



CLINICAL ARTICLE

Pulp canal obliteration: an endodontic diagnosis and treatment challenge**P. S. McCabe¹ & P. M. H. Dummer²**¹Oranhill Dental Suite, Oranmore, Galway, Ireland; and ²School of Dentistry, Cardiff University, Cardiff, UK**Abstract****McCabe PS, Dummer PMH.** Pulp canal obliteration: an endodontic diagnosis and treatment challenge. *International Endodontic Journal*.**Aim** To review the literature on pulp chamber and root canal obliteration in anterior teeth and to establish a clear protocol for managing teeth with fine, tortuous canal systems.**Summary** Pulp canal obliteration (PCO) occurs commonly following traumatic injuries to teeth. Approximately 4–24% of traumatized teeth develop varying degrees of pulpal obliteration that is characterized by the apparent loss of the pulp space radiographically and a yellow discoloration of the clinical crown. These teeth provide an endodontic treatment challenge; the critical management decision being whether to treat these teeth endodontically immediately upon detection of the pulpal obliteration or to wait until symptoms or signs of pulp and or periapical disease occur. The inevitable lack of responses to normal sensibility tests and the crown discoloration add uncertainty to the management; however, only approximately 7–27% of teeth with PCO will develop pulp necrosis with radiographic signs of periapical disease. Root canal treatment of teeth with pulpal obliteration is often challenging. This article discusses the various management approaches and highlights treatment strategies for overcoming potential complications.**Key learning points**

- Up to 25% of traumatized anterior teeth can develop pulp canal obliteration;
- Discolouration is a common clinical finding in teeth with pulp canal obliteration;
- Up to 75% of teeth with pulp canal obliterations are symptom-free and require no treatment other than radiographic monitoring;
- Routine pulp sensibility tests are unreliable in the presence of pulp canal obliteration;
- Teeth with pulp canal obliteration in need of root canal treatment pose particular diagnostic and treatment challenges.

Keywords: dental trauma, discolouration, pulp canal obliteration, root canal treatment.

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Introduction

Pulp canal obliteration (PCO), also called calcific metamorphosis (CM), is a sequelae of tooth trauma and is reported to develop more often in teeth following concussion and subluxation injuries (Oginni & Adekoya-Sofowora 2007). It is characterized by the deposition of hard tissue within the root canal space and a yellow discoloration of the clinical crown. The exact mechanism of canal obliteration is unknown but is believed to be related to damage to the neurovascular supply of the pulp at the time of injury (Yaacob & Hamid 1986, Robertson 1998). It is the calcification of the pulp chamber that results in the darker hue, the loss of translucency and the yellowish appearance of the crown of the tooth (Pateresson & Mitchell 1965). Figures 1–4 show the typical clinical and radiographic appearances of teeth with pulpal obliteration. The condition may be recognized clinically as early as 3 months after the injury but in most cases is not detected for approximately 1 year (Andreasen 1970, Rock & Grundy 1981, Torneck 1990). Figures 5 and 6 illustrate the various radiographic stages of pulpal obliteration following a luxation injury to the maxillary central incisors of a 9-year-old male.

Aetiology and incidence

Pulp canal obliteration occurs commonly as a result of trauma and usually affects the anterior teeth of young adults. Holcomb & Gregory (1967) examined 882 servicemen and found that 34 of them had a total of 41 anterior teeth exhibiting partial or total obliteration of the pulp spaces, representing an incidence of 4%. Over a 4-year period, only 3 of the 41 teeth (7%) developed periapical rarefactions on radiographs.

Andreasen (1970) assessed 108 patients with 189 luxated permanent teeth over a mean observation period of 3.4 years; PCO was found in 42 teeth (22%).

In a study by Robertson *et al.* (1996), 82 concussed, subluxated, extruded, laterally luxated and intruded permanent incisors presenting with PCO were followed for a period of 7–22 years (mean 16 years). Radiographic periapical bone lesions suggestive of pulp necrosis and infection developed in seven teeth (9%); the incidence of pulpal necrosis in teeth with PCO increased over time.

Jacobsen & Kerekes (1977) conducted a follow-up study of traumatized teeth with radiographic evidence of PCO for an average of 16 years after the initial injury. Partial obliteration occurred in 36% of the cases, and total obliteration was found in 64%. Of the population studied, 13% demonstrated radiographic periapical change indicative of pulpal



Figure 1 Maxillary right lateral incisor showing the typical yellowish discoloration associated with pulp canal obliteration.

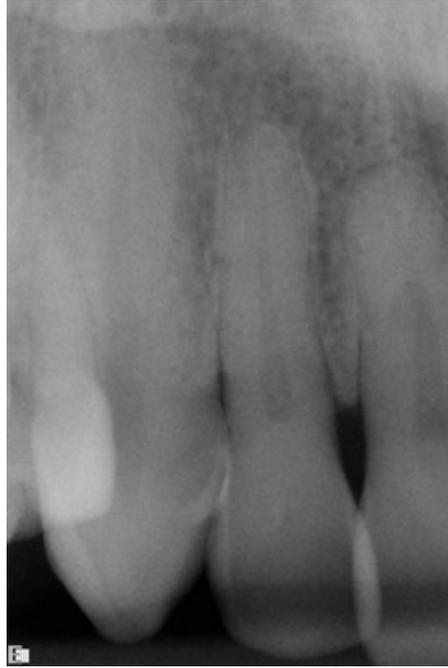


Figure 2 Radiographic periapical view of the maxillary lateral incisor as seen in Fig. 1. This shows partial obliteration of the pulp canal space.



Figure 3 Maxillary right central incisor showing marked discoloration. This grey discoloration is more commonly associated with pulpal necrosis following trauma rather than pulp canal obliteration.

necrosis and infection. All cases of pulpal necrosis were associated significantly with teeth that were severely injured and with complete root formation.

Stalhane & Hedegard (1975) carried out a long-term follow-up study on 76 teeth with PCO following trauma. The teeth were examined 3–21 years after the accident with 12 of the teeth (16%) developing a periradicular rarefaction during this period. Rock & Grundy (1981) found in a retrospective study of traumatized teeth that 16% developed PCO, mainly in younger patients.

It is generally accepted that the frequency of PCO is dependent on the extent of the luxation injury and the stage of root formation (de Cleen 2002). Pulpal obliteration after a concussion injury occurred in 3% of teeth with immature roots and 7% of teeth with



Figure 4 Periapical radiographic view of the same maxillary central incisor as seen in Fig. 3 showing complete pulp canal obliteration with associated periapical pathosis.

completely formed roots (Andreasen *et al.* 1987). The incidence of pulp obliteration after subluxation injuries is marginally higher; obliteration took place in 11% of teeth with immature roots and 8% of teeth with completely formed roots (Andreasen *et al.* 1987). After more accentuated luxation injuries, e.g. intruded, extruded, and laterally luxated teeth, both pulpal necrosis and pulpal obliteration are encountered more frequently (Andreasen *et al.* 1987). In these cases, pulpal necrosis occurs more often in teeth with complete root formation (Andreasen & Vestergaard Pedersen 1985), and pulp obliteration is more prevalent in teeth that have immature roots at the time of injury (Andreasen *et al.* 1987). Table 1 summarizes the studies that described the frequency of pulp necrosis following pulpal obliteration.

Clinical findings

Colour

A yellow discolouration or reduced transparency of the crown has been reported to occur in 79% of 122 teeth with pulpal obliteration (Jacobsen & Kerekes 1977). Robertson *et al.* (1996) found that 69% of the teeth in their study exhibited a yellow discoloration and 2.5% of the teeth (3 of 82 teeth examined) had grey discoloration. It was interesting to note that these three grey teeth reacted normally to sensibility tests. Although the numbers of teeth in this study were small, they suggest that a change in tooth colour was not a reliable indication of pulp or periapical pathosis (Jacobsen & Kerekes 1977, Robertson *et al.* 1996). In a more recent study (Oginni *et al.* 2009), of a total of 276 teeth with PCO, 186 (67%) had yellow discoloration and a further 34 (12%) teeth were grey. Although a greater number of teeth with grey discoloration had developed periapical lesions and had a negative electric pulp test response than those with yellow discoloration, the results were

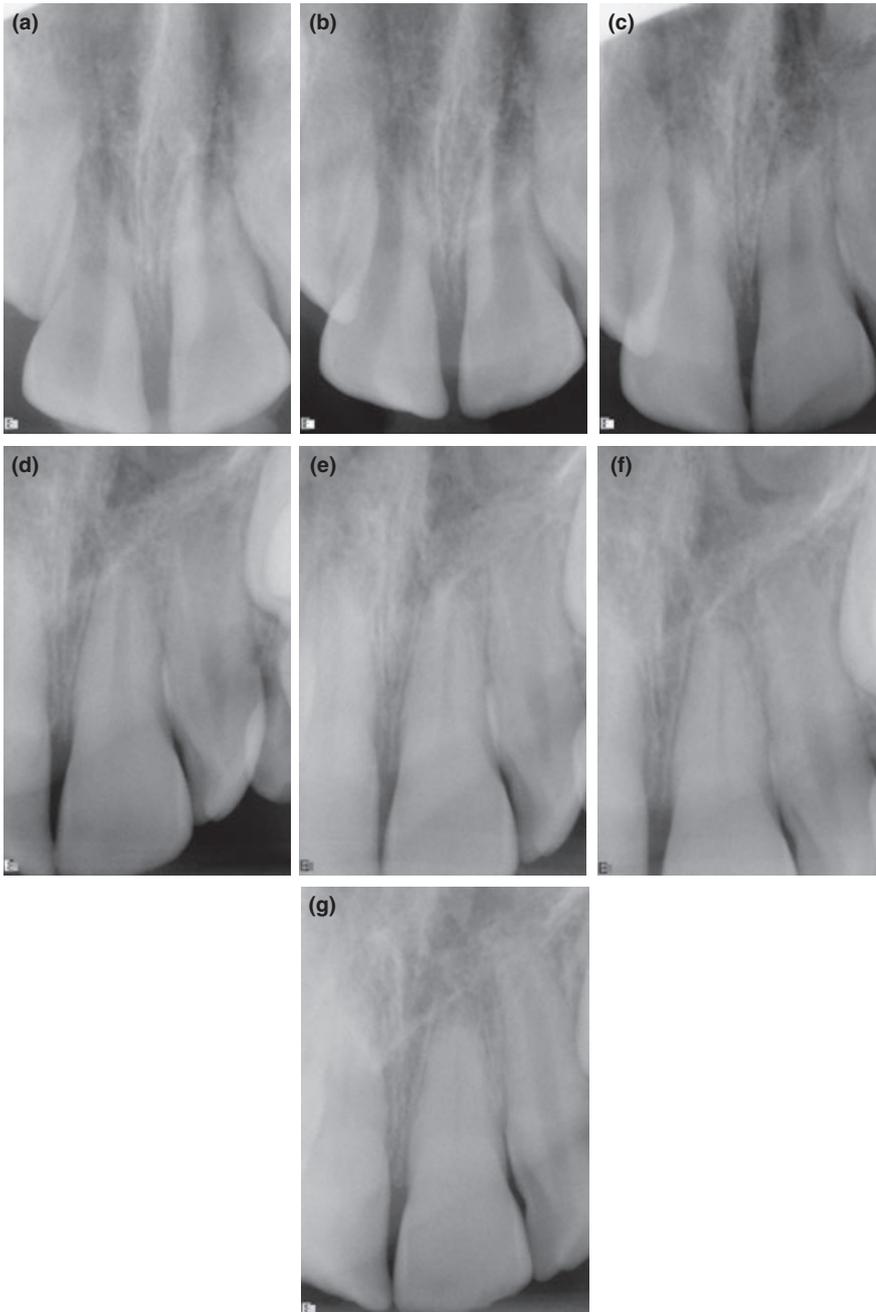


Figure 5 Periapical radiographic view of the maxillary central incisors of a (a) 9-year-old boy at 14 presentation immediately after a luxation injury to both central incisors (October 2008). (b) Fig. 5, 3 months later (January 2009). Fig. 5, 6 months later (March 2009). (c) Fig. 5, 9 months later (June 2009). (d) Fig. 5, 12 months later (October 2010). (e) Fig. 5, 18 months later (April 2010). (f) Fig. 5, 28 months later (February 2011). The injury occurred whilst playing football. The boy had attended a local hospital where the teeth were splinted before being referred.

not statistically significant and the authors concluded that tooth discoloration had no diagnostic value. It should be remembered that not all teeth with radiographic signs of pulpal obliteration undergo a colour change. Figure 6 shows the clinical appearance of



Figure 6 Clinical view of the same maxillary central incisors as Fig. 5, 28 months post-trauma showing minor coronal discoloration given the degree of pulpal obliteration that is evident radiographically.

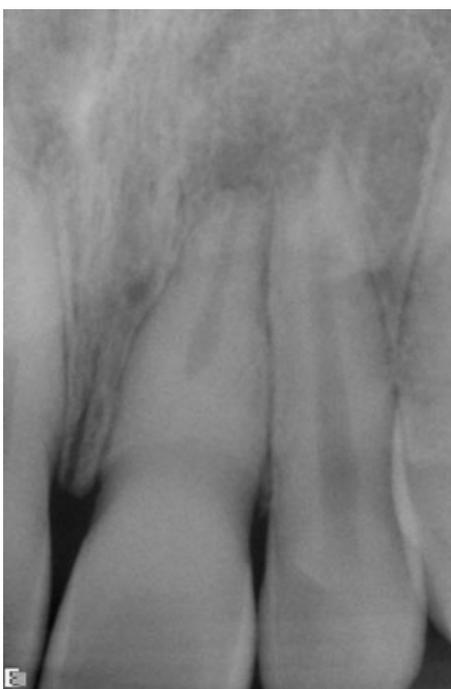


Figure 7 Periapical radiographic view of a maxillary left central incisor showing partial pulp canal obliteration with associated periapical pathosis.

both maxillary central incisors of a 9-year-old boy following trauma. Both teeth underwent total pulpal obliteration with no obvious signs of discoloration evident.

Pulp sensibility testing

After concussion or subluxation injuries, the affected teeth do not always react to sensibility tests for some time (Andreasen 1970). This lack of a response can be reversible, and it is possible that after some weeks, sensibility tests will show positive results (Andreasen 1970, de Cleen 2002). In the presence of PCO, it is generally accepted that sensibility tests are unreliable (Holcomb & Gregory 1967, Robertson *et al.* 1996, Oginni *et al.* 2009).



Figure 8 Periapical radiographic view of a maxillary left central incisor showing complete pulpal obliteration with no evidence of periapical pathosis.

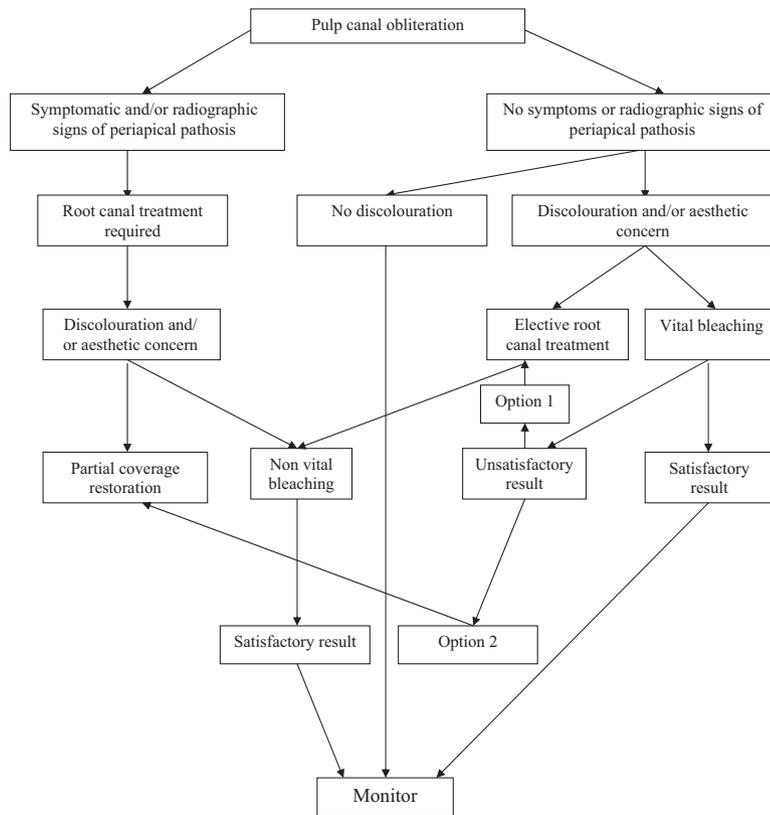


Figure 9 Treatment Decision Flowchart.



Figure 10 Tooth seen in Fig. 3. It is isolated under rubber dam with the access cavity prepared up to the labial enamel plate (Black arrows). The calcified pulp chamber is visible (Red arrow) as a darkened line.



Figure 11 Tooth as seen in Fig. 10 with a size 10 hand file inserted into the pulp chamber.

There is a progressive decrease in the response to thermal and electrical pulp testing as PCO becomes more pronounced (Patersson & Mitchell 1965, Schindler & Gullickson 1988, Oginni *et al.* 2009). It has also been reported there is a significant difference to electric pulp testing between partially obliterated teeth compared to those that were totally obliterated (Oginni *et al.* 2009); teeth with partial pulpal obliteration were more responsive than those teeth that were totally obliterated with significantly more nonresponsive teeth in the totally obliterated group (Oginni *et al.* 2009). It is generally accepted that the absence of a positive response to the electric pulp test does not automatically imply pulp necrosis (Holcomb & Gregory 1967, Schindler & Gullickson 1988, Robertson *et al.* 1996, Oginni *et al.* 2009).

Symptoms

Teeth undergoing pulpal obliteration are generally asymptomatic (Robertson *et al.* 1996, Oginni *et al.* 2009). It has been reported that 52% of teeth were asymptomatic when first examined with a further 21% exhibiting mild symptoms, which did not merit any treatment other than an annual review (Oginni *et al.* 2009). Thus, these teeth are often an incidental finding following clinical or radiographic investigations.



Figure 12 Tooth as seen in Figs 10 and 11 after the canal preparation has been completed.

Radiographic findings

The radiographic appearance of PCO is one of either partial (Figs 2 and 7) or total obliteration of the pulp canal space (Figs 4 and 8) with or without associated periapical pathosis (Holan 1998, Amir *et al.* 2001). Complete radiographic obliteration of the pulp space does not necessarily mean the absence of the pulp canal space; in the majority of these cases, a pulp space with pulp tissue is present, but the sensitivity of conventional radiographs is too low to allow their image to be captured (Pateresson & Mitchell 1965, Schindler & Gullickson 1988, Torneck 1990).

Histological findings

Histopathological studies designed to assess the pulp status of teeth with pulpal obliteration have failed to show any signs of inflammation indicative of a pathological process (Pateresson & Mitchell 1965, Cvek *et al.* 1982, Torneck 1990). Lundberg & Cvek (1980) evaluated histologically the pulps of 20 maxillary permanent incisors with reduced pulp spaces. Treatment was performed an average of 44 months after the injury. Eighteen teeth exhibited narrowing of the entire pulpal lumen, and two teeth demonstrated narrowing in the apical half of the root. The pulps varied from being rich in cells and only a slight increase in collagen content to being rich in collagen with a marked decrease in the number of cells. No microorganisms were found in any specimen. A moderate inflammatory response was seen in only one pulp.

Table 1 Frequency of pulpal necrosis and apical rarefaction in permanent teeth with pulp canal obliterations (PCO)

Study	Observation period (years)	No. of units studied	No. of teeth with PCO	No. of teeth with pulpal necrosis (%)
Holcomb & Gregory 1967	4	88 patients	41	3 (7)
Andreasen 1970	1–12 (3.4)	189 luxated teeth	42	3 (7)
Stalhane & Hedegard 1975	13–21	76 teeth	76	12 (16)
Jacobsen & Kerekas 1977	10–23 (16)	122 traumatized teeth	122	16 (13)
Andreasen <i>et al.</i> 1987	1–10 (3.6)	637 teeth	96	1 (1)
Robertson <i>et al.</i> 1996	7–22 (16)	82 traumatized teeth	82	7 (8.5)
Oginni <i>et al.</i> 2009		276 teeth	276	75 (27.2)

Torneck (1990) described pulpal obliteration as a tertiary dentine response to trauma that was highly irregular in pattern and calcification. However, this is not universally accepted, and pulpal obliteration or CM has also been characterized as multifocal, dystrophic calcifications usually composed of ill-defined secondary dentine (Johnson & Bevelander 1956, Eversole 1978, Kuster 1981).

Robertson *et al.* (1997) in a study of 123 traumatized primary teeth found that the tissues occluding the pulpal lumen were dentine-like, bone-like or fibrotic in nature and no correlation could be made between the varying tissue responses and the clinical diagnosis. Holan (1998) described a tube-like calcified structure that extended along the entire length of the pulp canal in traumatized primary incisors. It had the histological appearance of osteodentine with cell inclusions and a ring-like formation. It is difficult to know whether the obliteration process seen in primary incisors is similar to that seen in the permanent successors.

Clinical management of pulpal obliteration

There is considerable disagreement in the literature regarding the optimum treatment of teeth showing signs of pulpal obliteration. Patersson & Mitchell (1965) felt that a tooth with signs of pulpal obliteration because of trauma should be regarded as a potential focus for infection and that root canal treatment was merited on that basis. Rock & Grundy (1981) recommended root canal treatment in teeth undergoing pulpal obliteration based on two clinical parameters:

1. Once the guidance afforded by the pulp space is lost, it is more difficult to prepare a post hole without perforation; and
2. Should pulpal necrosis occur the only possible access may be surgical intervention.



Figure 13 Radiographic view of the tooth seen in Fig. 7 undergoing treatment. The rubber dam clamp has been removed to allow assessment of the access cavity and its orientation relative to the position of the pulp canal space.

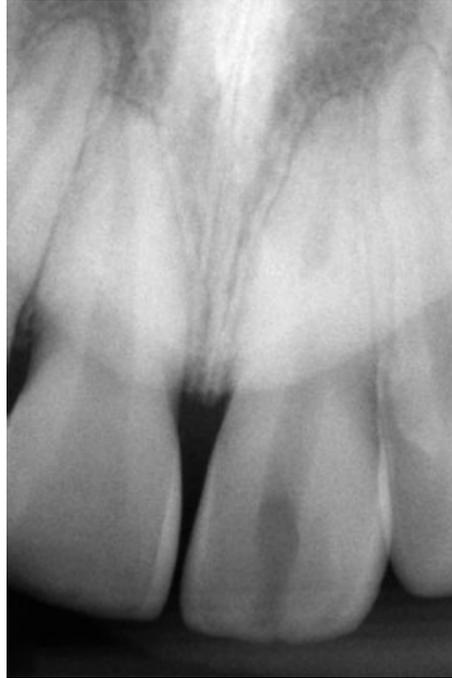


Figure 14 Same tooth as seen in Figs 7 and 13 except that the angle of the radiograph has been altered to assist with the orientation of the access cavity. One view of the tooth is insufficient as it only indicates orientation in that plane, which is most commonly the buccolingual view.

Fischer (1974) postulated that the reduced cellular content seen in pulps undergoing obliteration makes them more susceptible to infection and on that basis recommended prophylactic root canal treatment. Lundberg & Cvek (1980) concluded that the tissue changes in the pulps of teeth undergoing obliteration were virtually free from inflammation. Only one tooth in the 20 teeth examined showed moderate inflammation, and they concluded that there was no indication for root canal treatment.

Holcomb & Gregory (1967) reported that only 3 of 43 (7%) teeth with partial or total pulp obliteration had a periapical rarefaction 4 years after the diagnosis. Jacobsen & Kerekes (1977) and Stalhane & Hedegard (1975) reported that 16% and 13%, respectively, of teeth with PCO developed pulp necrosis and periapical rarefaction. Both of these studies (Stalhane & Hedegard 1975, Jacobsen & Kerekes 1977) support the recommendation of Holcomb & Gregory (1967) that endodontic treatment should only be initiated following the development of periapical disease radiographically. Robertson *et al.* (1996) in a study of 82 teeth with PCO were followed for a period of 7–22 years (mean 16 years). They found that periapical bone lesions suggesting pulpal necrosis developed in seven teeth (9%). They estimated the 20-year pulp survival rate was 84% and concluded that prophylactic root canal treatment on a routine basis was not justified.

A more recent study (Oginni *et al.* 2009) found that the incidence of endodontic complications (pulp necrosis and apical rarefaction) occurred in less than one-third (27%) of the 276 teeth examined. Although this is a much higher rate than most other studies (Holcomb & Gregory 1967, Stalhane & Hedegard 1975, Jacobsen & Kerekes 1977, Robertson *et al.* 1996), the patients in these latter reports were followed up from the time of injury, as a baseline to monitor those teeth that could develop PCO. This is in contrast to the study by Oginni *et al.* (2009), where the patients presented sometime after the injury with mostly a discoloured tooth.

In summary, the literature suggests that pulpal necrosis and periapical disease are not a common complication of PCO, and if root canal treatment is selected as a routine procedure, most would be unnecessary as the majority of teeth with PCO will never suffer pulpal necrosis and periapical disease.

If indicated – when should root canal treatment be initiated?

Smith (1982) recommended delaying treatment until there were symptoms or radiographic signs of periapical disease, a view accepted by many (Holcomb & Gregory 1967, Jacobsen & Kerekes 1977, Schindler & Gullickson 1988, Amir *et al.* 2001, de Cleen 2002, Munley & Goodell 2005).

In a more recent study (Oginni *et al.* 2009) of 276 teeth diagnosed with PCO, it was recommended that root canal treatment should be initiated in teeth with tenderness to percussion, PAI scores ≥ 3 (The PAI quantifies periapical inflammation/disease and scores 2–5 represent disease) and a negative response to sensibility testing.

However, it may be reasonable to consider an elective or intentional root canal treatment where there are aesthetic concerns, and the tooth is unresponsive to vital bleaching techniques (Munley & Goodell 2005, Greenwall 2007, West 2007).

The Decision Flow Chart (Fig. 9) outlines the various treatment options that can be considered depending on the presenting signs and symptoms.

Endodontic management of calcified pulp chambers and canal systems

The management of anterior teeth with obliterated pulp chambers and root canal systems in need of treatment is identical to that of any other tooth.

What specific challenges do these teeth pose?

It is well known that the apparent radiographic diameter of the canal does not correspond to its true width. Kuyk & Walton (1990) measured the canal diameters of 36 teeth from radiographs and then compared them with the true widths of the canals as measured from histological sections. They found that all sections of the roots demonstrated a canal histologically, although some regions had no canal visible radiographically. Complete radiographic obliteration does not necessarily mean the absence of the pulp or canal space; in the majority of the cases, a pulp canal space with pulp tissue is present. This study confirmed the earlier findings of Pateresson & Mitchell (1965) who observed that some form of patent canal usually persists.

Cvek *et al.* (1982) treated 54 incisors with post-traumatically reduced canal lumens. The teeth were treated an average of 8 years after the injury, and all teeth had evidence of periapical disease. It was possible to locate and treat the root canals in 53 of the 54 teeth, irrespective of the extent of canal obliteration seen on radiograph; however, treatment was often complicated. The technical complications included root perforation or irretrievable instrument fracture. There was a higher frequency of technical failures in mandibular incisors, especially root perforation. However, they did note that tooth preparation to locate the canal in the cervical part of these teeth may have weakened them to such an extent that they would be at risk of subsequent root fracture. Unfortunately, this tooth substance loss was not quantifiable. When teeth with technical failures were excluded from evaluation, the frequency of periradicular healing corresponded to that reported for the treatment of young teeth with necrotic pulps and nonreduced pulpal lumens (Cvek *et al.* 1982). However, 50% of the teeth with technical problems such as perforation and instrument failure did not heal radiographically. This



Figure 15 This is the same tooth as in Figs 7, 13 and 14 with the rubber dam replaced and butterfly clamp *in situ*. The area of interest has now moved beyond the cervical area of the tooth and so there is no benefit in removing the rubber dam. The pulp canal space has finally been captured, and the process of cleaning and shaping can now begin.

study suggests that without technical complications, the outcome for root canal treatment of teeth with reduced canal lumens is the same as for a 'normal' tooth with a necrotic pulp. The complications created or encountered in treating these teeth were excessive tooth structure removal, perforation and retained/fractured instruments.

The problem of excessive tooth substance removal and perforation

The standard access preparation traditionally described for maxillary anterior teeth is in the exact centre of the palatal surface of the crown buccolingually and incisogingivally (Lovdahl & Gutman 1997, Ngeow & Thong 1998, Amir *et al.* 2001). At an angle of 45° to the long axis, bur penetration will generally intersect with the pulp chamber within 3–4 mm in a tooth of average size, and it is noted as a 'drop off', which is characterized by a sudden sensation of entering the pulp chamber space. This sudden sensation of entering a space will not occur in cases where there is pulp chamber obliteration as the chamber will be filled with calcified material and the cutting sensation will be no different to that of normal dentine. In other words, the operator will not experience the normal 'drop off'. If this traditional axis of the pathway is continued, a perforation of the labial root surface somewhere below the gingival attachment will occur (Amir *et al.* 2001, McCabe 2006). To avoid this happening, Amir *et al.* (2001) suggested that when the pulp chamber is calcified and the chamber has not been located after 3–4 mm of penetration, the bur must be rotated to lie parallel to the long axis of the tooth.

A much better solution is to prepare the access cavity close to or through the incisal edge (Amir *et al.* 2001, McCabe 2006). This approach facilitates straight-line access (McCabe 2006) and is a more predictable approach to locating the pulp chamber whilst

avoiding unnecessary damage. Clearly, it is the preferred approach where the incisal edge has already been compromised through trauma or where there are restorations present. However, when a more incisal starting point to the access cavity is undertaken, up to the incisal edge but not through it, then the axis of the access cavity prepared will lie along the long axis of the tooth (Figs 10–12).

It is essential to remember that the pulp chamber is always located in the centre of the tooth at the level of the CEJ (Amir *et al.* 2001, Krasner & Rankow 2004). Secondly, that the CEJ is the most consistent repeatable landmark for locating the pulp chamber (Krasner & Rankow 2004). Finally, the calcified pulp chamber is darker than, and appears a different colour to, the axial wall root dentine (Krasner & Rankow 2004, Fig. 10).

Thus, if the access preparation remains well-centred, aligned to the long axis of the tooth and limited initially to the level of the CEJ, the root canal system is normally easy to locate. This can be enhanced further using the operating microscope to detect the subtle colour differences between the dentine deposited in the pulp chamber and that of the 'normal' surrounding dentine of the crown. Selden (1989) recognized the role of the dental operating microscope in treating calcified canals and improving the treatment outcome. Others have also noted the same benefit of using the operating microscope in the treatment of obliterated canals (da Cunha *et al.* 2009, Johnson 2009, Reis *et al.* 2009).

Various burs and ultrasonic tips have been designed for performing the deep troughing required to locate and enter calcified pulp chambers and canals. Dyes such as methylene blue may assist in locating the canal system under the microscope. Sodium hypochlorite may also be used to assist, with the identification of a calcified canal being enhanced using the 'bubble' or 'champagne' test. That is, placing 5% sodium hypochlorite into the pulp chamber over a calcified canal containing remnants of pulp tissue will result in a stream of



Figure 16 Radiograph of a maxillary central incisor with pulp obliteration, which was perforated and repaired with amalgam. A traditional apicectomy was carried out using an amalgam retrograde filling which subsequently failed.

bubbles emerging from the oxygenation of the tissue. This can be seen under the microscope and be used to identify the canal orifice (Johnson 2009).

In very deep access preparations, it is wise to take radiographic images at multiple angles to maintain alignment and direction (O'Connor *et al.* 1994). In certain situations, it may be of benefit to remove the rubber dam clamp as this often lies over the area of interest at the level of the CEJ (Figs 13–15).

The mandibular incisors appear to pose a special problem largely because they are small and have complicated root anatomy (Cvek *et al.* 1982, Amir *et al.* 2001). Some of the associated difficulties in treating these teeth are because of the traditional location of the access cavity on the lingual aspect of the tooth (McCabe 2006) and because small errors in access cavity orientation can have disastrous consequences (McCabe 2006). However, the same principals in locating the calcified pulp chamber and canal orifices apply to these teeth also, that is an access cavity through or close to the incisal edge.

Canal negotiation and penetration

The negotiation of small calcified canals is challenging (Dodds *et al.* 1985). Cvek *et al.* (1982) not surprisingly found that the highest number of irretrievable instrument fractures occurred in totally obliterated root canals. Typically, small files are required for initial pathfinding; however, these files lack the rigidity required to transverse restricted spaces and can often buckle or fracture when used with vertical watch-winding forces. One approach is to alternate between size 8 and 10 K-files with a gentle watch-winding motion with minimal vertical pressure with regular replacement of the instruments before fatigue occurs. However, a variety of 'pathfinding' instruments are available with this objective in mind. These instruments have various designs, but the most common has a quadrangular cross-section that has enhanced rigidity (Allen *et al.* 2007); however, the value of these instruments remains to be demonstrated (Allen *et al.* 2007). Chelating agents are of limited value except as a lubricant or to assist instrumentation after the canal has been negotiated (Ngeow & Thong 1998, Amir *et al.* 2001). A 'crown down' approach has been recommended to improve tactile sensation and better apical penetration (Amir *et al.* 2001). As a general rule, the calcification process as seen in pulpal obliteration occurs in a corono-apical direction so once the initial canal has been captured, an instrument tends to progress more easily as it advances towards the canal terminus. This process of calcification is illustrated in Fig 5 where the radiographic changes are recorded in two maxillary central incisors going through the process of total pulpal obliteration over a 2-year period.

The outcome of treatments on teeth with pulpal obliteration

Cvek *et al.* (1982) reported that 80% of the teeth re-examined 4 years after root canal treatment (45 teeth) were free from radiographic signs of periapical disease. Akerbolm & Hasselgren (1988) in a study to investigate the outcome of root canal treatment in 64 obliterated canals found that the overall success rate was 89% after a follow period of 2–12 years. However, the majority of the teeth used in this study were molars, and trauma was an unlikely cause for the obliteration. There are limited numbers of studies on the outcome of root treatments on teeth with pulpal obliteration, but it is reasonable to conclude that teeth with pulpal obliteration in need of treatment have a reasonable outcome/prognosis once a technically adequate treatment has been carried out.

Teeth that have encountered technical problems such as perforation and instrument failure do significantly less well (Cvek *et al.* 1982). Therefore, to afford these teeth the best outcome, technical complications should be avoided and then the outcome will be similar to any other anterior tooth with a necrotic pulp.

Aesthetic concerns

West (2007) considered that there are potentially four treatment options for the restoration of discoloured pulpally obliterated teeth to an acceptable colour.

Vital bleaching

External or vital bleaching should be considered first as it is the most conservative option (Munley & Goodell 2005, Greenwall 2007, West 2007). Greenwall (2007) described a single vital tooth whitening technique using 20% carbamide peroxide gel in a conventional vital bleaching tray with windows cut out of the tray adjacent to the discoloured tooth, on either side. However, progress can be slow because of the nature of the discoloration (Greenwall 2007). There is generally little or no sensitivity experienced during the whitening treatment (Greenwall 2007).

Intentional root canal treatment followed by intracoronal bleaching

de Cleen (2002) recommended opening up a fully extended access cavity identical to that in a tooth with normal chamber size. In this way, he believed a large amount of tertiary dentine was removed, thereby contributing to the restoration of translucency in the crown.

Rotstein & Walton (2002) felt that such teeth could be bleached with a reasonable aesthetic result. Colour regression tends to be a problem for all teeth that undergo nonvital bleaching (Friedman 1997). The reason for such colour regression is poorly understood although microleakage through the restoration is thought to be a major factor (Friedman 1997). A study by Friedman *et al.* (1988) found that after a recall period of 1–8 years, 79% of internally bleached teeth had maintained a better colour than the initial colour.

Internal and external bleaching without root canal treatment

Pedorella *et al.* (2000) described preparing an access cavity and removing the coronal sclerotic dentine and placing an appropriate base on the floor of the access cavity without considering root canal treatment and then carrying out internal and external bleaching. Whilst this technique is a possible treatment option, it does not have widespread support. Studies show that there is, in the majority of these cases, a pulp space with pulp tissue present, but the sensitivity of conventional radiographs is too low to allow their image to be captured (Petersson & Mitchell 1965, Schindler & Gullickson 1988, Torneck 1990). Therefore, opening into the pulp chamber of these teeth without considering root canal treatment opens up this pulp tissue to infection.

Extracoronal full or partial coverage restorations

West (2007) suggested that the most expedient option to restore aesthetically a discoloured tooth was often a full coverage restoration. Given that most of these teeth are intact, such a destructive measure should really only be considered when the more conservative approaches have not been successful.

Surgical considerations

Schindler & Gullickson (1988) suggested that root-end resection and filling should be considered when a canal cannot be located. Clearly, such endodontic microsurgery is

an option in the treatment of calcified canals as it offers a direct approach to the root apex (Carrotte 2005, American Association of Endodontists 2010). However, canal identification may also be problematic in the calcified canal after root resection. Dyes such as methylene blue may be used to identify pulp tissue and the root outline (Kim & Kratchman 2006). The root-end preparation should be parallel to and coincident with the anatomical outline of the root canal space (Kim & Kratchman 2006). The guiding influence of a canal space will be nonexistent in the calcified and previously unprepared canal system. It is likely therefore that this will be a further complicating factor in carrying out surgery on a calcified canal system where there has been no attempt at orthograde root filling. Amir *et al.* (2001) suggested that once a root-end resection was performed on a calcified canal system, many of the pockets of necrotic tissue, which have been trapped in the calcification process, may be opened to the periradicular tissues, resulting in persistent chronic inflammation and inevitable failure (Fig. 10). It seems reasonable to conclude that the surgical treatment approach should be considered only in cases where nonsurgical treatment or retreatment has resulted in a persistence of periapical disease and/or symptoms (Carrotte 2005, American Association of Endodontists 2010).

The fate of teeth with pulpal obliteration

The incidence of pulp necrosis in teeth with pulpal obliteration increases over time (Robertson *et al.* 1996). Jacobsen & Kerekes (1977) found that the development of pulpal necrosis was significantly related to teeth classified as 'severely injured' and to teeth with complete root formation at the time of the injury. Furthermore, they found that the rate of the obliteration process was also related to the development of subsequent pulpal necrosis (Jacobsen & Kerekes 1977).

Robertson *et al.* (1996) found that there was no higher frequency of pulpal necrosis in obliterated teeth subjected to caries, new trauma, orthodontic treatment or complete crown coverage than intact teeth. This is in contrast to the findings of Bauss *et al.* (2008) who reported that traumatized teeth with total pulpal obliteration undergoing orthodontic intrusion had a higher incidence of pulpal complications than traumatized teeth with either partial obliteration or no obliteration. Numerous studies have reported orthodontic tooth movement can affect the blood supply to the dental pulp (Kvinnslund *et al.* 1989, Vandevska-Radunovic *et al.* 1994, Derringer *et al.* 1996). Orthodontic intrusive movements are considered to have the greatest impact on the apical region and pulp blood supply (Bauss *et al.* 2008). Bauss *et al.* (2008) postulated that pulpal obliteration might also lead to a constriction in the apical foramen and pulpal blood supply, which may account for the loss of pulp vitality seen following orthodontic intrusion. Partial obliteration on the other hand revealed no detrimental effect on the pulp. This may be explained by the fact that partial obliteration involves primarily the pulp chamber and has a more limited effect in the root canal and apical region. This might allow the circulatory system of these teeth to react adequately to maintain sufficient blood perfusion during orthodontic intrusion (Bauss *et al.* 2008).

Whilst this view appears to be in contrast to the findings of Robertson *et al.* (1996), the numbers of teeth included in that were small (82 teeth) and it was primarily an observational study.

In summary, although there is limited data available on the long-term fate of teeth with pulpal obliteration, it is clear that there is an increase in the incidence of pulpal necrosis over time. Teeth with complete pulpal obliteration are more susceptible than those with incomplete obliteration to pulp necrosis following orthodontic treatment. Orthodontic treatment may impact on pulp survival on teeth with total pulpal obliteration.

Summary

Overall, less than quarter of traumatized anterior teeth develop varying degrees of pulpal obliteration. It is generally accepted that the frequency of PCO is dependent on the extent of the luxation injury and the stage of root formation. Most studies suggest that the incidence of pulpal necrosis in these teeth is in the range of 1–16%. Histological examination of pulps in teeth with pulpal obliteration showed no signs of inflammation when clinical and radiographic signs of disease were absent. Most of the literature does not support endodontic intervention unless pulpal necrosis as evidenced by periapical pathosis (PAI \geq 3) and/or symptoms and when a negative response to EPT has been detected (Oginni *et al.* 2009). The literature suggests that teeth with pulpal obliteration are frequently root filled unnecessarily (Munley & Goodell 2005). Because the overall failure rate of root canal treatment is low, it would seem reasonable that teeth demonstrating pulpal obliteration should be managed conservatively through clinical observation and periodic radiographic examination.

If root canal treatment is required, teeth with pulpal obliteration fall into the high difficulty category of the American Association of Endodontists Case Assessment criteria (American Association of Endodontists 2010). This is evidenced by numerous case reports in the literature that highlight the difficulties encountered when treating such teeth (Ngeow & Thong 1998, da Cunha *et al.* 2009, Reis *et al.* 2009). Figure 16 illustrates these difficulties. However, treatment can be completed successfully in a large proportion of cases. If tooth discoloration is the sole presenting complaint, a vital bleaching technique can be considered.

Conclusions

1. Yellow discoloration is a common finding in teeth with pulpal obliteration but does not imply the presence of pulp or periapical disease;
2. The absence of a response to the electric pulp test does not imply pulpal necrosis in the presence of PCO;
3. More than two-thirds of teeth with pulpal obliteration are asymptomatic;
4. Complete radiographic obliteration of the pulp space does not necessarily imply an absence of pulp tissue or space clinically or microscopically;
5. The nature of the calcified material varies from secondary and tertiary dentine to osteodentine;
6. The mechanism controlling pulpal obliteration is poorly understood;
7. The incidence of pulp necrosis following PCO is variable ranging from 1% to 27% but is generally considered low;
8. Root canal treatment is indicated when there are clinical symptoms and/or definite radiographic findings suggestive of periapical disease;
9. Straight-line access to the pulp chamber is better than the traditional access cavity when initiating treatment on teeth with obliterated pulp canals;
10. The use of the dental operating microscope is recommended;
11. Technical complications such as fractured instruments and perforations impact adversely on treatment outcome and are best prevented;
12. Using long neck burs in the slow handpiece or preferably ultrasonic tips to penetrate deeply into the canal system is recommended;
13. If root canal treatment is not indicated and there are aesthetic concerns, a single tooth vital bleaching technique can be considered;
14. If root canal treatment is required and there are aesthetic concerns, a nonvital bleaching technique can be considered;
15. Teeth with PCO requiring root canal treatment are challenging.

Disclaimer

Whilst this article has been subjected to Editorial review, the opinions expressed, unless otherwise stated, are those of the authors. The views expressed do not necessarily represent best practice, or the views of the IEJ Editorial Board, or its affiliated Specialist Societies.

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