

# The single discoloured tooth: vital and non-vital bleaching techniques

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## Key points

Demonstrates the approach to the management of the single discoloured tooth.

Highlights the aetiologies of the single discoloured tooth.

Discusses bleaching techniques available for the management of the single discoloured tooth.

## Abstract

The single discoloured tooth poses an aesthetic dilemma. While several treatment approaches are available, bleaching offers a minimally invasive, aesthetic treatment modality. Predictability and success with bleaching stems from correct diagnosis, didactic treatment planning and the utilisation of appropriate techniques. This article aims to discuss the aetiologies of a single discoloured tooth and, through evaluation of the literature and discussion of clinical cases, explore the theory, safety and bleaching techniques available.

## Introduction

Single tooth discolouration can be an important aesthetic concern to patients. There are several different approaches to the management of the single discoloured tooth and the treatment choice is often dependent on a range of factors including: the cause of discolouration, operator experience, patient finances, patient wishes, coronal tooth structure remaining, and previous treatment. With more patients now retaining their teeth for longer, selecting treatment options with the least biological costs should be highly prioritised.

Intracoronary bleaching, also known as non-vital bleaching, has been around since 1848,<sup>1</sup> when chloride of lime was placed inside the pulp chamber and utilised as an oxidising agent. Since 1848, bleaching techniques for the management of the single discoloured tooth have evolved to maximise safety and

predictability. In this paper, through evaluation of the literature and discussion of clinical cases, contemporary bleaching techniques for the management of a single discoloured tooth will be discussed.

## Aetiology

Obtaining a correct diagnosis through detailed history taking, examinations and special tests is key to ensure that the most appropriate management is provided. It is, therefore, necessary that dental practitioners are aware of the aetiology of tooth discolouration, to arrive at a correct diagnosis leading to an appropriate treatment plan. Discolouration of a single tooth may result from numerous aetiologies (Figs 1, 2, 3, 4) including, but not limited to:<sup>2,3</sup>

- Intrapulpal haemorrhage following trauma, where blood enters the dentinal tubules and then decomposes leading to a deposit of chromogenic blood degradation products, such as haemosiderin, hemine, haematin and haematoidin
- Pulpal necrosis leading to chromogenic degradation products
- Root canal cement or gutta percha remaining in the coronal portion of the pulp chamber
- Failure to completely remove the pulp and pulp horns

- Combining sodium hypochlorite, even at low concentrations, and chlorhexidine during irrigation, may result in formation of brownish-red precipitate
- Dental caries
- Failing or leaking coronal restorations
- Cervical resorption
- Calcific metamorphosis
- Enamel hypoplasia/ hypomineralisation defects resulting from disturbances to the developing tooth germ
- Malaligned/in-standing tooth which due to an increased susceptibility to extrinsic staining and shadowing, may appear discoloured.

## Initial examination

### History

A detailed history, especially relating to the single discoloured tooth, is essential to aid in the diagnosis of discolouration aetiology. History-taking should be methodical and systematic. Questioning regarding the duration, progression, precipitating factors, habits (such as smoking), trauma, pain and previous treatment is key. Evaluation of the patient's presenting complaint is also essential, as this may provide insight into the patient's expectations. Patients with unrealistic expectations can be problematic

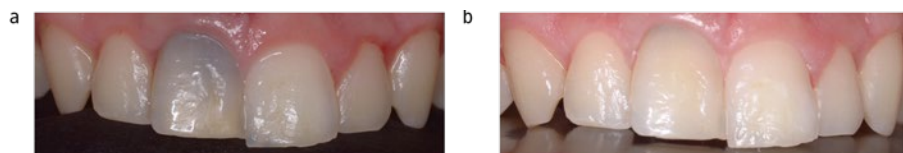
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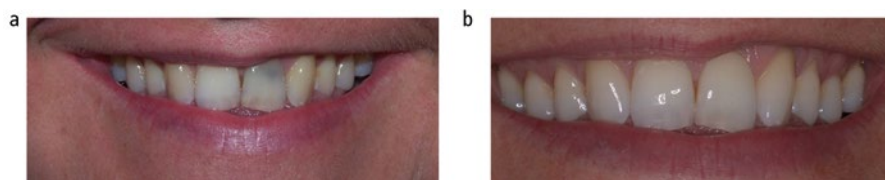
Refereed Paper.

Accepted 4 March 2019

DOI: 10.1038/s41415-019-0373-9



**Fig. 1** a) A labial view demonstrating a discoloured non-vital upper right central incisor. The tooth presented with a grey/black discoloration as a result of intra-pulpal haemorrhage following trauma at the age of 12. Despite the patient being under the age of 18 (age 14 at presentation), a decision to undertake single tooth bleaching was agreed upon, as bleaching was being utilised wholly for the treatment of dental disease.<sup>4</sup> Following isolation, the access cavity was re-opened, appropriately refined and debrided, to ensure complete removal of the remnants of the pulp and pulp horns. Root canal treatment was completed and a RMGIC barrier prepared as described below. The 16% CP gel was placed into the access cavity, followed by a PTFE mesh and sealed in with a 3 mm thick RMGIC restoration. The 'single tooth' bleaching tray was delivered to the patient and the patient instructed on placement of the bleaching gel into the labial section of the bleaching tray corresponding with the discoloured tooth; b) a labial view showing the tooth post-two weeks of bleaching utilising the closed inside/outside bleaching technique. Despite grey discoloration remaining in the cervical region of the tooth, the patient was extremely satisfied with the result



**Fig. 2** a) A labial view demonstrating a discoloured upper left central incisor following root canal treatment. The grey discoloration in the cervical region of the tooth is common and typically results from a failure to sufficiently reduce the gutta percha below the CEJ or gingival margin. Re-access of the tooth revealed endodontic sealer and pulpal remnants in the pulp chamber which also contributed to the discoloration; b) a post-operative labial view of the tooth. After adequate debridement of the pulp chamber and appropriate reduction of the GP, a distinct improvement in the discoloration was noted. A RMGIC barrier, as described below was then prepared. The 16% CP gel was placed into the access cavity, followed by a PTFE mesh and sealed in with a 3 mm thick RMGIC restoration. The 'single tooth' bleaching tray was delivered to the patient who was instructed on placement of the bleaching gel into the labial section of the bleaching tray corresponding with the discoloured tooth (as described in the inside/outside closed bleaching technique)



**Fig. 3** A labial view demonstrating a discoloured upper left central incisor. The patient had a history of trauma and despite the discoloration, the tooth remained vital. The loss of translucency and yellowing of the tooth, especially in the incisal third of the clinical crown is common with calcific metamorphosis

with regards to bleaching. An example of unrealistic expectations for bleaching would be a patient whose primary concern relates to discoloration associated with recession.

If a history of trauma is provided, details regarding the timing, type of trauma, and treatment undertaken is essential. Traumatized teeth may display a reversible pink discoloration that occurs 2–3 days following injury, which only requires clinical monitoring as a course of action.<sup>5</sup> Discoloration can take 2–3 months to resolve in traumatized teeth following survival or revascularisation of the pulp.<sup>6</sup> It is also worth noting that discoloration following trauma may be delayed by 2–3 months.



**Fig. 4** Labial views demonstrating discoloration of the upper left central and lateral incisors. The patient suffered trauma to the primary dentition at the age of five, resulting in damage to the developing tooth germ and an enamel defect on the labial surface of the permanent central incisors. Using a 'single tooth' bleaching tray that incorporated both central incisors, bleaching agent was applied from the external surface alone. It is essential to continue with the bleaching treatment until the discoloration has been completely removed, as shown in the during and after images

### Extraoral and intraoral examination

Following a detailed history, a comprehensive extraoral and intraoral examination is required. The colour and presentation of the discoloration may aid in the diagnosis. The range of colours associated with non-vital discoloration is vast. In severe discolorations, the tooth can appear black, purple or deep brown; in moderate discolorations the tooth can range in colour from light brown to grey; or in mild discolorations the non-vital tooth is only slightly darker than the neighbouring tooth.<sup>7</sup> External cervical resorption may present as pink discoloration at the cervical region of a tooth. Calcific metamorphosis may present as a yellow discoloration associated with a lack of lustre and translucency. It is commonly seen as early as three months after traumatic tooth injury in up to 24% of traumatized teeth.<sup>8</sup>

### Aesthetic evaluation

A comprehensive aesthetic evaluation must be undertaken at the initial examination. This must include an initial shade evaluation

of both the single discoloured tooth and the entire dentition. Other factors to evaluate include length and diameter of the discoloured and adjacent teeth, smile symmetry, gingival display and gingival architecture with associated lip lines; identification of any white spot and brown spot lesions; identification of translucency related discolourations; and identification of any restorations in the anterior region. Evaluation of the quality and quantity of remaining tooth structure must be assessed and alternative treatment options discussed.

It is essential that, before bleaching, patients with existing white spot lesions are warned these may become more noticeable during bleaching, especially during the first few days of treatment.<sup>9</sup> This is commonly referred to as the 'splotchy stage' of treatment and occurs as a result of the bleaching agent penetrating the weakest part of the tooth first, which is commonly the white spot lesion.<sup>9</sup> Although this may resolve following completion of bleaching, further treatment may be required post-bleaching, such as resin infiltration or microabrasion.

Additionally, patients should be warned before bleaching that restorations in the anterior may require replacement post-bleaching due to the shade no longer being harmonious with that of the bleached dentition.

### Special tests and radiographic assessment

It is essential that single discoloured teeth undergo relevant special tests before treatment. Calcific metamorphosis may result in a negative response to thermal testing and electric pulp testing, despite remaining vital and as such should be supplemented by an appropriate periapical radiograph.

A good quality periapical radiograph is also required in cases of discolouration resulting from trauma, pulp necrosis or previous endodontic or root canal treatment. Radiographic assessment of previous endodontic treatment should also be used to aid in the assessment of the need for secondary endodontic treatment before bleaching. Further information regarding indications for secondary endodontic treatment before bleaching can be found in the European Society of Endodontology quality guidelines for endodontic treatment.<sup>10</sup> Radiographs should also be assessed for periapical pathology, potential pulp anatomical complications, pulp canal obliteration, failing restorations, caries and resorption (both internal and external).

### Initial treatment

Prior to undertaking bleaching, existing carious lesions, periodontal disease and periapical pathology should be managed, as bleaching treatment can exacerbate existing periapical lesions. An initial dental prophylaxis is also recommended before impression-taking for bleaching trays to remove extrinsic staining and to assess the colour of the labial enamel.

Intraoral photography is also very useful when undertaking bleaching treatment. A labial view with a shade tab correlating to the darkest tooth, placed in the region of the canine is essential and allows vital comparisons for the progression of bleaching treatment.

### Alternate treatment options

Following initial treatment, treatment planning for the single discoloured tooth can commence. Detailed discussions with the patient, including detailing the risks and benefits of treatment, as well as alternative treatments, is essential to ensure valid informed consent is obtained. A list of alternative treatment options for a single discoloured tooth are provided in Box 1.

### Bleaching indications and contraindications

Indications for bleaching of the single discoloured tooth include:

- Discolourations of pulp chamber origin
- Dentine discolourations
- Discolourations resulting from calcific metamorphosis
- Enamel hypoplasia/hypomineralisation discolourations.

Enamel hypoplasia and hypomineralisation discolourations may require additional treatment to completely mask the discolouration.

Contraindications to undertaking bleaching include:

- Pregnancy and breastfeeding
- Patients with unrealistic expectations regarding the aesthetic outcome
- Patients exhibiting or with a history of extreme dental sensitivity
- Insufficient coronal tooth tissue to allow sealing of bleaching material inside the pulp chamber
- Teeth with deep surface cracks and fracture lines
- Existing crowns or large restorations in the aesthetic smile zone

#### Box 1 A list of alternative treatment options for the single discoloured tooth in order of invasiveness

1. Review and monitor
2. Scale and polish
3. Micro abrasion
4. Mega abrasion
5. Direct composite veneer
6. Porcelain veneer
7. Full coverage crown
8. Extraction and prosthetic replacement

- Teeth with caries and periapical lesions
- Symptomatic teeth.

Existing restorations or crowns may be considered a contraindication for patients unwilling to replace the restorations or whereby financial burden limits the replacement of the restorations or crowns. As mentioned previously, caries and periapical lesions should be treated before undertaking bleaching.

### Factors influencing the prognosis of intracoronal bleaching

#### Duration of discolouration

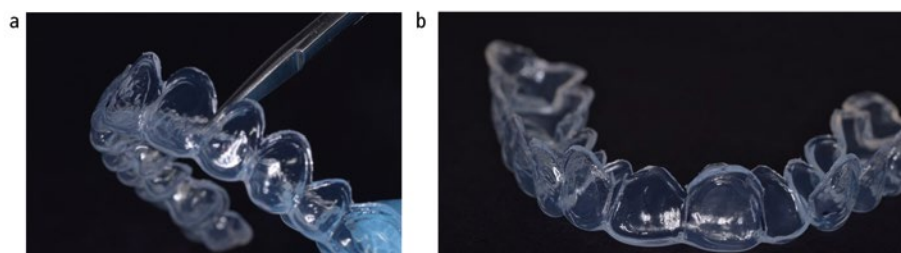
The shorter the duration of the discolouration, the greater the success of bleaching. Brown<sup>11</sup> conducted a retrospective study of 68 patients and 80 bleached teeth to examine factors affecting bleaching. It was found that, of teeth which had been discoloured for less than one year, 87.5% were successfully bleached; whereas teeth discoloured over five years successfully bleached 66% of the time. This is thought to result from a more complex integration of the discolouration into the dentine.

#### Intensity of discolouration

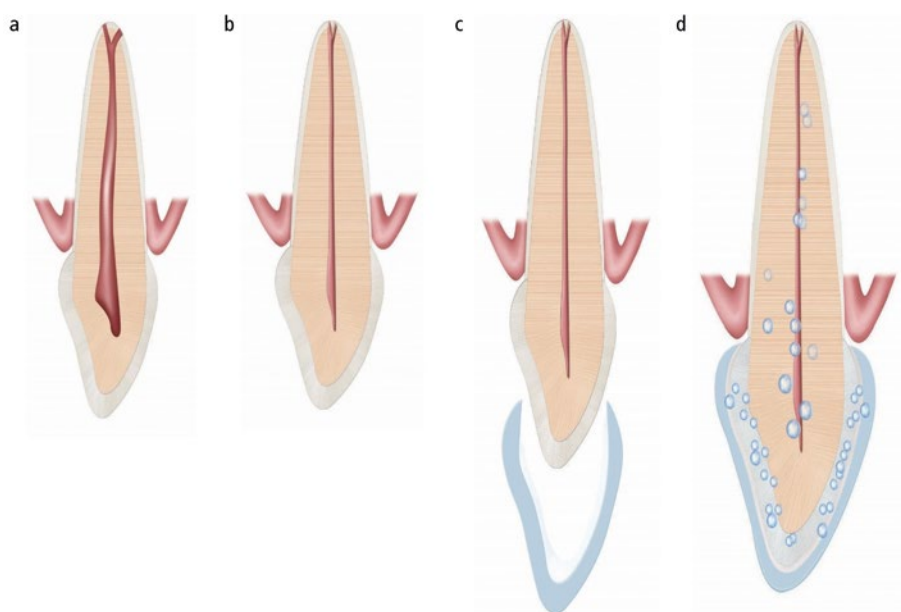
According to Brown,<sup>11</sup> severely discoloured teeth bleached successfully in 75% of cases; however, slight or moderate discolourations bleached successfully in 90–100% of cases

#### Patient's age

There is much discussion in the literature regarding whether age is a prognostic factor for intracoronal bleaching. Brown<sup>11</sup> found no direct link between age and success, and this has been reiterated by further research.<sup>12</sup> However, Dietz reported a direct correlation between age and success.<sup>13</sup> Camps *et al.* evaluated the diffusion of 20% hydrogen peroxide (HP)



**Fig. 5** A 'single tooth' bleaching tray is made by marking the labial surfaces of the teeth adjacent to the target tooth and using a pair of sharp tissue scissors to remove the labial surface of the adjacent teeth. Reproduced with permission from L H Greenwall (ed). *Tooth Whitening Techniques*. 2nd ed. London: CRC Press, 2017, Taylor & Francis



**Fig. 6** a) Initial pulp complex before trauma; b) a diagrammatic representation, demonstrating the rapid deposition of hard tissue in the pulp canal space as a result of calcific metamorphosis; c) use of a 'single tooth' bleaching tray allows bleaching agent to be applied externally to the discoloured tooth alone; d) bleaching agent rapidly diffuses through the tooth, reaching the pulp in 5–15 minutes. This rapid diffusion ensures that discolourations within close proximity to the pulp can be sufficiently bleached with an external application

through human dentine in patients under 20 years old and in patients between 40 and 60 years old.<sup>14</sup> They found that the diffusive flux and maximal diffusion were higher through young teeth than through old teeth.

### Predictions for success of single tooth discolouration

The aetiology of discolouration is an important predictor for the success of bleaching. The prognosis for discolouration resulting from pulpal necrosis or endodontic sealers is usually good. However, discolourations resulting from metallic stains, silver containing medicaments or metal oxidation is less successful and may not be possible to be removed by bleaching alone.<sup>15</sup>

## Bleaching techniques

### Vital tooth bleaching

In certain cases, such as teeth with calcific metamorphosis, hypoplasia or hypomineralisation defects, teeth may remain vital despite being discoloured. Elective devitalisation should not be undertaken in these cases. Rather, a single tooth bleaching tray should be utilised to bleach the tooth from the external aspect.

A 'single tooth' bleaching tray (Fig. 5) is fabricated by removing the labial surface of the bleaching tray on the teeth adjacent to the discoloured tooth. The design of the bleaching tray is 0.035", soft, flexible, vacuum-formed, non-reservoir and scalloped (although this is

authors' preference and a non-scalloped design is also acceptable). Reservoirs or spacers have been shown to be unnecessary and therefore are not included in tray design.<sup>16</sup>

Bleaching of the discoloured tooth should be undertaken first, to allow for assessment of the response of the discoloured tooth to the bleaching agent. Teeth with calcific metamorphosis will take longer to bleach as a result of the increased dentine deposition (Fig. 6). Regular monitoring is required in such cases and bleaching should be continued until either the desired shade is reached or a failure of the shade to lighten between review appointments is noted. If needs be, bleaching of the remaining dentition can then be undertaken.

### Does external or internal bleaching effect success or rate of bleaching?

Many argue that teeth lighten faster when the bleaching agent is applied internally rather than externally. However, it is essential to realise that bleaching agents diffuse rapidly through teeth, reaching the pulp in 5–15 minutes when applied from the external surfaces.<sup>17</sup> Additionally, an *in vitro* study by McCaslin and Haywood in 1999<sup>18</sup> demonstrated that an externally applied bleaching agent provides a uniform change in the shade of dentine regardless of depth. This study suggests that even in discolouration associated in close proximity or within the pulp chamber, should be sufficiently bleached with externally applied bleaching agent.

## Endodontically treated anterior teeth

An endodontically treated tooth may discolour for several reasons, as discussed previously. Endodontically treated teeth can be bleached externally, internally or utilising a combination of both. Selection of treatment will be dependent on the aetiology of the discolouration (Fig. 7).

Discolourations associated with the cervical third of the crown are commonly associated with a failure to remove pulp horns in access cavity preparation, however, they can also result from a failure to remove endodontic material from the pulp chamber surface. Grey discolourations associated with the neck of the tooth commonly results from a failure to reduce the endodontic obturation sufficiently. This may further be confirmed from radiographic assessment. Discolourations may also be associated with microleakage or the incorrect shade selection of restorations.

If a tooth has discoloured despite receiving adequate endodontic treatment, thorough debridement and satisfactory restoration placement, external bleaching can be utilised as the first line of treatment. Each time restorations are removed and access cavities are extended, more tooth tissue is removed which ultimately weakens the tooth. This approach will require a thorough knowledge of the previous endodontic treatment. An example of a situation where external bleaching may be utilised, is a previously intracorally-bleached tooth which has discoloured as a result of bleaching relapse. In this situation, externally-applied bleaching can be utilised to 'top up' the previous bleaching treatment, without requiring re-access of the pulp chamber.

### Intracoronally bleaching of non-vital teeth

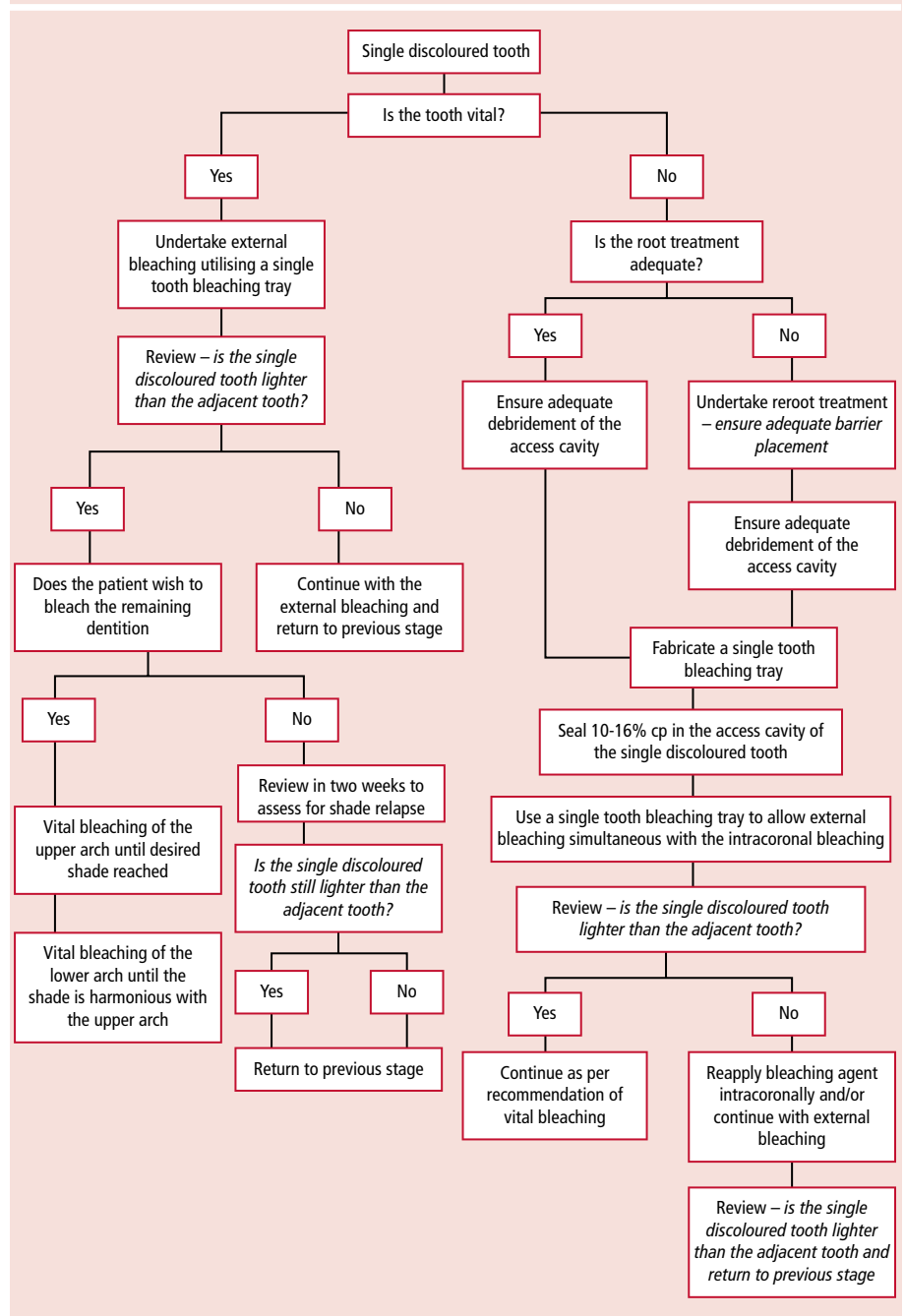
Intracoronally bleaching of non-vital teeth involves the use of oxidising agents in the coronal portion of an endodontically treated tooth to remove tooth discolourations.<sup>19</sup> There are several different techniques used for intracoronally bleaching.

#### In-office bleaching

In-office bleaching is one of the oldest forms of bleaching. Traditionally, in-office bleaching utilised high concentrations of HP or HP mixed with sodium perborate (SP), applied internally or externally. The bleaching agent may also have been supplemented with heat, referred to as thermocatalytic bleaching.

There are several issues associated with in-office bleaching. Firstly, appropriating shade is difficult as a result of dehydration and demineralisation, which is associated with the low pH and high concentration of HP used with the technique. Secondly, as will be discussed later, the use of heat and high concentrations of HP increases the risk of side effects, especially cervical resorption. Finally, there are additional concerns regarding the efficacy of in-office bleaching. Several clinical studies<sup>20,21,22</sup> have shown that at least two or three in-office bleaching sessions may be required to obtain a similar whitening degree as two or three weeks of at-home bleaching. While these studies have been undertaken on vital teeth, it still raises questions regarding the applicability of the technique for intracoronally use, especially with the increased risk of the procedure.

Fig. 7 A flowchart demonstrating the management of a single discoloured tooth



Finally, with EU Council Directive 2011/84/EU limiting the use of HP in the United Kingdom to less than 6%, one must further question the applicability of the technique in the United Kingdom.<sup>23</sup>

#### Walking bleach technique

In the early 1960s, several dentists realised that utilising the pulp space in non-vital teeth for the placement of a bleaching agent could be advantageous. In 1961, Spasser<sup>24</sup> described a method of sealing in a mixture of SP with water into the pulp chamber and leaving it for a week. Nutting and Poe<sup>25</sup> described a

modification of the technique in 1963, whereby SP and HP were sealed into the tooth and used synergistically to bleach the tooth. In 1988, Holmstrup *et al.*<sup>26</sup> demonstrated the clinical success of the walking bleach technique, utilising SP mixed with water. They reported that in 57 out of 95 teeth (60%) a good or acceptable result was obtained after one or two visits. The remaining 38 teeth (40%) were treated over three to nine visits successfully. No reports of cervical resorption were noted in the study.

Modifications of the technique have continued, mainly regarding the selection of

bleaching agent. In 2000, an *in vitro* study by Perrine *et al.*<sup>27</sup> compared 10% carbamide peroxide (CP) to the combination of SP and water as intracoronal bleaching agents. No significant difference was found between the two agents. SP has been banned by the European Commission,<sup>28</sup> and is not allowed for use in Europe. It is the authors' recommendation to utilise 10–16% CP for the technique to stay within the European guidelines.

In the walking bleach techniques, following barrier preparation (as described later) the bleaching agent is placed into the tooth over the barrier. The tooth is sealed with an appropriate palatal restoration. The patient is evaluated on a two-weekly basis and the procedure is repeated as appropriate until the desired shade has been achieved.

### The inside/outside open technique (IOO)

First described by Settembrini *et al.*<sup>29</sup> in 1997, and later modified by Liebenberg *et al.*,<sup>30</sup> this technique involves leaving the access cavity open following adequate barrier preparation and the patient directly applying the bleaching agent with a syringe into the access cavity and the bleaching tray. The bleaching tray is then seated into the mouth to cover the access cavity. The bleaching agent is subsequently replaced every 4–6 hours and the patient reviewed at 2–3 days to reassess the degree of lightening of the tooth.

In January 2018, a randomised control trial by Lise *et al.*,<sup>31</sup> compared the use of SP mixed with 20% HP in the walking bleach technique and the use of 10% CP in the inside/outside bleaching technique (open). No statistically significant difference between the techniques was noted, however the walking bleach technique was shown to take on average one week longer to reach the appropriate result. The results were shown to remain stable at one year.

### The inside/outside closed technique (IOC)

This technique, first described by Haywood and DiAngelis in 2010,<sup>32</sup> is a modification of the inside/outside technique described previously and is the authors' technique of choice for intracoronal bleaching.

The technique involves sealing the bleaching agent into the access cavity following appropriate barrier preparation, and then utilising a 'single tooth' bleaching tray, as described previously, to apply the bleaching agent from the external surface. A palatal restoration is placed to seal the bleaching

**Box 2** A list of suggestions for safer intracoronal bleaching. Adapted with permission from L H Greenwall (ed). *Tooth Whitening Techniques*. 2nd ed. London: CRC Press, 2017, Taylor & Francis

Delay bleaching following recent trauma  
Avoid heat  
Avoid etching before bleaching  
Avoid smear layer removal before bleaching  
Avoid high concentrations of bleaching agent (especially HP)  
Isolate the tooth effectively  
Protect the oral mucosa  
Verify adequate endodontic obturation  
Recall periodically

agent into the tooth. The bleaching tray is worn overnight until the desired shade is achieved or until the review appointment. Further re-application of the bleaching agent intracoronal can be undertaken at the review appointment, if needs be.

There are several advantages of the inside/outside closed (IOC) technique over the alternative techniques described earlier. Firstly, the technique reduced the risks associated with leaving an access cavity open such as microleakage, damage to the coronal seal, and food packing and trapping in the access cavity. Additionally, the technique allows control over the shade progression of the bleaching treatment, which is difficult in the walking bleach technique. The IOC technique also allows a more rapid result when compared to the walking bleach technique, as bleaching is undertaken frequently from the external surface in addition to the 'sealed in' bleaching agent.

Some may argue that IOC is not as quick as the IOO technique due to the increased frequency of bleaching agent applied internally in the IOO technique. However, for the reasons discussed earlier regarding internally-applied versus externally-applied bleaching agent, it is current opinion that this is not the case.

## Adverse effects

### External cervical resorption (ECR)

External root resorption is the progressive loss of dentine and cementum through the continued action of osteoclastic cells which remains localised to the cervical area of the root below the epithelial attachment.<sup>33,34</sup> Clinical reports<sup>35,36,37,38,39,40,41</sup> and histological studies<sup>42,43,44</sup> have demonstrated that intracoronal bleaching may induce ECR. The mechanism for this is not fully understood,

however this is believed to result from bleaching agent passage through the dentinal tubules and cemental defects, resulting in necrosis of the cementum, inflammation of the periodontal ligament and, finally, ECR.<sup>45</sup>

The literature highlights several risk factors associated with ECR and bleaching. These include:<sup>37,38,45,46</sup>

1. Use of HP concentration greater than 30%
2. Application of heat
3. A history of trauma
4. Orthodontic treatment
5. Presence of bacteria
6. No barrier over the gutta percha to protect the odontoblasts and dentinal tubules close to the cervical dentine.

A study by Heithersay<sup>46</sup> (1999) demonstrated that orthodontic treatment was the most important predisposing factor for ECR and bleaching. It is important to note that, in these cases, it is very difficult to determine if the root resorption was because of the bleach or the orthodontics/trauma. For reasons mentioned earlier regarding transient discolouration and for risks of ECR, delaying bleaching following trauma may be prudent.

Age has been suggested as a risk factor for ECR,<sup>37</sup> however a study by Friedman *et al.*<sup>47</sup> demonstrated that this may not be the case, with fewer than 20 patients experiencing ECR following bleaching with 30% HP than patients over 20 years of age and as such, age may not be a risk factor.

Suggestions for safer intracoronal bleaching are listed in Box 2. The use of acid etching with phosphoric acid or smear layer removal with EDTA and/or sodium hypochlorite before bleaching has been shown to have the potential to increase the dentinal permeability to bleaching agents and thus should be avoided.<sup>48,49</sup>

It must be stressed, however, that in this paper, the use of 10–16% CP (which is the equivalent of 3.4–5.4% HP) without heat is being advocated. There are no reported cases of ECR occurring with the lower strength CP or HP.

### Chemical burns

High concentrations of HP (30–35%) can cause chemical burns and sloughing of the gingiva. If using bleaching agents with such high concentrations, all oral soft tissues as well as the face and eyes of the patient should be protected from contact. Lip retractors, gingival barriers with appropriate light-cured flowable resin, cheek retractors and constant suction is required. Removal of the gel with careful aspiration followed by washing is required post-treatment. However, as mentioned previously, such high concentrations of HP are not permitted in the United Kingdom. Lower concentrations of HP and CP are unlikely to cause soft tissue damage during application and, by contrast, have the potential to be beneficial to surrounding mucosa.<sup>50</sup>

### Bond strength

Following bleaching, a reduction in bond strength by 25–50% to composite resin<sup>51</sup> occurs for a period of two weeks. This is believed to result from residual oxygen, resulting from the decomposition of the bleaching agent, remaining in the tooth structure and interacting with the formation of resin tags in the etched enamel. Bond strength to glass ionomer cements and resin-modified glass ionomer cements (GIC and RMGIC) remains normal following bleaching.<sup>52</sup> As such, placement of GIC or RMGIC in the access cavity immediately following bleaching is preferred to composite.

### Effect on tooth structure

An *in vitro* study by Carrasco-Guerisoli *et al.*<sup>53</sup> in 2009 examined the effect of intracoronal bleaching systems on surface morphology in bovine dentine. The study found that intracoronal bleaching systems have the potential to alter dentine morphology; HP products, especially those with low pH, had the greatest effect on dentine morphology. An *in vitro* study by Chng *et al.*<sup>54</sup> demonstrated that intracoronal bleaching undertaken with 35% HP gel, 30% HP solution and 35% CP gel has the potential to reduce the microhardness of dentine.

The significance of these findings, however, must be questioned, as both studies used concentrations of bleaching agents greater than is allowed for intracoronal bleaching in

the UK. Additionally, the use of composite resin to restore the tooth post-intracoronal bleaching has also been found to successfully restore the fracture resistance of the teeth.<sup>55</sup> Finally, the effect of dentine microhardness reduction resulting from the bleaching agents in comparison to the reduction in strength from loss of tooth tissue associated with root treatment may be insignificant.

### Key procedural steps for intracoronal bleaching

Regardless of the clinical technique utilised, there are several key procedural steps required to maximise the predictability and success of intracoronal bleaching.

#### Isolation

Intracoronal bleaching must always be undertaken with a rubber dam. Adaption of the rubber dam in the cervical region of the tooth is especially prudent.

#### Access cavity refinement and pulp chamber debridement

Tissue debris remaining in the pulp chamber will disintegrate gradually, resulting in breakdown products that may cause discolouration. It is essential to realise that access cavity preparation for endodontic treatment may not include a thorough debridement of the pulp chamber and, as such, debridement of the pulp chamber before bleaching treatment is essential. Ideally, all restorative material should be removed from the access cavity and the access cavity refined to ensure that the pulp horns and other areas containing pulpal material are appropriately debrided. Often, adequate debridement of the pulp chamber alone will result in a significant improvement in the discolouration.

It is worth noting that, in patients that have received endodontic treatment performed following trauma on younger teeth, the pulp chamber is large with high pulp horns. These patients may require extensive debridement before undertaking bleaching.

#### Barrier preparation

A protective barrier is essential in intracoronal bleaching to prevent leakage of bleaching agents between the gutta percha (GP) and the root canal walls. This is to ensure that the bleaching agent does not reach the periodontal ligament via dentinal tubules, lateral canals or root apex.<sup>7</sup>

A periodontal probe with Williams markings should be utilised to measure the height of the coronal tooth structure. Following this, 2–3 mm of GP should be removed appropriately, to allow the placement of a 2 mm thick resin-modified glass ionomer cement (RMGIC) barrier. This barrier should match the contour of the epithelial attachment, as proposed by Steiner and West.<sup>56</sup> It is essential that the barrier does not extend coronally beyond the gingival margin, as this may result in a subsequent grey discolouration (Fig. 2b).

Other materials that may be used for the barrier include polycarboxylate cements and glass ionomer cements; however, ideally a bond between dentine and material should be present. Acid etching before application of the bleaching agent has been suggested in order to remove the smear layer and allow for increased penetration of the oxidiser. However, Casey *et al.*<sup>57</sup> demonstrated that etching was not beneficial for intracoronal bleaching. Additionally, as mentioned previously, this has the potential to increase the dentinal permeability to bleaching agents, potentially increasing the risk of ECR.

#### Application of the bleaching agent

The bleaching agent must be packed into the access cavity, and excess removed with a cotton pellet. Ideally, a 3 mm thick temporary restorative material should be placed over the bleaching agent. Use of polytetrafluoroethylene (PTFE) mesh, placed over the bleaching agent, will aid in the placement of the temporary restorative material.

As mentioned previously, 10–16% CP is the authors' recommendation for bleaching a single dark tooth. This is due to the additional urea presenting in CP having beneficial cariostatic effects and an antibacterial effect, which have been shown to improve gingival scores.<sup>50,58,59</sup> Furthermore, carbopol, a slow oxygen-releasing agent present in CP, results in a steady slow release of oxygen, making the process sustainable through the night, unlike HP which releases all oxygen within 30 minutes.<sup>60</sup> Finally, as mentioned previously, HP is more commonly associated with adverse effects when compared to CP.

#### Single tooth bleaching tray

It is essential that a single discoloured tooth is bleached before undertaking further bleaching of the remaining dentition. This is to ensure that the response of the single discoloured tooth to bleaching can be sufficiently assessed



**Fig. 8** A labial view showing the discoloured, non-vital upper right central incisor at the initial examination

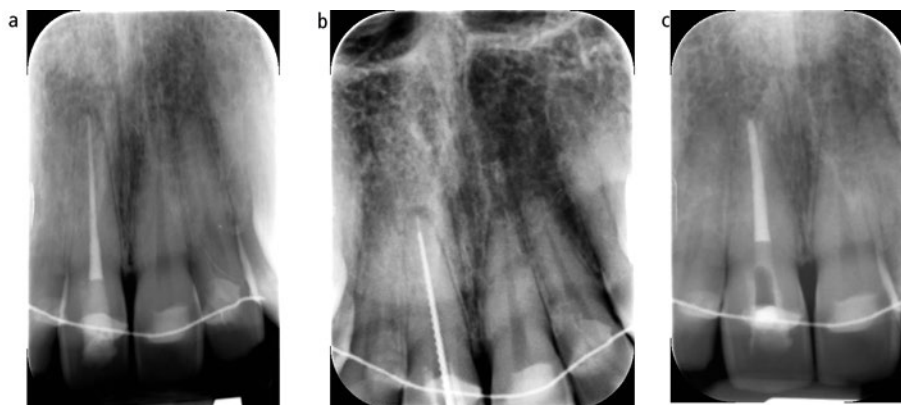
without altering the value of the adjacent teeth. As mentioned previously, a 'single tooth bleaching tray' allows the single dark tooth to be bleached externally, without bleaching the adjacent teeth. Additionally, the use of a single tooth bleaching tray helps to maintain the bleaching gel on the labial surface of the discoloured tooth and to continually replenish the fresh bleaching agent daily to enhance the bleaching effect.

### Review appointments

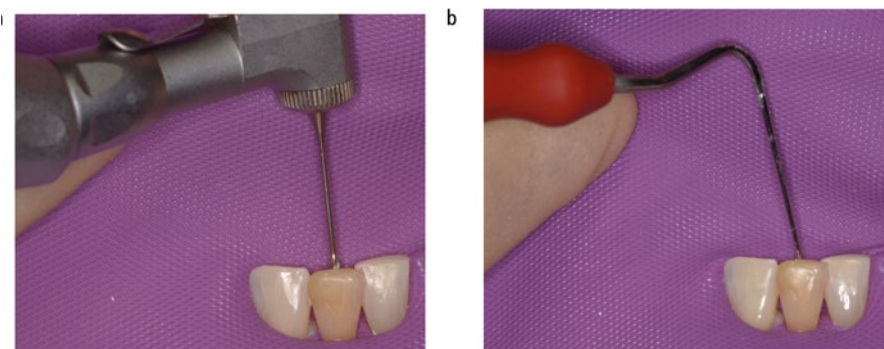
The average treatment time for single dark teeth is 6–8 weeks, although there is a wide range of variability.<sup>32</sup> Patients undertaking intracoronal bleaching should be reviewed at least on a two-week basis. This is to evaluate the response of the single dark tooth, appropriately manage any complications, to reassure and re-motivate the patient, and replace intracoronal bleaching agents if required. If the single discoloured tooth has sufficiently bleached to a shade lighter than the adjacent teeth, a two-week re-review is required to reassess the shade of the tooth following shade regression. Two weeks is sufficient time to allow oxygen to fully dissipate out of the bleached tooth and thus for a stable shade to be reached. Access cavity restoration.

As discussed previously, bond strength to composite resin is reduced by 25–50%<sup>51</sup> for up to two weeks post-bleaching. Additionally, as mentioned previously, shade regression occurs for two weeks following bleaching. As such, composite bonding should only be undertaken two weeks post-bleaching treatment to minimise microleakage and ensure sufficient shade matching. Bond strength to RMGIC and GIC is not reduced during bleaching and, as such, these restorative materials can be placed immediately.

If the endodontically treated tooth remains slightly darker than the remaining teeth post-bleaching, an opaque stark-white composite is used internally to the pulp chamber and provides an additional slight lightening of the tooth.<sup>32</sup>



**Fig. 9** a) A pre-operative periapical radiograph of the tooth in Fig. 8 showing a periapical lesion; b) a working length radiograph of the tooth; c) a periapical radiograph of the post-obturation and barrier placement. The material used for the barrier is resin-modified glass ionomer. Treatment undertaken by Endodontist Dr Jude Ferreira



**Fig. 10** The preparation of the apical barrier before application of the bleaching agent (pictures from a different patient). Reproduced with permission from L H Greenwall (ed). *Tooth Whitening Techniques*. 2nd ed. London: CRC Press, 2017, Taylor & Francis

### Recall appointments

Single discoloured bleached teeth should be frequently recalled and reviewed, clinically and radiographically. ECR can be detected as early as six months following bleaching. Early detection ensures the best prognosis for management of ECR.

### Case one

A 32-year-old male patient presented with a discoloured, non-vital upper right central incisor following a previous episode of trauma during orthodontic treatment with fixed braces. The patient had a lingual wire retainer (Fig. 8) placed on the six upper anterior teeth. The tooth had a dark yellow-brown discoloration, and this was causing concern to the patient. A periapical radiograph of the discoloured central incisor revealed a previous root treatment with an associated periapical lesion (Fig. 9). Discolouration was

believed to have resulted from a combination of intrapulpal haemorrhage and inadequate debridement of the pulp chamber.

After further assessment and discussions with the patient, a decision was made to undertake re-root treatment followed by intracoronal bleaching. The re-root canal treatment was carried out in two stages. An intracanal calcium hydroxide medication was placed into the access cavity as a dressing between appointments. Following isolation, the access cavity was re-opened, appropriately refined and debrided to ensure complete removal of the remnants of the pulp and pulp horns, which had previously not been removed. Furthermore, endodontic cement residue was appropriately cleaned and removed from the surface of the access cavity. Re-root treatment was undertaken. Following obturation, the height of the coronal tooth structure was measured using a periodontal probe with Williams markings. Following this, 2–3 mm of



GP was removed beyond the gingival margin (Fig. 10). This was verified using the Williams marking measurement. A 2 mm RMGIC (FUJI II, GC, Tokyo, Japan) protective barrier was applied over the gutta percha (Fig. 10) and a temporary restorative material was placed in the access cavity. Following completion of the root canal treatment (Fig. 9c), impressions were undertaken for an upper arch 'single tooth' bleaching tray.

One week later, the bleaching tray had been received and the patient returned for bleaching treatment. The temporary restorative material was removed and 16% CP (PolaNight, SDI, Bayswater, Australia) was applied into the access cavity. Teflon tape was rolled into a pellet and placed over the bleaching gel as a mesh so that the access cavity could be closed with a 3 mm thick RMGIC (Figs 11 and 12).

The patient was instructed how to correctly apply the bleaching gel into the single tooth tray (only in the region of the discoloured tooth on the labial section). The patient was instructed to change the bleaching gel at an interval of every 4–6 hours. It was explained to the patient that, if they preferred overnight bleaching the bleaching may progress at a slower rate. The patient was also instructed to stop applying the bleaching agent when the discoloured tooth was slightly lighter than the adjacent, non-discoloured tooth.

Two weeks later the patient was reviewed. At the review appointment, the non-vital tooth was still discoloured in comparison to the adjacent tooth. As such, the access cavity was re-opened and thoroughly cleaned. A new 16% CP bleaching agent was placed into the access cavity and the cavity was re-sealed. An appointment two weeks later was rearranged.

At the second two-week review, the shade of the bleached tooth was now lighter than the adjacent tooth. The access cavity was thoroughly cleaned and a temporary restorative material placed. A review in two weeks was scheduled for the patient to assess changes following shade regression. At the review, the shade of the tooth remained sufficiently brighter than the adjacent teeth.

The patient was now instructed to use a full arch, 0.035", soft, flexible, vacuum-formed scalloped, non-reservoir upper bleaching tray, so that all the upper teeth could be bleached to the same lighter shade. Following three weeks of bleaching, the shade of the upper dentition was harmonious, eventually reaching a B1 shade (Fig. 6). The cervical region of the bleached tooth remained slightly darker than the adjacent teeth (Fig. 6). The patient was warned that this might happen before commencing bleaching treatment, however as he had a low lip line he was delighted with the outcome of the whitening treatment.

Two weeks after commencement of bleaching, the patient returned and a composite restoration was placed into the access cavity of the treated central incisor. Two weeks ensured that the bond strength of the restorative material to the bleached tooth returned to normal, thus reducing the risk of microleakage.

### Case two

A 20-year-old female patient presented with a discoloured upper right central incisor, following an episode of trauma three years previously. The patient had previously received root canal treatment on the tooth by a different dentist and radiographic examination revealed a periapical lesion and an inadequately condensed obturation. Discolouration was believed to result from a combination of intrapulpal haemorrhage and failure to adequately debride the pulp chamber. Following discussions with the patient, a treatment plan was formulated involving re-root treatment and intracoronal bleaching of the affected tooth with an option to bleach the whole dentition if needs be. At this appointment, impressions were taken for a 'single tooth' bleaching tray.

Re-root treatment was undertaken and a RMGIC barrier prepared. The 16% CP gel was placed into the access cavity, followed by a PTFE mesh and then sealed in with a 3 mm thick RMGIC restoration. The 'single tooth' bleaching tray was delivered to the patient who was instructed on placement, as



**Fig. 11** Following application of the bleaching agent and the Teflon mesh, RMGIC was applied to seal in the bleaching agent (pictures from a different patient). Reproduced with permission from L H Greenwall (ed). *Tooth Whitening Techniques*. 2nd ed. London: CRC Press, 2017, Taylor & Francis



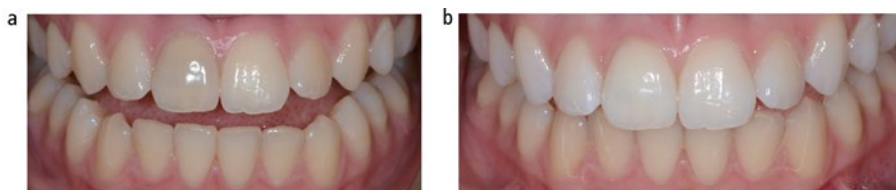
**Fig. 12** Following bleaching of the non-vital upper right central incisor when the tooth has lightened sufficiently, the entire upper arch is bleached with 10% carbamide peroxide in a full arch bleaching tray

described previously. The patient was reviewed frequently and the intracoronal bleaching agent was replaced three times until the tooth had sufficiently whitened. In total, eight weeks of single tooth bleaching was required.

Following a two-week review to assess for shade regression, a full arch upper bleaching tray was provided to the patient to bleach the upper arch. Once the upper arch reached a B1 shade, a lower bleaching tray was provided. Two weeks following bleaching, the previous RMGIC was removed, the pulp chamber appropriately cleaned and a resin composite placed as a definitive restoration for the tooth (Fig. 13).

### Case three

A 42-year-old female patient complained of a dark yellow, discoloured upper left central incisor (Fig. 14), following an episode of trauma 3–5 months previously. The tooth had progressively discoloured over this period and was now causing the patient concerns. Vitality testing of the tooth revealed that it remained vital despite the discolouration. Radiographic evaluation revealed obliteration



**Fig. 13** a) A labial view of a discoloured upper right central incisor upon presentation; b) a labial view following bleaching of the tooth and full upper arch bleaching



**Fig. 14** A labial view demonstrating a dark yellow discoloured upper left central incisor following trauma



**Fig. 15** A post-operative labial view showing a harmonious aesthetic result

of the pulp canal space. The diagnosis was that of discolouration from calcific metamorphosis. After further discussions with the patient, bleaching treatment was decided as the treatment of choice. At this appointment, impressions were taken for a 'single tooth' bleaching tray.

One week later, the single tooth tray was delivered to the patient, along with instructions to apply 16% CP only to the area of the bleaching tray corresponding to the single discoloured tooth. Traditionally, 10% CP is used for vital bleaching as this is optimum for maximising the rate of bleaching while minimising side effects, however in cases of calcific metamorphosis, due to less of a concern regarding sensitivity, a higher concentration bleaching agent can be used. It was explained to the patient that due to the calcific metamorphosis, bleaching of the discoloured tooth would take longer than average.

The patient was reviewed frequently; eight weeks of bleaching was required for the single discoloured tooth to sufficiently whiten. After a two-week review to reassess for shade regression, a full arch 0.035", soft, flexible, vacuum-formed scalloped, non-reservoir upper bleaching tray was provided to bleach the whole upper arch. Once all of the upper arch had reached a B1 shade, bleaching treatment was commenced on the lower arch (Fig. 15).

## Discussion

Externally-applied bleaching is a key component of successfully managing a single

discoloured tooth and is the least invasive of all approaches. This can be successfully utilised in cases of vital discoloured teeth and to 'top up' discoloured non-vital teeth with adequate endodontic treatment and restorations. Furthermore, externally-applied bleaching can be utilised to minimise complications associated with intracoronal bleaching, as demonstrated in the inside/outside closed bleaching technique, which is the authors' favoured treatment choice for intracoronal bleaching.

## Conclusion

The single discoloured tooth is an aesthetic challenge. Management can be complex, however through appropriate diagnosis, didactic treatment planning and appropriate treatment protocols, a predictable result is achievable. Bleaching provides a successful, minimally invasive treatment modality. The ability to provide treatment with minimal biological side effects continues to make bleaching a first line choice in cases presenting with a single discoloured tooth.

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