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Mineral trioxide aggregate pulpotomy for permanent molars with clinical signs indicative of irreversible pulpitis: a preliminary study

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Abstract

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Aim To prospectively investigate the clinical and radiographic success rates of pulpotomy in permanent molars with clinical signs and symptoms suggestive of irreversible pulpitis using mineral trioxide aggregate (MTA) as a pulp dressing agent.

Methodology Sixteen patients with 23 restorable permanent molars exhibiting signs and symptoms indicative of irreversible pulpitis were enrolled. A standardized operative procedure was followed for all participants. All teeth were isolated with a dental dam and caries was removed, and then, pulpotomy performed with a sterile round and/or flame shape diamond burs. Haemostasis was achieved with 5% sodium hypochlorite (NaOCl). A mixture of MTA was placed against the wound, and a moistened cotton pellet was placed over the MTA. Teeth were temporized with a glass–ionomer restoration. Three to ten days later, the interim restoration was removed and setting of MTA was evaluated. Teeth were restored with stainless steel crowns. Follow-up evaluations were scheduled at 3, 6, 12 months and annually thereafter. Descriptive statistics were used to assess outcomes.

Results The age of patients at time of pulpotomy ranged between 7.6 and 13.6 years (mean = 10.7 ± 1.7 yrs). The majority of teeth (91%) had clinical signs and symptoms consistent with a diagnosis of symptomatic irreversible pulpitis and symptomatic apical periodontitis (78%). The follow-up examination period ranged from 18.9 to 73.6 months. Clinically and radiographically, all pulpotomies were considered successful at the end of the follow-up period. Radiographically, a hard tissue barrier was noticed in 13 (57%) teeth.

Conclusion In children, MTA was associated with high clinical and radiographic success as a pulpotomy agent in permanent teeth with clinical signs and symptoms suggestive of irreversible pulpitis.

Keywords: apical Periodontitis, molar, MTA, pulpitis, pulpotomy.

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Introduction

The diagnosis and treatment of infected dental pulps exposed by caries in young permanent molars present a challenge (Alqaderi *et al.* 2014). The current definition of irreversible pulpitis implies the presence of a severe degenerative process that will not heal and that, if left untreated, will result in pulpal necrosis

followed by apical periodontitis (Levin *et al.* 2009). However, differentiating between reversible and irreversible pulpitis is largely carried out on an empirical basis (Mejàre & Cvek 1993, Waterhouse *et al.* 2011).

The response of dental pulps to carious exposures differs between children and adults. In immature permanent teeth, the natural defences and rich blood supply of the pulp may allow a greater resistance to bacterial infection for longer periods (Mejàre & Cvek 1993, Waterhouse *et al.* 2011). However, some differences are found in the literature with respect to success rates of traditional conservative pulp therapy procedures between young and adult pulps (Haskell *et al.* 1978, Caliskan 1993, Barrieshi-Nusair & Qudeimat 2006, Eghbal *et al.* 2009, Waterhouse *et al.* 2011, Alqaderi *et al.* 2014).

One established option is complete pulpotomy, indicated when exposed tissue is inflamed to deeper levels of the coronal pulp during caries removal (Eghbal *et al.* 2009, Waterhouse *et al.* 2011, Asgary & Eghbal 2013, Nosrat *et al.* 2013, Alqaderi *et al.* 2014).

Many studies reported high clinical success rates when mineral trioxide aggregate (MTA) was used for vital pulp therapy of cariously exposed permanent teeth diagnosed with reversible pulpitis (Barrieshi-Nusair & Qudeimat 2006, El-Meligy & Avery 2006, Qudeimat *et al.* 2007, Ghoddusi *et al.* 2012, Simon *et al.* 2013, Alqaderi *et al.* 2014). However, for irreversibly inflamed pulps, it is not well established if recovery is possible when conservative treatment strategies are provided (Levin *et al.* 2009). Under these conditions, it has been suggested that appropriate clinical intervention may result in the arrest or resolution of pulpal inflammation (Bjørndal 2008). Others have recommended that when caries and bacterial contamination have been largely eliminated from the dentine–pulp complex and a hermetic coronal seal has been achieved using MTA pulpotomy, the tooth may have a chance to return to a healthy and functional status (Chueh & Chiang 2010). Few studies investigated pulpotomy as a treatment modality for cariously exposed permanent teeth diagnosed with pulpitis in young patients using MTA (Witherspoon *et al.* 2006, Eghbal *et al.* 2009, Asgary & Eghbal 2013, Nosrat *et al.* 2013). Therefore, the aim of this prospective study was to investigate the clinical and radiographic success of pulpotomy for permanent molars in children presenting with clinical signs and symptoms consistent with a traditional diagnosis of irreversible pulpitis using MTA as a pulp dressing material.

Material and methods

Ethical approval was obtained from the Health Sciences Centre Ethical Committee, Kuwait University. Prior to teeth examination and after explanation of the study objectives, benefits and risks, parents of all participating children signed a written consent. Participants were considered as having clinical signs and symptoms consistent with a diagnosis of irreversible pulpitis if they presented with the following chief complaint: (i) intermittent or spontaneous, sharp or dull, localized, diffuse, or referred pain; (ii) rapid exposure to dramatic temperature changes elicited heightened and prolonged episodes of pain even after the thermal stimulus has been removed; and (iii) no clinical symptoms but pulpal bleeding produced by caries excavation (Glickman 2009). Children attending Kuwait University Dental Clinics were selected for possible enrolment, each satisfying one or more of the following criteria: (i) presented with a deeply carious permanent molar and a preoperative provisional diagnosis of irreversible pulpitis; and (ii) were unable to cooperate with traditional root canal treatment (RCT). In addition, patients and parents had to be interested in saving the tooth through operative intervention. Teeth were excluded from the study if they presented with the following conditions: (i) nonrestorable, (ii) pathological mobility, (iii) pus discharge through an associated sinus tract, (iv) swelling of associated tissues, (v) radiographic internal or external resorption or furcation radiolucency, and (vi) necrotic pulp upon exposure.

One examiner completed a thorough history and clinical examination for all participants. Sensibility testing with both refrigerant spray test (Endo ICE–Coltene/Whaledent, Inc., Cuyahoga Falls, OH, USA) and electrical pulp test (EPT – Analytic Technology, Redmond, WA, USA) was performed on candidate molars. Preoperative and postoperative periapical radiographs were taken using the Rinn® XCP holder (Dentsply, Elgin, IL, USA).

The same endodontist followed a standardized operative procedure for all cases. Following administration of local anaesthesia, teeth were isolated with a dental dam. Excavation of caries was completed using a large round bur in a low speed handpiece with water coolant. Complete pulpotomy was performed with a sterile round and/or flame shape diamond burs (Meisinger, Neuss, Germany) in a high speed hand piece under water coolant. Haemostasis was achieved with 5% sodium hypochlorite. A dental

assistant recorded the time for bleeding control for all teeth. Grey or white mineral trioxide aggregate (ProRoot, Dentsply, Tulsa Dental Specialties, Tulsa, OK, USA) was mixed according to manufacturer's instructions on a glass mixing pad. The mixture was gently placed against the wound using spoon excavators and plastic instruments. The material was adapted to the wound with a wet cotton pellet to a thickness of 2 mm and excess MTA removed. A moistened cotton pellet was placed directly over the MTA. All teeth were temporized with Ketac™ Molar Aplicap™ glass–ionomer filling (3M/ ESPE, Seefeld, Germany). Three to ten days later, the interim filling was removed and MTA setting was evaluated. Because all molars in this study were grossly carious, teeth were provided with a restoration of Ketac™ Molar Aplicap™ glass–ionomer filling and a stainless steel crown (3M/ESPE, St. Paul, MN, USA) by the same paediatric dentist. Aqua Meron glass–ionomer cement (VOCO, Cuxhaven, Germany) was used to cement all stainless steel crowns. Patients or parents/carers were instructed to seek permanent replacement of the stainless steel crown once adult teeth had fully erupted and reached a stable dentoalveolar position. Fig. 1 demonstrates a flow diagram of 16 participants with 23 permanent molars treated with MTA pulpotomy in this study.

Patients were scheduled for clinical and sensibility examinations (excluding EPT) at 3, 6, 12 months and annually thereafter. Follow-up radiographs were taken at 6, 12 months and annually thereafter. The images were later evaluated independently by two investigators for root maturity, hard tissue bridge formation, canal obliteration and periradicular status. The examiners agreed upon the radiographic findings in 88% of cases. Cases were later reviewed with an experienced oral and maxillofacial radiologist, who negotiated a consensus in case of disagreement.

At the end of the recall interval, the treatment was considered as a failure if one or more of the following were present: history of continuous and persistent pain, exaggerated tenderness to percussion, pathologic mobility, swelling or sinus tract related to the treated tooth. Radiographic signs of failure included evidence of increased periradicular radiolucency, furcal pathosis, root resorption or lack of continuation of root development in immature molars. The data were analysed using Statistical Package for the Social Sciences software version 17.0 (SPSS Inc., Chicago, IL, USA), and descriptive statistics were obtained.

Results

Sixteen participants (8 males and 8 females) with 23 permanent molars were included. The age of patients at time of pulp therapy ranged between 7.6 and 13.6 years (mean = 10.7 ± 1.7 yrs.). Table 1 demonstrates the characteristics of patients and fate of permanent molars that were enrolled in this study. The majority of teeth (91%) exhibited pulps that demonstrated signs and symptoms suggestive of symptomatic irreversible pulpitis, with 78% showing signs of symptomatic apical periodontitis. The average time to stop pulp bleeding was 15.4 ± 7.1 min (range: 5–25 min). White MTA was used for 13 molars (57%) and grey MTA for 10 (43%). The follow-up examination period ranged from 18.9 to 73.6 months with a mean of 57.5 ± 13.9 months.

Clinically and radiographically, all pulpotomies were considered successful at the end of the follow-up period. Radiographically, a hard tissue barrier was noticed in 13 (57%) teeth (Fig. 2). All molars that had open apices at the beginning of the study (43%) showed continued root maturation. For seven molars that showed radiographic apical radiolucencies, lesions resolved completely by the end of the study (Fig. 3). No signs of periradicular bone or root resorption were noted in any of the teeth. In addition, no evidence of internal root resorption or calcification was detected.

Discussion

Extensively, carious permanent molars with pulp involvement amongst children and adolescents are not uncommon. Therefore, immature permanent molars may require more advanced and complex treatment at a young age (Ghanim *et al.* 2012). In these cases, it may be important to establish whether vital pulp therapy procedures can benefit these cariously involved permanent teeth (Chueh & Chiang 2010). The advantages for permanent teeth pulpotomy in children include the following: (i) elimination of pain and infection, (ii) preservation of a grossly decayed and cariously exposed tooth, and (iii) the procedure is less demanding clinically, is inexpensive compared to RCT and is better tolerated by a child patient (Neiburgern 2012, Alqaderi *et al.* 2014). In a recent systematic review, investigators indicated that permanent teeth with cariously exposed pulp can be treated successfully with vital pulp therapy. However, they concluded that currently the evidence is

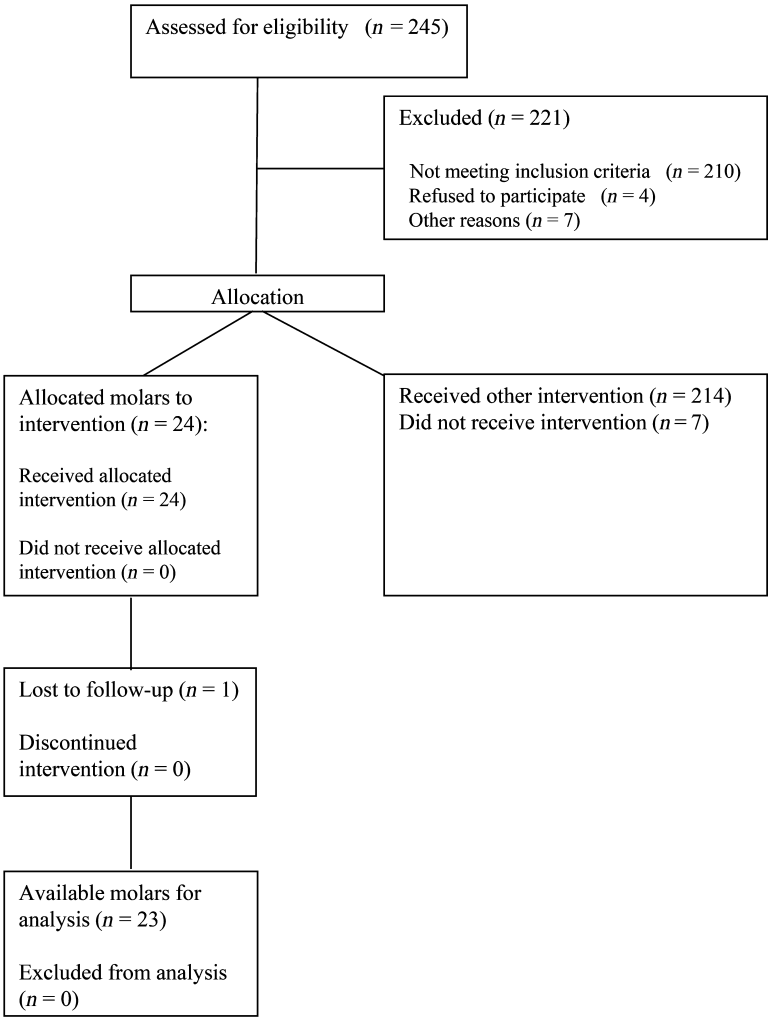

Figure 1 Flow of 16 participants with 23 permanent molars treated with MTA pulpotomy through each stage of the study.

inconclusive regarding factors influencing treatment outcome and called for further observational studies (Aguilar & Linsuwanont 2011).

Using the histological term, irreversible pulpitis to clinically describe pulp conditions remains controversial (Dummer *et al.* 1980, Hyman & Cohen 1980, Ricucci *et al.* 2014). Investigators found no clear correlation between clinical signs or symptoms of pulpitis and pulp histological conditions and concluded that it may be difficult to accurately diagnose the pulp status of symptomatic teeth (Dummer *et al.* 1980, Hyman & Cohen 1980). More recently, using different clinical and histological diagnostic criteria, and improved histological/histobacteriologic techniques, researchers concluded that clinical diagnosis of irreversible pulpitis matched the histological diagnosis in 84% of teeth (Ricucci *et al.* 2014). In the current study, all teeth included exhibited clinical signs and symptoms consistent with a diagnosis of irreversible pulpitis; however, the accurate histological diagnosis remains uncertain and it is probable that although the coronal pulp was irreversibly inflamed, the radicular pulp remained reversibly inflamed.

Treatment of the exposed pulp remains quite controversial, with various approaches endorsed by different dental specialties (Bergenholtz & Spangberg 2004). However, clinicians agree that the success of pulp therapy is dependent on case selection, proper diagnosis, skills of the clinician, availability of contemporary restorative materials, and in the case of a child patient, the cooperation level (Barrieshi-Nusair & Qudeimat 2006, El-Meligy & Avery 2006, Qudeimat *et al.* 2007,

Table 1 Characteristics of 16 patients with 23 permanent molars treated with MTA pulpotomy

Case#	Sex	Age at Treatment (years)	Tooth	Condition at Presentation	Pulpal Diagnosis at Treatment	Apical Diagnosis at Treatment	Periapical Radiographic Changes	Root Maturation	Bleeding Stoppage Time	Pulp Dressing Material	Bridge Formation	Canal Obliteration	Follow-up Time (months)
1	F	9.1	36	Carious	SIP	SAP	No	Open	20 min	GMTA	No	Partial	24.3
2	F	10.2	46	Carious	SIP	SAP	Yes	Closed	17 min	GMTA	Yes	Partial	67
3	M	8.5	26	Carious	SIP	SAP	No	Open	7 min	GMTA	No	None	60.5
4	F	9.3	26	Carious	SIP	SAP	No	Open	5 min	GMTA	No	None	73.6
5	M	10.7	46	Carious	SIP	SAP	Yes	Closed	20 min	GMTA	No	None	72.0
	M	10.7	36	Carious	SIP	SAP	Yes	Closed	20 min	WMTA	No	None	71.9
6	F	9.4	16	Restored	SIP	NAT	No	Open	5 min	WMTA	No	Partial	68.5
7	F	12.4	36	Restored	SIP	SAP	No	Closed	15 min	GMTA	No	None	63.0
8	M	10.9	46	Carious	SIP	SAP	Yes	Closed	15 min	GMTA	No	None	18.9
9	M	8.9	36	Carious	SIP	SAP	No	Open	22 min	GMTA	Yes	Partial	68.3
10	M	10.8	36	Restored	SIP	SAP	No	Open	15 min	WMTA	Yes	None	61.4
	M	10.8	16	Carious	SIP	AAP	Yes	Closed	5 min	GMTA	Yes	None	60.7
11	M	11.0	36	Carious	SIP	SAP	No	Closed	21 min	GMTA	Yes	Partial	66.9
12	M	10.4	36	Carious	SIP	SAP	No	Closed	20 min	WMTA	Yes	Partial	60.5
	M	10.4	26	Carious	SIP	NAT	No	Closed	5 min	WMTA	Yes	None	60.4
	M	10.4	16	Carious	AIP	NAT	No	Open	5 min	WMTA	Yes	Partial	60.3
13	F	8.6	36	Carious	SIP	SAP	No	Open	15 min	WMTA	Yes	Partial	55.8
14	F	13.5	26	Carious	SIP	SAP	Yes	Closed	24 min	WMTA	No	None	56.1
	F	13.6	37	Carious	SIP	SAP	Yes	Closed	17 min	WMTA	Yes	None	54.9
	F	13.6	47	Carious	SIP	SAP	No	Open	22 min	WMTA	Yes	None	54.9
	F	13.6	46	Carious	AIP	NAT	No	Closed	10 min	WMTA	Yes	None	54.9
15	F	7.6	46	Carious	SIP	SAP	No	Open	25 min	WMTA	Yes	Partial	51.5
16	M	11.6	26	Carious	SIP	SAP	No	Closed	25 min	WMTA	No	None	36.6

SIP; symptomatic irreversible pulpitis, AIP; asymptomatic irreversible pulpitis, SAP; symptomatic apical periodontitis, AAP; asymptomatic apical periodontitis, NAT; normal apical tissues, GMTA; grey MTA, WMTA; white MTA.

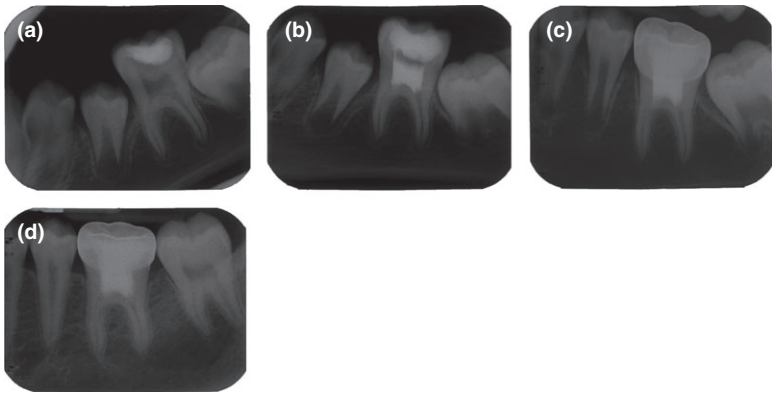

Figure 2 Radiographic evaluation of case 10 (a) preoperative radiograph demonstrating an immature root development of tooth 36, (b) immediately after MTA pulpotomy, (c) 7-month postoperative radiograph demonstrating a dentinal bridge formation and (d) 5-year postoperative radiograph.

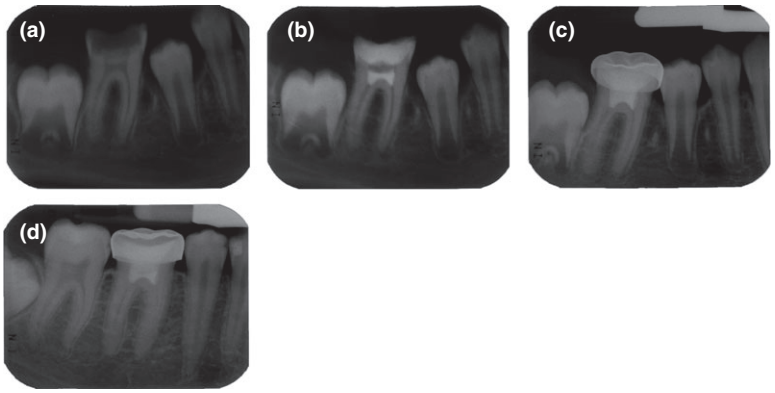

Figure 3 Radiographic evaluation of case 2 (a) preoperative radiograph demonstrating radiolucency around the mesial root of tooth 46, (b) immediately after MTA pulpotomy, (c) 6-month postoperative radiograph and (d) 5.5-year postoperative radiograph demonstrating PCO.

Ghoddusi *et al.* 2012, Simon *et al.* 2013, Alqaderi *et al.* 2014, Clarke *et al.* 2015).

Several restorative materials have been suggested for vital pulp therapy. Clinical studies that have examined the use of calcium hydroxide (CH) for preserving pulp vitality in cariously exposed teeth have shown inconsistent results (Bergenholtz & Spangberg 2004). Potential factors associated with this material that may contribute to these outcomes may include the caustic effects of CH on the pulp tissue, lack of the ability to seal, a tendency to dissolve over time and presence of tunnel defects within formed hard tissue bridges that can act as pathways for microleakage (Stanley 2002). Therefore, researchers have suggested MTA as an alternative to CH in vital pulp therapy. Advantages for using MTA include its favourable biocompatibility, sealing ability, antibacterial and antifungal properties, dentinogenic activity and encouraging clinical outcomes (Aeinehchi *et al.* 2003, Barrieshi-Nusair & Qudeimat 2006, El-Meligy & Avery 2006, Witherspoon *et al.* 2006, Qudeimat *et al.* 2007, Parirokh & Torabinejad 2010, Torabinejad & Parirokh 2010, Asgary & Eghbal 2013).

Clinical investigations of cariously exposed permanent molars diagnosed with reversible pulpitis and treated with MTA have shown high success rates ranging from 82% to 100% (Barrieshi-Nusair & Qudeimat 2006, El-Meligy & Avery 2006, Qudeimat *et al.* 2007, Ghoddusi *et al.* 2012, Simon *et al.* 2013, Alqaderi *et al.* 2014). However, very few studies investigated the use of MTA for pulpotomies of permanent molars with clinical signs and symptoms indicative of irreversibly inflamed pulps. An earlier study investigated the success of MTA pulpotomy for

13 teeth in 10 patients (mean age of 9.7 years.) who were available for a follow-up assessment. The authors reported a success rate of 92% after 6–53 months (Witherspoon *et al.* 2006). The other two studies investigated the success rate of MTA pulpotomy in adult patients. The success rate ranged from 95 to 100% after a follow-up period of 12–42 months (Asgary & Eghbal 2013, Barngkgei *et al.* 2013). In the current study, MTA pulpotomy success rate for young permanent molars with signs and symptoms often associated with irreversible pulpitis was 100% over a follow-up period of 18.9–73.6 months.

Bleeding time of exposed pulps plays a critical role in the success or failure of vital pulp therapy (Stanley 1989, Mass & Zilberman 1993, Matsuo *et al.* 1996). In a recent systematic review, Aguilar & Linsuwanont (2011) concluded that if the pulpal bleeding cannot be stopped within 1–10 min, this indicates progression of the pulpal inflammation into the radicular pulp. The authors suggested that the pulp therapy procedure in such cases should be modified, shifting from partial pulpotomy to full pulpotomy or from full pulpotomy to pulpectomy. The time to stop pulp bleeding in this study ranged from 5 to 25 min. It is possible that the longer bleeding control time observed here was due to the fact that these teeth had irreversibly inflamed pulps at least in the pulp chamber. Also, for some teeth, progression of inflammation into the radicular pulp cannot be ruled out. However, the pulp bleeding control time did not influence the pulpotomy success rate.

For permanent molars with a diagnosis of apical periodontitis, it has been postulated that periapical changes take 2–10 months to be evident on radiographs. Hence, a tooth with periapical radiolucency has a pulpless, infected root canal system. Therefore, for teeth diagnosed with apical periodontitis, root canal treatment is usually the recommended treatment (Abbott & Yu 2007). However, case reports of resolution of periapical radiolucencies after indirect pulp capping and pulpotomy have been published (Foreman 1980, Russo *et al.* 1982, Moule & Oswald 1983, Calişkan 1995, Chueh & Chiang 2010). Out of 24 teeth with gross caries and periapical radiolucencies, one study reported a 46% success rate using CH and zinc oxide cement as an indirect pulp capping agents (Jordan *et al.* 1978). Pulps remained vital and showed resolution of periapical radiolucencies during a follow-up times ranging from 11 months to 7 years. For complete pulpotomies, clinicians used CH and a corticosteroid-antibiotic paste as a pulp dressing agent. In both case reports, the authors described a resolution of the radiolucency and a complete hard tissue bridge formation after 12 months of the initial treatment (Foreman 1980, Moule & Oswald 1983). In the current study, 19 teeth were diagnosed with apical periodontitis of which 7 teeth had a periapical radiolucency. At the completion of this study, all teeth that presented with apical radiolucencies showed remineralization and periapical healing. Three of the 7 teeth with apical radiolucency demonstrated a hard tissue bridge formation. This suggests that MTA pulpotomy can yield good results and can be an alternative to the traditional RCT in young molars with apical periodontitis but with viable pulp tissue with reversible inflammation in the canals.

The quality of the final restoration can be critical to the long-term maintenance of vitality and function of the pulpotomized tooth (Trope 2008). Bacterial recontamination through coronal microleakage should be avoided for the achievement of successful treatment (Saunders & Saunders 1990). Therefore, it is considered essential that a well-sealed coronal restoration be placed over all materials used for vital pulp therapy. Some investigators concluded that the coronal seal is more important than the material used on the vital pulp (Trope 2008). It is possible that one of the main factors for the high success rate seen in this study is due to the good quality seal provided by both MTA and the final stainless steel crown restoration (Ettinger *et al.* 1998, Qudeimat *et al.* 2007).

Although, pulp canal obliteration was found to be more frequent in teeth with open apices, histological and clinical studies have demonstrated calcific bridge formation and lack of canal obliteration as a favourable outcome of MTA pulpotomy for mature permanent molars with irreversible pulpitis (Eghbal *et al.* 2009, Asgary & Eghbal 2013). Previously, investigators reported 100% bridge formation and 0% canal obliteration using MTA for mature permanent molars with irreversible pulpitis (Eghbal *et al.* 2009, Asgary & Eghbal 2013). In the current study, a hard tissue bridge was seen in 57% of cases. Partial canal obliteration (PCO) was evident in 39% of cases. In response to infection, the dentine–pulp complex exhibits significant regenerative response with the tertiary dentine deposited arising from either the original primary odontoblasts or newly differentiated odontoblast-like cells (Cooper *et al.* 2010). The differences in complexity of the cellular events involving these two cell populations indicate that the impact of the inflammatory response will have differing effects (Cooper *et al.* 2010). The reason a hard tissue barrier formation or PCO is not

initiated in all cases is not well understood (Waterhouse *et al.* 2011). In this study, maturity of the tooth, bleeding stoppage time and the preoperative apical diagnosis did not seem to influence the hard tissue bridge formation or PCO. Because of the inability to evaluate pulp status after full pulpotomy and the risk of subsequent PCO, some authors recommended pulpectomy routinely after the roots have fully formed (Sjögren *et al.* 1990). However, in a recent study which evaluated the quality of RCTs carried out in children (average age of 13.4 ± 2.3 years), of 100 cases assessed, 61% were classified as satisfactory. In children who were apprehensive, moved during treatment or demonstrated an uncooperative behaviour, the outcomes were significantly less satisfactory than those who were compliant (Clarke *et al.* 2015). In addition, the incidence of pulp necrosis following canal obliteration is generally considered low (McCabe & Dummer 2012). The current recommendations for teeth with PCO are root canal treatment only when there are clinical symptoms and/or definite radiographic findings suggestive of periapical disease (McCabe & Dummer 2012, Malhotra & Mala 2013). In such cases, if executed properly, RCT can be highly successful (Malhotra & Mala 2013). Therefore, pulpotomy for permanent molars in children is a viable option.

Conclusion

In the light of findings from this preliminary study, for children and adolescents who are unable to cooperate with or afford the cost of traditional RCT, MTA pulpotomy can be considered an option for cariously exposed permanent molars with clinical signs and symptoms that would traditionally contraindicate such conservative management. However, more clinical studies on larger sample sizes are required to identify and assess risks, costs and benefits of MTA pulpotomy as a permanent endodontic procedure.

Conflict of interest

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

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