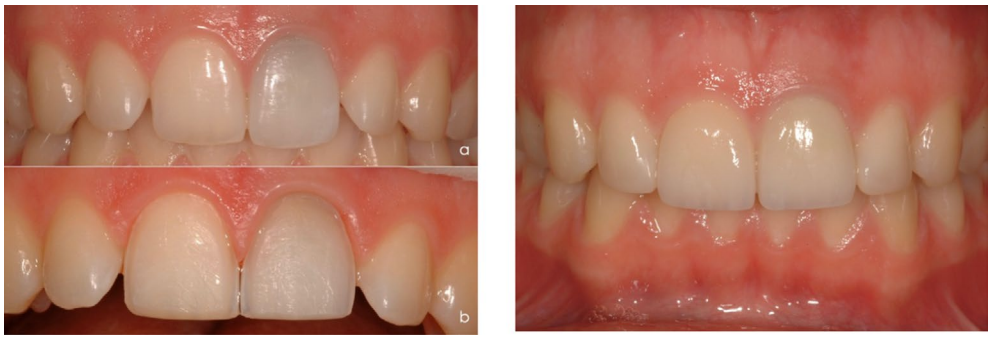


**FIGURE 12** | Management of DEO with porcelain veneer.



**FIGURE 13** | Management of a complex aesthetic case involving DEO, including a connective tissue graft to locally increase gingival thickness, followed by restorative treatment with all-ceramic crowns (courtesy E. Vandooren).

remains challenging, and opaque luting composites to block underlying discolouration may lead to unpredictable results (Pala et al. 2024; Wayakanon et al. 2025).

If a major shade change is required, a ceramic thickness of up to 1.5 mm may be necessary, including an opaque framework to block the underlying tooth colour (Sulikowski and Yoshida 2001; Calgaro et al. 2014; Coachman et al. 2014; Suzuki 2014a, 2014b; Gurrea and Bruguera 2016). In such cases, preparation is usually entirely in dentine. Together with endodontic treatment, this creates less favourable conditions for the long-term durability of bonded ceramic veneers (Peumans et al. 2004; Gurel et al. 2012; Blunck et al. 2020; Rinke et al. 2020; Etienne et al. 2025). In general, indirect ceramic veneers demonstrate survival rates of about 90% after 10–15 years (Gresnigt et al. 2019; Rinke et al. 2020; Etienne et al. 2025).

### 8.3 | Full-Coverage Crowns

Full-coverage crowns are indicated to mask discoloured teeth when the remaining tooth structure is extensively compromised, particularly in cases where the tooth is heavily restored or contains a post-and-core reconstruction (Figure 13).

In general, for full-coverage crowns at least 1.5 mm of space is required, although up to 2 mm of buccal reduction may be needed to allow adequate ceramic layering and optimal aesthetics. Predictable masking is usually achieved with an opaque core of about 0.5 mm that is subsequently layered with aesthetic ceramics. Commonly used core materials include $LiSi_2$ and zirconia, both of which can be used with an opaque substructure to mask the underlying discoloured substrate (Calgaro et al. 2014; Suzuki 2014a, 2014b). In cases with a dark underlying substrate, internal staining of the restoration with opaque colouring agents may be considered as an additional masking strategy (Pilecco et al. 2025).

When severe discolouration is caused by a metal post, removal and replacement with a fibre post and composite core build-up should be considered whenever feasible, as this may substantially improve the colour of the underlying substrate and facilitate the final aesthetic outcome. If post replacement is not possible, a flowable opaquer may be used to mask the dark axial walls of the preparation, provided an appropriate bonding protocol is followed.

Clinical studies have reported survival rates for full-coverage crowns on endodontically treated teeth ranging from 98% at 5 years (Signore et al. 2009) to 81% at 10 years (Stavropoulou and Koidis 2007).

Furthermore, when restoring a discoloured endodontically treated anterior tooth with an indirect veneer or a full crown the periodontal biotype plays an important role in the aesthetic outcome. In patients with a thin gingival biotype, dark cervical discolouration may show through the gingival tissues, negatively affecting the final appearance of the restored tooth. In such cases, a connective tissue graft may be placed to locally increase the gingival thickness, mask the underlying substrate and improve the overall aesthetic outcome (Figure 13) (Jung et al. 2007). In addition, this will provide long-term stability and natural appearance for the restored tooth in the anterior region.

In conclusion, regardless of the restorative technique used, masking a severely discoloured tooth remains a major challenge in aesthetic dentistry. Although substantial aesthetic improvement can often be achieved, a perfect outcome cannot be predicted with certainty. Successful treatment requires careful case



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selection, meticulous execution and a clear understanding of the limitations and optical properties of the restorative materials.

## 9 | Conclusion

DEO is a frequent and clinically relevant problem that may arise from trauma, pulp necrosis, pulp canal obliteration or endodontic treatment itself. Prevention is of central importance and requires preservation of pulp vitality whenever possible, careful selection of low-discolouration materials, meticulous cleaning of the pulp chamber and durable coronal sealing. When DEO occurs in adequately treated root-filled or revitalized teeth, intracoronal bleaching remains the preferred minimally invasive treatment, provided that appropriate case selection, cervical sealing and safe bleaching protocols are followed. In discoloured teeth with pulp canal obliteration and no signs of apical pathology, external bleaching should be preferred over more invasive intervention. Although bleaching can provide substantial aesthetic improvement, long-term colour stability cannot be guaranteed. Restorative treatment should be reserved for cases in which bleaching is unsuccessful or insufficient to achieve an acceptable aesthetic outcome. Overall, management of DEO should preserve as much tooth structure as possible while meeting the patient's aesthetic expectations.

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### References

AAE. 2021. AAE Position Statement on Vital Pulp Therapy.

Abbott, P., and S. Y. Heah. 2009. "Internal Bleaching of Teeth: An Analysis of 255 Teeth." *Australian Dental Journal* 54, no. 4: 326–333.

Ahmed, H. M., and P. V. Abbott. 2012. "Discolouration Potential of Endodontic Procedures and Materials: A Review." *International Endodontic Journal* 45, no. 10: 883–897.

Ahmed, H. M., G. Krastl, B. Zimmerli, M. Amer, and P. Parashos. 2022. "Management of Coronal Discolouration." In *Endodontic Advances and Evidence-Based Clinical Guidelines*, edited by H. M. Ahmed and P. M. Dummer, 617–644. Wiley Blackwell.

Aljanahi, M., A. Alhussin, and H. Elbishari. 2025. "Challenges Faced When Masking a Single Discoloured Tooth—Part 2: Indirect Restoration Procedures." *British Dental Journal* 239, no. 1: 25–30.

Amato, A., M. Caggiano, G. Pantaleo, and M. Amato. 2018. "In-Office and Walking Bleach Dental Treatments on Endodontically-Treated Teeth: 25 Years Follow-Up." *Minerva Stomatologica* 67, no. 6: 225–230.

Amato, M., and G. Krastl. 2012. "Discolored Obliterated Incisor. An Aesthetic Challenge?" *Stomatologie* 109, no. 4–5: 40–44.

Amato, M., M. S. Scaravilli, M. Farella, and F. Riccitiello. 2006. "Bleaching Teeth Treated Endodontically: Long-Term Evaluation of a Case Series." *Journal of Endodontics* 32, no. 4: 376–378.

Amer, M. 2023. "Intracoronal Tooth Bleaching - A Review and Treatment Guidelines." *Australian Dental Journal* 68, no. Suppl 1: S141–S152.

American Academy of Pediatric Dentistry. 2025. "Policy on the Use of Dental Bleaching for Child and Adolescent Patients." In *The Reference Manual of Pediatric Dentistry*, 136–140. American Academy of Pediatric Dentistry.

Amir, F. A., J. L. Gutmann, and D. E. Witherspoon. 2001. "Calcific Metamorphosis: A Challenge in Endodontic Diagnosis and Treatment." *Quintessence International* 32, no. 6: 447–455.

Andreasen, F. M. 1986. "Transient Apical Breakdown and Its Relation to Color and Sensibility Changes After Luxation Injuries to Teeth." *Endodontics & Dental Traumatology* 2, no. 1: 9–19.

Andreasen, F. M. 1989. "Pulpal Healing After Luxation Injuries and Root Fracture in the Permanent Dentition." *Endodontics & Dental Traumatology* 5, no. 3: 111–131.

Andreasen, F. M., and B. Kahler. 2015. "Pulpal Response After Acute Dental Injury in the Permanent Dentition: Clinical Implications—A Review." *Journal of Endodontics* 41, no. 3: 299–308.

Andreasen, F. M., Y. Zhijie, B. L. Thomsen, and P. K. Andersen. 1987. "Occurrence of Pulp Canal Obliteration After Luxation Injuries in the Permanent Dentition." *Endodontics & Dental Traumatology* 3, no. 3: 103–115.

Anitua, E., B. Zabalegui, J. Gil, and F. Gascon. 1990. "Internal Bleaching of Severe Tetracycline Discolorations: Four-Year Clinical Evaluation." *Quintessence International* 21, no. 10: 783–788.

Arcari, G. M., E. Araujo, L. N. Baratieri, and G. C. Lopes. 2007. "Microtensile Bond Strength of a Nanofilled Composite Resin to Human Dentin After Nonvital Tooth Bleaching." *Journal of Adhesive Dentistry* 9, no. 3: 333–340.

Attin, T., F. Paque, F. Ajam, and A. M. Lennon. 2003. "Review of the Current Status of Tooth Whitening With the Walking Bleach Technique." *International Endodontic Journal* 36, no. 5: 313–329.

Awawdeh, L., A. Al-Qudah, H. Hamouri, and R. J. Chakra. 2018. "Outcomes of Vital Pulp Therapy Using Mineral Trioxide Aggregate or Biodentine: A Prospective Randomized Clinical Trial." *Journal of Endodontics* 44, no. 11: 1603–1609.

Azevedo, R. A., Y. T. Silva-Sousa, A. E. Souza-Gabriel, D. C. Messias, E. Alfredo, and R. G. Silva. 2011. "Fracture Resistance of Teeth Subjected to Internal Bleaching and Restored With Different Procedures." *Brazilian Dental Journal* 22, no. 2: 117–121.

Badi, M. A., F. Yilmaz, E. Odabasi Sezer, and M. Dartar Oztan. 2026. "Spectrophotometric Analysis of Antibiotic-Induced Tooth Discolouration: An In Vitro Study." *European Endodontic Journal* 11, no. 5: 228–234.

Baik, U. B., H. Kim, H. S. Chae, J. Y. Myung, and Y. S. Chun. 2017. "Teeth Discoloration During Orthodontic Treatment." *Korean Journal of Orthodontics* 47, no. 5: 334–339.



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Basrani, B. R., S. Manek, R. N. Sodhi, E. Fillery, and A. Manzur. 2007. "Interaction Between Sodium Hypochlorite and Chlorhexidine Gluconate." *Journal of Endodontics* 33, no. 8: 966–969.

Bastos, J. V., and M. I. S. Cortes. 2018. "Pulp Canal Obliteration After Traumatic Injuries in Permanent Teeth—Scientific Fact or Fiction?" *Brazilian Oral Research* 32, no. suppl 1: e75.

Bersezio, C., P. Ledezma, C. Mayer, O. Rivera, O. B. O. Junior, and E. Fernandez. 2018. "Effectiveness and Effect of Non-Vital Bleaching on the Quality of Life of Patients up to 6 Months Post-Treatment: A Randomized Clinical Trial." *Clinical Oral Investigations* 22, no. 9: 3013–3019.

Bersezio, C., J. Martin, F. Pena, et al. 2017. "Effectiveness and Impact of the Walking Bleach Technique on Esthetic Self-Perception and Psychosocial Factors: A Randomized Double-Blind Clinical Trial." *Operative Dentistry* 42, no. 6: 596–605.

Bitter, N. C. 1998. "A Scanning Electron Microscope Study of the Long-Term Effect of Bleaching Agents on the Enamel Surface in Vivo." *General Dentistry* 46, no. 1: 84–88.

Blunck, U., S. Fischer, J. Hajto, S. Frei, and R. Frankenberger. 2020. "Ceramic Laminate Veneers: Effect of Preparation Design and Ceramic Thickness on Fracture Resistance and Marginal Quality In Vitro." *Clinical Oral Investigations* 24, no. 8: 2745–2754.

Bodere, P. J., F. Calberson, M. De Bruyne, R. De Moor, and M. Meire. 2022. "Protocols for Cleaning the Incisor Access Cavity Contaminated With Epoxy Resin Sealer." *European Journal of Oral Sciences* 130, no. 5: e12894.

Bonafe, E., M. Rezende, M. M. Machado, et al. 2021. "Personality Traits, Psychosocial Effects and Quality of Life of Patients Submitted to Dental Bleaching." *BMC Oral Health* 21, no. 1: 7.

Bonfante, G., O. B. Kaizer, L. F. Pegoraro, and A. L. do Valle. 2006. "Fracture Resistance and Failure Pattern of Teeth Submitted to Internal Bleaching With 37% Carbamide Peroxide, With Application of Different Restorative Procedures." *Journal of Applied Oral Science: Revista FOB* 14, no. 4: 247–252.

Bosenbecker, J., F. J. Barbon, N. de Souza Ferreira, R. D. Morgental, and N. Boscato. 2020. "Tooth Discoloration Caused by Endodontic Treatment: A Cross-Sectional Study." *Journal of Esthetic and Restorative Dentistry* 32, no. 6: 569–574.

Brown, G. 1965. "Factors Influencing Successful Bleaching of the Discolored Root-Filled Tooth." *Oral Surgery, Oral Medicine, and Oral Pathology* 20: 238–244.

Bruzell, E. M., U. Pallesen, N. R. Thoresen, C. Wallman, and J. E. Dahl. 2013. "Side Effects of External Tooth Bleaching: A Multi-Centre Practice-Based Prospective Study." *British Dental Journal* 215, no. 9: E17.

Calgaro, M., V. Clavijo, R. Goulart, and W. Clavijo. 2014. "Succesful Ceramic Application on Various Substructures." In *High-Strength Ceramics. Interdisciplinary Perspectives*, 205–223. Quintessence books.

Camilleri, J. 2014. "Color Stability of White Mineral Trioxide Aggregate in Contact With Hypochlorite Solution." *Journal of Endodontics* 40, no. 3: 436–440.

Camilleri, J. 2026. "An Updated Classification of Hydraulic Cements Used in Dentistry." *International Endodontic Journal* 59: 1760–1765.

Camilleri, J., A. Atmeh, X. Li, and N. Meschi. 2022. "Present Status and Future Directions: Hydraulic Materials for Endodontic Use." *International Endodontic Journal* 55, no. Suppl 3: 710–777.

Camilleri, J., P. Zaslansky, and N. Ramanan. 2026. "Delta-Bismuth Oxide Responsible for Tooth Discolouration-A Laboratory Investigation." *International Endodontic Journal* 59, no. 3: 538–548.

Camps, J., L. Pommel, V. Aubut, and I. About. 2010. "Influence of Acid Etching on Hydrogen Peroxide Diffusion Through Human Dentin." *American Journal of Dentistry* 23, no. 3: 168–170.

Cardinali, F., and J. Camilleri. 2023. "A Critical Review of the Material Properties Guiding the Clinician's Choice of Root Canal Sealers." *Clinical Oral Investigations* 27, no. 8: 4147–4155.

Carrillo, A., M. V. Arredondo Trevino, and V. B. Haywood. 1998. "Simultaneous Bleaching of Vital Teeth and an Open-Chamber Nonvital Tooth With 10% Carbamide Peroxide." *Quintessence International* 29, no. 10: 643–648.

Casey, L. J., W. G. Schindler, S. M. Murata, and J. O. Burgess. 1989. "The Use of Dentinal Etching With Endodontic Bleaching Procedures." *Journal of Endodontics* 15, no. 11: 535–538.

Cavalli, V., A. F. Reis, M. Giannini, and G. M. Ambrosano. 2001. "The Effect of Elapsed Time Following Bleaching on Enamel Bond Strength of Resin Composite." *Operative Dentistry* 26, no. 6: 597–602.

Chng, H. K., H. N. Ramli, A. U. Yap, and C. T. Lim. 2005. "Effect of Hydrogen Peroxide on Intertubular Dentine." *Journal of Dentistry* 33, no. 5: 363–369.

Chong, Y. H. 1993. "Single Discolored Tooth: An Alternative Treatment Approach." *Quintessence International* 24, no. 4: 233–235.

Chu, S. J., and A. J. Mieleszko. 2014. "Color-Matching Strategies for Non-Vital Discolored Teeth: Part 1. Laboratory Ceramic Veneer Fabrication Solutions." *Journal of Esthetic and Restorative Dentistry* 26, no. 4: 240–246.

Clavijo, V. 2024a. "Ceramic Systems." In *Anterior Ceramic Restorations. Details That Make the Difference*, 155–205. Quintessence Publishing Co.

Clavijo, V. 2024b. "Tooth Preparations for Anterior Ceramic Restorations." In *Anterior Ceramic Restorations. Details That Make the Difference*, 155–205. Quintessence Publishing Co.

Coachman, C., G. Gurel, M. Calamita, S. Morimoto, B. Paolucci, and N. Sesma. 2014. "The Influence of Tooth Color on Preparation Design for Laminate Veneers From a Minimally Invasive Perspective: Case Report." *International Journal of Periodontics & Restorative Dentistry* 34, no. 4: 453–459.

Coelho-de-Souza, F. H., D. S. Goncalves, M. P. Sales, et al. 2015. "Direct Anterior Composite Veneers in Vital and Non-Vital Teeth: A Retrospective Clinical Evaluation." *Journal of Dentistry* 43, no. 11: 1330–1336.

Cvek, M., and A. M. Lindvall. 1985. "External Root Resorption Following Bleaching of Pulpless Teeth With Oxygen Peroxide." *Endodontics & Dental Traumatology* 1, no. 2: 56–60.

Dahl, J. E., S. E. Kopperud, and U. Pallesen. 2019. "Bleaching of the Discolored Traumatized Tooth." In *Textbook and Color Atlas of Traumatic Injuries to the Teeth*, edited by J. O. Andreasen, F. M. Andreasen, and L. Andersson, 5th ed., 972–981. John Wiley & Sons Ltd.

Dahl, J. E., and U. Pallesen. 2003. "Tooth Bleaching—A Critical Review of the Biological Aspects." *Critical Reviews in Oral Biology and Medicine: An Official Publication of the American Association of Oral Biologists* 14, no. 4: 292–304.

Dahlstrom, S. W., G. S. Heithersay, and T. E. Bridges. 1997. "Hydroxyl Radical Activity in Thermo-Catalytically Bleached Root-Filled Teeth." *Endodontics & Dental Traumatology* 13, no. 3: 119–125.

Day, P. F., M. Duggal, and H. Nazzal. 2019. "Interventions for Treating Traumatised Permanent Front Teeth: Avulsed (Knocked Out) and Replanted." *Cochrane Database of Systematic Reviews* 2, no. 2: CD006542.

de Oliveira, L. D., C. A. Carvalho, E. Hilgert, I. R. Bondioli, M. A. de Araujo, and M. C. Valera. 2003. "Sealing Evaluation of the Cervical Base in Intracoronal Bleaching." *Dental Traumatology* 19, no. 6: 309–313.

Deari, S., D. Mohn, and M. Zehnder. 2019. "Dentine Decalcification and Smear Layer Removal by Different Ethylenediaminetetraacetic Acid and 1-Hydroxyethane-1,1-Diphosphonic Acid Species." *International Endodontic Journal* 52, no. 2: 237–243.



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Delgado, A. H. S., M. Alves, I. Pires, M. Nunes Ferreira, and C. E. Cuevas-Suarez. 2025. "Self-Adhesive Flowable Resin Composites-Are we Going Somewhere?" *Journal of Esthetic and Restorative Dentistry* 38: 287–306.

Deny, O., E. Moliner, K. Nasr, et al. 2026. "Dentin Etching Prior to Internal Tooth Bleaching to Improve Whitening Efficacy: An Ex Vivo Study." *European Journal of Oral Sciences* 134, no. 2: e70058.

Dettwiler, C. A., M. Walter, L. K. Zaugg, P. Lenherr, R. Weiger, and G. Krastl. 2016. "In Vitro Assessment of the Tooth Staining Potential of Endodontic Materials in a Bovine Tooth Model." *Dental Traumatology* 32, no. 6: 480–487.

Dietschi, D. 2008. "Optimizing Smile Composition and Esthetics With Resin Composites and Other Conservative Esthetic Procedures." *European Journal of Esthetic Dentistry* 3, no. 1: 14–29.

Dietschi, D., C. Shadidi, and I. Krejci. 2019. "Clinical Perfomance of Direct Anterior Composite Restorations: A Systematic Literature Review and Critical Appraisal." *International Journal of Esthetic Dentistry* 14: 252–270.

Duncan, H. F., K. M. Galler, P. L. Tomson, et al. 2019. "European Society of Endodontology Position Statement: Management of Deep Caries and the Exposed Pulp." *International Endodontic Journal* 52, no. 7: 923–934.

Etienne, O., C. J. Wang, R. Bourgi, D. Watzki, and T. Roman. 2025. "Survival of Ceramic Veneers: Impact of Dentin Exposure and Tooth Vitality After 1 to 15 Years of Follow-Up." *Journal of Esthetic and Restorative Dentistry* 37, no. 12: 2519–2532.

European_Parliament_and_Council. 2006. Regulation No 1907/2006 Concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).

European_Union_Council. 2011. "Council Directive 2011/84/ EU." *Official Journal of the European Union Council*. https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:283:0036:0038:en:PDF.

Fahl, N., and A. V. Ritter. 2020. "Veneers With Preparation: Discolored Teeth." In *Composite Veneers: The Direct-Indirect Technique*, 127–188. Quintessence Publishing Co, Inc.

Fasoulas, A., G. Keratiotis, L. Spineli, et al. 2023. "Comparative Efficacy of Materials Used in Patients Undergoing Pulpotomy or Direct Pulp Capping in Carious Teeth: A Systematic Review and Meta-Analysis." *Cllinical and Experimental Dental Research* 9, no. 6: 1129–1148.

Faus-Matoses, V., E. Ruiz-Bell, I. Faus-Matoses, M. Ozcan, S. Salvatore, and V. J. Faus-Llacer. 2020. "An 8-Year Prospective Clinical Investigation on the Survival Rate of Feldspathic Veneers: Influence of Occlusal Splint in Patients With Bruxism." *Journal of Dentistry* 99: 103352.

Felippe, L. A., S. Monteiro Jr., L. N. Baratieri, M. A. Caldeira de Andrada, and A. V. Ritter. 2003. "Using Opaquers Under Direct Composite Resin Veneers: An Illustrated Review of the Technique." *Journal of Esthetic and Restorative Dentistry* 15, no. 6: 327–336.

Ferracane, J. L. 2011. "Resin Composite—State of the Art." *Dental Materials* 27, no. 1: 29–38.

Frank, A. C., P. Kanzow, T. Rodig, and A. Wiegand. 2022. "Comparison of the Bleaching Efficacy of Different Agents Used for Internal Bleaching: A Systematic Review and Meta-Analysis." *Journal of Endodontics* 48, no. 2: 171–178.

Freccia, W. F., D. D. Peters, L. Lorton, and W. E. Bernier. 1982. "An In Vitro Comparison of Nonvital Bleaching Techniques in the Discolored Tooth." *Journal of Endodontics* 8, no. 2: 70–77.

Friedman, S. 1997. "Internal Bleaching: Long-Term Outcomes and Complications." *Journal of the American Dental Association* 128, no. Suppl: 51S–55S.

Friedman, S., I. Rotstein, H. Libfeld, A. Stabholz, and I. Heling. 1988. "Incidence of External Root Resorption and Esthetic Results in 58 Bleached Pulpless Teeth." *Endodontics & Dental Traumatology* 4, no. 1: 23–26.

Fuss, Z., S. Szajkis, and M. Tagger. 1989. "Tubular Permeability to Calcium Hydroxide and to Bleaching Agents." *Journal of Endodontics* 15, no. 8: 362–364.

Galler, K. M., T. Akamp, H. Knuttel, and M. Widbiller. 2022. "A Critical Analysis of Clinical Research Methods to Study Regenerative Endodontics." *International Endodontic Journal* 55, no. Suppl 2: 456–470.

General_Dental_Council. 2016. Tooth Whitening Position Statement. https://www.gdc-uk.org/docs/default-source/what-is-the-legal-position/tooth-whitening-position-statement.pdf.

Gonzalez, O. L., J. Vera, M. S. Orozco, J. T. Mancera, K. V. Gonzalez, and G. V. Malagon. 2014. "Transient Apical Breakdown and Its Relationship With Orthodontic Forces: A Case Report." *Journal of Endodontics* 40, no. 8: 1265–1267.

Grazioli, G., L. L. Valente, C. P. Isolan, H. A. Pinheiro, C. G. Duarte, and E. A. Munchow. 2018. "Bleaching and Enamel Surface Interactions Resulting From the Use of Highly-Concentrated Bleaching Gels." *Archives of Oral Biology* 87: 157–162.

Greenwall, L. 2007. "Single Vital Tooth Whitening." *International Dentistry SA* 10, no. 1: 48–52.

Gresnigt, M. M., W. Kalk, and M. Ozcan. 2012. "Randomized Controlled Split-Mouth Clinical Trial of Direct Laminate Veneers With Two Micro-Hybrid Resin Composites." *Journal of Dentistry* 40, no. 9: 766–775.

Gresnigt, M. M. M., M. S. Cune, J. Schuitemaker, et al. 2019. "Performance of Ceramic Laminate Veneers With Immediate Dentine Sealing: An 11 Year Prospective Clinical Trial." *Dental Materials* 35, no. 7: 1042–1052.

Guimaraes, B. M., T. Tartari, M. A. Marciano, et al. 2015. "Color Stability, Radiopacity, and Chemical Characteristics of White Mineral Trioxide Aggregate Associated With 2 Different Vehicles in Contact With Blood." *Journal of Endodontics* 41, no. 6: 947–952.

Guneser, M. B., A. N. Dincer, and D. Arslan. 2017. "Comparison of Conventional Syringe, CanalBrush, EndoActivator, Photon-Induced Photoacoustic Streaming, and Manual Instrumentation in Removing Orange-Brown Precipitate: An In Vitro Study." *Photomedicine and Laser Surgery* 35, no. 6: 311–316.

Gurel, G., S. Morimoto, M. A. Calamita, C. Coachman, and N. Sesma. 2012. "Clinical Performance of Porcelain Laminate Veneers: Outcomes of the Aesthetic Pre-Evaluative Temporary (APT) Technique." *International Journal of Periodontics & Restorative Dentistry* 32, no. 6: 625–635.

Gurrea, J., and A. Bruguera. 2016. "Tooth Preparation and Ceramic Layering Guidelines for Bonded Porcelain Restorations in Different Challenging Situations." *Quintessence of Dental Technology* 39: 95–110.

Harrington, G. W., and E. Natkin. 1979. "External Resorption Associated With Bleaching of Pulpless Teeth." *Journal of Endodontics* 5, no. 11: 344–348.

Heithersay, G. S., S. W. Dahlstrom, and P. D. Marin. 1994. "Incidence of Invasive Cervical Resorption in Bleached Root-Filled Teeth." *Australian Dental Journal* 39, no. 2: 82–87.

Heithersay, G. S., and R. S. Hirsch. 1993. "Tooth Discoloration and Resolution Following a Luxation Injury: Significance of Blood Pigment in Dentin to Laser Doppler Flowmetry Readings." *Quintessence International* 24, no. 9: 669–676.

Holmstrup, G., A. M. Palm, and H. Lambjerg-Hansen. 1988. "Bleaching of Discoloured Root-Filled Teeth." *Endodontics & Dental Traumatology* 4, no. 5: 197–201.

Horn, D. J., M. L. Hicks, and J. Bulan-Brady. 1998. "Effect of Smear Layer Removal on Bleaching of Human Teeth In Vitro." *Journal of Endodontics* 24, no. 12: 791–795.



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Hosoya, N., C. F. Cox, T. Arai, and J. Nakamura. 2000. "The Walking Bleach Procedure: An In Vitro Study to Measure Microleakage of Five Temporary Sealing Agents." *Journal of Endodontics* 26, no. 12: 716–718.

Jacobsen, I., and K. Kerekes. 1977. "Long-Term Prognosis of Traumatized Permanent Anterior Teeth Showing Calcifying Processes in the Pulp Cavity." *Scandinavian Journal of Dental Research* 85, no. 7: 588–598.

Jung, R. E., I. Sailer, C. H. Hammerle, T. Attin, and P. Schmidlin. 2007. "In Vitro Color Changes of Soft Tissues Caused by Restorative Materials." *International Journal of Periodontics & Restorative Dentistry* 27, no. 3: 251–257.

Kahler, B. 2022. "Present Status and Future Directions - Managing Discoloured Teeth." *International Endodontic Journal* 55, no. Suppl 4: 922–950.

Kahler, B., and G. Rossi-Fedele. 2016. "A Review of Tooth Discoloration After Regenerative Endodontic Therapy." *Journal of Endodontics* 42, no. 4: 563–569.

Keskin, C., E. O. Demiryurek, and T. Ozyurek. 2015. "Color Stabilities of Calcium Silicate-Based Materials in Contact With Different Irrigation Solutions." *Journal of Endodontics* 41, no. 3: 409–411.

Kohli, M. R., M. Yamaguchi, F. C. Setzer, and B. Karabucak. 2015. "Spectrophotometric Analysis of Coronal Tooth Discoloration Induced by Various Bioceramic Cements and Other Endodontic Materials." *Journal of Endodontics* 41, no. 11: 1862–1866.

Komabayashi, T., D. Colmenar, N. Cvach, A. Bhat, C. Primus, and Y. Imai. 2020. "Comprehensive Review of Current Endodontic Sealers." *Dental Materials Journal* 39, no. 5: 703–720.

Kopp, R. 1973. "A Safe, Simplified Bleaching Technic for Pulpless Teeth." *Dental Survey* 49, no. 4: 42–44.

Krastl, G., N. Allgayer, P. Lenherr, A. Filippi, P. Taneja, and R. Weiger. 2013. "Tooth Discoloration Induced by Endodontic Materials: A Literature Review." *Dental Traumatology* 29, no. 1: 2–7.

Krastl, G., R. Weiger, A. Filippi, et al. 2021. "European Society of Endodontology Position Statement: Endodontic Management of Traumatized Permanent Teeth." *International Endodontic Journal* 54, no. 9: 1473–1481.

Krishnamurthy, S., and S. Sudhakaran. 2010. "Evaluation and Prevention of the Precipitate Formed on Interaction Between Sodium Hypochlorite and Chlorhexidine." *Journal of Endodontics* 36, no. 7: 1154–1157.

Kwon, S. R. 2011. "Whitening the Single Discolored Tooth." *Dental Clinics of North America* 55, no. 2: 229–239 vii.

Lado, E. A., H. R. Stanley, and M. I. Weisman. 1983. "Cervical Resorption in Bleached Teeth." *Oral Surgery, Oral Medicine, and Oral Pathology* 55, no. 1: 78–80.

Leith, R., A. Moore, and A. C. O'Connell. 2009. "An Effective Bleaching Technique for Non-Vital, Discoloured Teeth in Children and Adolescents." *Journal of the Irish Dental Association* 55, no. 4: 184–189.

Lenherr, P., N. Allgayer, R. Weiger, A. Filippi, T. Attin, and G. Krastl. 2012. "Tooth Discoloration Induced by Endodontic Materials: A Laboratory Study." *International Endodontic Journal* 45, no. 10: 942–949.

Leonardo, R. T., M. C. Kuga, F. A. Guiotti, et al. 2014. "Fracture Resistance of Teeth Submitted to Several Internal Bleaching Protocols." *Journal of Contemporary Dental Practice* 15, no. 2: 186–189.

Lewinstein, I., Z. Hirschfeld, A. Stabholz, and I. Rotstein. 1994. "Effect of Hydrogen Peroxide and Sodium Perborate on the Microhardness of Human Enamel and Dentin." *Journal of Endodontics* 20, no. 2: 61–63.

Lim, M. Y., S. O. Lum, R. S. Poh, G. P. Lee, and K. C. Lim. 2004. "An In Vitro Comparison of the Bleaching Efficacy of 35% Carbamide Peroxide With Established Intracoronal Bleaching Agents." *International Endodontic Journal* 37, no. 7: 483–488.

Lopes, C., F. J. D. de Oliveira, E. S. T. C. Lucena, I. A. Ferreira, and B. C. D. Borges. 2025. "Are Tooth Bleaching Procedures Safe for Children and Adolescents? A Scoping Review of Color Change, Side Effects, and Impact on Patient Satisfaction." *Journal of Dentistry* 159: 105794.

Lopes, G. C., L. Bonissoni, L. N. Baratieri, L. C. Vieira, and S. Monteiro Jr. 2002. "Effect of Bleaching Agents on the Hardness and Morphology of Enamel." *Journal of Esthetic and Restorative Dentistry* 14, no. 1: 24–30.

Madison, S., and R. Walton. 1990. "Cervical Root Resorption Following Bleaching of Endodontically Treated Teeth." *Journal of Endodontics* 16, no. 12: 570–574.

Magne, M., I. Magne, P. Bazos, and M. P. Paranhos. 2010. "The Parallel Stratification Masking Technique: An Analytical Approach to Predictably Mask Discolored Dental Substrate." *European Journal of Esthetic Dentistry* 5, no. 4: 330–339.

Magne, P., and U. Belser. 2021a. "Quintessence Quintessence Publishing co, 2nd Edition 2021 Volume 2–6.9: Tooth Preparation Principles: 620–665." In *Biomimetic Restorative Dentistry*, 2nd ed., 620–665. Quintessence Quintessence Publishing Co.

Magne, P., and U. Belser. 2021b. "Quintessence Quintessence Publishing co, 2nd Edition 2021 Volume 2: 6.12: Laboratory Procedures: 682-729." In *Biomimetic Restorative Dentistry*, 2nd ed., 682–729. Quintessence Quintessence Publishing Co.

Magni, E., W. Leontiev, C. Meller, R. Weiger, and T. Connert. 2022. "Detection and Removal of Tooth-Colored Composite Resin Using the Fluorescence-Aided Identification Technique." *Journal of Visualized Experiments* 185.

Maran, B. M., A. Burey, T. de Paris Matos, A. D. Loguercio, and A. Reis. 2018. "In-Office Dental Bleaching With Light vs. Without Light: A Systematic Review and Meta-Analysis." *Journal of Dentistry* 70: 1–13.

Marchesan, M. A., C. M. James, A. Lloyd, B. R. Morrow, and F. Garcia-Godoy. 2018. "Effect of Access Design on Intracoronal Bleaching of Endodontically Treated Teeth: An Ex Vivo Study." *Journal of Esthetic and Restorative Dentistry* 30, no. 2: E61–E67.

Marciano, M., J. Camilleri, R. Lia Mondelli, et al. 2015. "Potential Tooth Staining due to Root Canal Sealers Containing Bismuth Oxide and Formaldehyde." *ENDO-Endodontic Practice Today* 9, no. 1: 39–45.

Marciano, M., R. Costa, J. Camilleri, R. Mondelli, B. Guimares, and M. Duarte. 2014. "Assessment of Color Stability of White Mineral Trioxide Aggregate Angelus and Bismuth Oxide in Contact With Tooth Structure." *Journal of Endodontics* 40: 1235–1240.

Marin, P. D., P. M. Bartold, and G. S. Heithersay. 1997. "Tooth Discoloration by Blood: An In Vitro Histochemical Study." *Endodontics & Dental Traumatology* 13, no. 3: 132–138.

Mavridou, A. M., L. Bergmans, D. Barendregt, and P. Lambrechts. 2017. "Descriptive Analysis of Factors Associated With External Cervical Resorption." *Journal of Endodontics* 43, no. 10: 1602–1610.

Mayer, R. M., A. Gubler, T. Attin, and M. Zehnder. 2024. "In Vitro and Ex Vivo Comparison of Reactive Oxygen-Releasing Granules for Internal Tooth Bleaching." *Frontiers in Dental Medicine* 5: 1447459.

Mazzetti, T., K. Collares, B. Rodolfo, P. A. da Rosa Rodolpho, F. H. van de Sande, and M. S. Cenci. 2022. "10-Year Practice-Based Evaluation of Ceramic and Direct Composite Veneers." *Dental Materials* 38, no. 5: 898–906.

McCabe, P. S., and P. M. Dummer. 2012. "Pulp Canal Obliteration: An Endodontic Diagnosis and Treatment Challenge." *International Endodontic Journal* 45, no. 2: 177–197.

Mozynska, J., M. Metlerski, M. Lipski, and A. Nowicka. 2017. "Tooth Discoloration Induced by Different Calcium Silicate-Based Cements: A Systematic Review of In Vitro Studies." *Journal of Endodontics* 43, no. 10: 1593–1601.



13652591, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/iej.70263 by University Of Leeds The Brotherton Library, Wiley Online Library on [05/10/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Murchison, D. F., D. G. Charlton, and B. K. Moore. 1992. "Carbamide Peroxide Bleaching: Effects on Enamel Surface Hardness and Bonding." *Operative Dentistry* 17, no. 5: 181–185.

Neuvald, L., and A. Consolaro. 2000. "Cementoenamel Junction: Microscopic Analysis and External Cervical Resorption." *Journal of Endodontics* 26, no. 9: 503–508.

Newton, R., and J. Hayes. 2020. "The Association of External Cervical Resorption With Modern Internal Bleaching Protocols: What Is the Current Evidence?" *British Dental Journal* 228, no. 5: 333–337.

Nocca, G., H. M. A. Ahmed, G. E. Martorana, et al. 2017. "Chromographic Analysis and Cytotoxic Effects of Chlorhexidine and Sodium Hypochlorite Reaction Mixtures." *Journal of Endodontics* 43, no. 9: 1545–1552.

Olmedo, D., M. Kury, B. A. Resende, and V. Cavalli. 2021. "Use of Antioxidants to Restore Bond Strength After Tooth Bleaching With Peroxides." *European Journal of Oral Sciences* 129, no. 2: e12773.

Oltu, U., and S. Gurgan. 2000. "Effects of Three Concentrations of Carbamide Peroxide on the Structure of Enamel." *Journal of Oral Rehabilitation* 27, no. 4: 332–340.

Orhan, E. O., O. Irmak, D. Hur, B. C. Yaman, and B. Karabucak. 2016. "Does Para-Chloroaniline Really Form After Mixing Sodium Hypochlorite and Chlorhexidine?" *Journal of Endodontics* 42, no. 3: 455–459.

Pala, K., E. M. Reinshagen, T. Attin, J. Husler, R. E. Jung, and A. Ioannidis. 2024. "Masking Capacity of Minimally Invasive Lithium Disilicate Restorations on Discolored Teeth—The Impact of Ceramic Thickness, the Material's Translucency, and the Cement Color." *Journal of Esthetic and Restorative Dentistry* 36, no. 1: 107–115.

Parinyaprom, N., A. Nirunsittirat, P. Chuveera, et al. 2018. "Outcomes of Direct Pulp Capping by Using Either ProRoot Mineral Trioxide Aggregate or Biodentine in Permanent Teeth With Carious Pulp Exposure in 6- to 18-Year-Old Patients: A Randomized Controlled Trial." *Journal of Endodontics* 44, no. 3: 341–348.

Park, T. Y., S. R. Jung, J. H. Jeong, J. B. Min, and H. H. Jo. 2023. "Management of Discolored Anterior Teeth With Pulp Canal Obliteration." *Operative Dentistry* 48, no. 1: 1b–5b.

Patel, S., G. Krastl, R. Weiger, et al. 2023. "ESE Position Statement on Root Resorption." *International Endodontic Journal* 56, no. 7: 792–801.

Patterson, S. S., and D. F. Mitchell. 1965. "Calcific Metamorphosis of the Dental Pulp." *Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology* 20, no. 1: 94–101.

Pedorella, C. A., R. D. Meyer, and G. W. Woollard. 2000. "Whitening of Endodontically Untreated Calcified Anterior Teeth." *General Dentistry* 48, no. 3: 252–255.

Peumans, M., J. De Munck, S. Fieuws, P. Lambrechts, G. Vanherle, and B. Van Meerbeek. 2004. "A Prospective Ten-Year Clinical Trial of Porcelain Veneers." *Journal of Adhesive Dentistry* 6, no. 1: 65–76.

Pilecco, R. O., M. R. Konzen, F. S. Binotto, G. K. R. Pereira, and A. Bacchi. 2025. "Enhancing the Opacity of Glass Ceramics by Applying Opaque Stains to the Intaglio Surface." *Journal of Esthetic and Restorative Dentistry* 37, no. 8: 2021–2031.

Plotino, G., L. Buono, N. M. Grande, C. H. Pameijer, and F. Somma. 2008. "Nonvital Tooth Bleaching: A Review of the Literature and Clinical Procedures." *Journal of Endodontics* 34, no. 4: 394–407.

Powell, L. V., and D. J. Bales. 1991. "Tooth Bleaching: Its Effect on Oral Tissues." *Journal of the American Dental Association (1939)* 122, no. 11: 50–54.

Prashanth, D. 2017. "Recent Advancements in Medicated Root Canal Sealers: An Advanced Step in Creating Bacteria Free Obturation." *International Journal of Applied Oral Sciences* 3, no. 3: 37–41.

Rinke, S., L. Bettenhauser-Hartung, A. Leha, M. Rodiger, G. Schmalz, and D. Ziebolz. 2020. "Retrospective Evaluation of Extended Glass-Ceramic Ceramic Laminate Veneers After a Mean Observational Period of 10 Years." *Journal of Esthetic and Restorative Dentistry* 32, no. 5: 487–495.

Robertson, A., F. M. Andreasen, G. Bergenholtz, J. O. Andreasen, and J. G. Noren. 1996. "Incidence of Pulp Necrosis Subsequent to Pulp Canal Obliteration From Trauma of Permanent Incisors." *Journal of Endodontics* 22, no. 10: 557–560.

Rotstein, I. 2019. "Tooth Discoloration and Bleaching of Non-Vital Teeth." In *Ingles Endodontics*, edited by I. Rotstein and J. I. Ingle, 1203–1214. PMPH USA, Ltd.

Rotstein, I., Z. Lehr, and I. Gedalia. 1992. "Effect of Bleaching Agents on Inorganic Components of Human Dentin and Cementum." *Journal of Endodontics* 18, no. 6: 290–293.

Rotstein, I., Y. Torek, and R. Misgav. 1991. "Effect of Cementum Defects on Radicular Penetration of 30% $H_2O_2$ During Intracoronal Bleaching." *Journal of Endodontics* 17, no. 5: 230–233.

Rotstein, I., D. Zyskind, I. Lewinstein, and N. Bamberger. 1992. "Effect of Different Protective Base Materials on Hydrogen Peroxide Leakage During Intracoronal Bleaching In Vitro." *Journal of Endodontics* 18, no. 3: 114–117.

Schlichting, L. H., K. Stanley, M. Magne, and P. Magne. 2015. "The Non-Vital Discolored Central Incisor Dilemma." *International Journal of Esthetic Dentistry* 10, no. 4: 548–562.

Setzer, F. 2020. "Bleaching Procedures." In *Pathways of the Pulp*, edited by L. H. Berman and K. M. Hargreaves, 12th ed., e2–e22. Elsevier.

Shinohara, M. S., A. R. Peris, L. A. Pimenta, and G. M. Ambrosano. 2005. "Shear Bond Strength Evaluation of Composite Resin on Enamel and Dentin After Nonvital Bleaching." *Journal of Esthetic and Restorative Dentistry* 17, no. 1: 22–29.

Shinohara, M. S., A. R. Peris, J. A. Rodrigues, L. A. Pimenta, and G. M. Ambrosano. 2004. "The Effect of Nonvital Bleaching on the Shear Bond Strength of Composite Resin Using Three Adhesive Systems." *Journal of Adhesive Dentistry* 6, no. 3: 205–209.

Shinohara, M. S., J. A. Rodrigues, and L. A. Pimenta. 2001. "In Vitro Microleakage of Composite Restorations After Nonvital Bleaching." *Quintessence International* 32, no. 5: 413–417.

Shokouhinejad, N., M. Khoshkhounejad, M. Alikhasi, P. Bagheri, and J. Camilleri. 2018. "Prevention of Coronal Discoloration Induced by Regenerative Endodontic Treatment in an Ex Vivo Model." *Clinical Oral Investigations* 22, no. 4: 1725–1731.

Shokouhinejad, N., M. H. Nekoofar, S. Pirmoazen, A. R. Shamshiri, and P. M. Dummer. 2016. "Evaluation and Comparison of Occurrence of Tooth Discoloration After the Application of Various Calcium Silicate-Based Cements: An Ex Vivo Study." *Journal of Endodontics* 42, no. 1: 140–144.

Shokouhinejad, N., H. Razmi, M. Farbod, M. Alikhasi, and J. Camilleri. 2019. "Coronal Tooth Discoloration Induced by Regenerative Endodontic Treatment Using Different Scaffolds and Intracanal Coronal Barriers: A 6-Month Ex Vivo Study." *Restorative Dentistry & Endodontics* 44, no. 3: e25.

Signore, A., S. Benedicenti, V. Kaitsas, M. Barone, F. Angiero, and G. Ravera. 2009. "Long-Term Survival of Endodontically Treated, Maxillary Anterior Teeth Restored With Either Tapered or Parallel-Sided Glass-Fiber Posts and Full-Ceramic Crown Coverage." *Journal of Dentistry* 37, no. 2: 115–121.

Silva, A. A., F. G. Belladonna, G. Rover, et al. 2020. "Does Ultraconservative Access Affect the Efficacy of Root Canal Treatment and the Fracture Resistance of Two-Rooted Maxillary Premolars?" *International Endodontic Journal* 53, no. 2: 265–275.

Silva-Sousa, A. C., M. D. Sousa-Neto, R. V. Camargo, et al. 2024. "Influence of Minimally Invasive Cavities on Color Stability of Dental



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Crowns With Different Filling Sealers." *Brazilian Oral Research* 38: e104.

Souza, M., D. Cecchin, J. V. Barbizam, et al. 2013. "Evaluation of the Colour Change in Enamel and Dentine Promoted by the Interaction Between 2% Chlorhexidine and Auxiliary Chemical Solutions." *Australian Endodontic Journal* 39, no. 3: 107–111.

Stavropoulou, A. F., and P. T. Koidis. 2007. "A Systematic Review of Single Crowns on Endodontically Treated Teeth." *Journal of Dentistry* 35, no. 10: 761–767.

Sulieman, M. A. 2008. "An Overview of Tooth-Bleaching Techniques: Chemistry, Safety and Efficacy." *Periodontology 2000* 48: 148–169.

Sulikowski, A. V., and O. Yoshida. 2001. "Clinical and Laboratory Protocol for Porcelain Laminate Restorations on Anterior Teeth." *Quintessence of Dental Technology* 24: 8–22.

Suzuki, A. 2014a. "Opacity Control Using Pressed Ceramic: Part 1: Material Selection." *Quintessence of Dental Technology* 37: 149–156.

Suzuki, A. 2014b. "Opacity Control Using Pressed Ceramic: Part 2: Layering Guidelines." *Quintessence of Dental Technology* 37: 185–196.

Taha, N. A., and M. A. Khazali. 2017. "Partial Pulpotomy in Mature Permanent Teeth With Clinical Signs Indicative of Irreversible Pulpitis: A Randomized Clinical Trial." *Journal of Endodontics* 43, no. 9: 1417–1421.

Thomson, A. D., B. Athanassiadis, B. Kahler, and L. Walsh. 2012. "Tooth Discolouration: Staining Effects of Various Sealers and Medicaments." *Australian Endodontic Journal* 38, no. 1: 2–9.

Tong, L. S., M. K. Pang, N. Y. Mok, N. M. King, and S. H. Wei. 1993. "The Effects of Etching, Micro-Abrasion, and Bleaching on Surface Enamel." *Journal of Dental Research* 72, no. 1: 67–71.

Traviglia, A., D. Re, L. De Micheli, A. E. Bianchi, and C. Coraini. 2019. "Speed Bleaching: The Importance of Temporary Filling With Hermetic Sealing." *Int J Esthet Dent* 14, no. 3: 310–323.

Tsukiboshi, M., Y. Berlin-Broner, and L. Levin. 2024. "Transient Apical Breakdown: Incidence, Pathogenesis, and Healing." *Dental Traumatology* 41: 72–79.

Uesrichai, N., A. Nirunsittirat, P. Chuveera, T. Srisuwan, T. Sastraruji, and P. Chompu-Inwai. 2019. "Partial Pulpotomy With Two Bioactive Cements in Permanent Teeth of 6- to 18-Year-Old Patients With Signs and Symptoms Indicative of Irreversible Pulpitis: A Noninferiority Randomized Controlled Trial." *International Endodontic Journal* 52, no. 6: 749–759.

Usta, S. N., and C. Keskin. 2024. "Color Stability and Solubility of Biodentine and NeoPutty in Contact With Different Irrigation Solutions." *Restor Dent Endod* 49, no. 3: e25.

Uzunoglu, E., A. Eymirli, M. O. Uyanik, E. Nagas, and Z. C. Cehreli. 2018. "Fracture Resistance of Simulated Immature Teeth After Internal Bleaching Procedures." *Australian Endodontic Journal* 44, no. 3: 235–239.

van de Sande, F. H., R. R. Moraes, R. V. Elias, et al. 2019. "Is Composite Repair Suitable for Anterior Restorations? A Long-Term Practice-Based Clinical Study." *Clinical Oral Investigations* 23, no. 6: 2795–2803.

Wang, J. D., and W. R. Hume. 1988. "Diffusion of Hydrogen Ion and Hydroxyl Ion From Various Sources Through Dentine." *International Endodontic Journal* 21, no. 1: 17–26.

Waterhouse, P. J., and J. H. Nunn. 1996. "Intracoronal Bleaching of Nonvital Teeth in Children and Adolescents: Interim Results." *Quintessence International* 27, no. 7: 447–453.

Watts, A., and M. Addy. 2001. "Tooth Discolouration and Staining: A Review of the Literature." *British Dental Journal* 190, no. 6: 309–316.

Wayakanon, K., C. Kamiam, R. Khamlue, A. Daengla, and S. Naorungroj. 2025. "Masking Discolored Substrates With Lithium Disilicate Veneers and Resin Cements: An In Vitro Quantitative Analysis." *Journal of Dentistry* 162: 106038.

White, D. J., K. M. Kozak, J. R. Zoladz, H. Duschner, and H. Gotz. 2002. "Peroxide Interactions With Hard Tissues: Effects on Surface Hardness and Surface/Subsurface Ultrastructural Properties." *Compendium of Continuing Education in Dentistry* 23, no. 1A: 42–48.

Yanikian, C., F. Yanikian, D. Sundfeld, R. Lins, and L. Martins. 2019. "Direct Composite Resin Veneers in Nonvital Teeth: A Still Viable Alternative to Mask Dark Substrates." *Operative Dentistry* 44, no. 4: E159–E166.

Zalkind, M., J. R. Arwaz, A. Goldman, and I. Rotstein. 1996. "Surface Morphology Changes in Human Enamel, Dentin and Cementum Following Bleaching: A Scanning Electron Microscopy Study." *Endodontics & Dental Traumatology* 12, no. 2: 82–88.

Zanolla, J., A. Marques, D. C. da Costa, A. S. de Souza, and M. Coutinho. 2017. "Influence of Tooth Bleaching on Dental Enamel Microhardness: A Systematic Review and Meta-Analysis." *Australian Dental Journal* 62, no. 3: 276–282.

Zehnder, M., P. Schmidlin, B. Sener, and T. Waltimo. 2005. "Chelation in Root Canal Therapy Reconsidered." *Journal of Endodontics* 31, no. 11: 817–820.

Zhu, Z. 2023. "Transient Apical Breakdown of a Discoloured Maxillary Central Incisor During Orthodontic Treatment: A Case Report." *Australian Endodontic Journal* 49, no. Suppl 1: 476–480.

Zizka, R., S. Belak, J. Sedy, K. Facevicova, I. Voborna, and D. Marincak. 2021. "Clinical and Radiographic Outcomes of Immature Teeth Treated With Different Treatment Protocols of Regenerative Endodontic Procedures: A Retrospective Cohort Study." *Journal of Clinical Medicine* 10, no. 8: 1600.



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