Outcome of Vital Pulp Therapy in Permanent Teeth with Carious Pulp Exposure: A Series of Successfully Treated Teeth

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Background: In modern Endodontic practice, vital pulp therapy (VPT) has been introduced as a biologically based modality of minimally invasive treatment. It encompasses diverse treatment modalities for deep carious lesions that approximate the pulp in vital teeth. The aim of these procedures is to preserve a healthy pulpal tissue with sustained vitality by eradicating bacteria from dentin-pulp complex and preventing apical periodontitis.

Objective: To prospectively investigate the clinical and radiographic short and intermediate success rates of pulpotomy in permanent teeth with various pulpal clinical diagnosis using different bioactive endodontic cements (BECs).

Setting: Ahmed Ali Kanoo Heath Center, Bahrain.

Design: Prospective study.

Method: Eleven patients were included of both categories (mature n=3 and immature n=8 roots) with established preoperative pulpal diagnosis for irreversible (n=8)/reversible pulpitis (n=3). All teeth received pulpotomy and capping cariously exposed vital pulp with hydraulic BECs (mineral trioxide aggregate (MTA) n=9, Bioceramic n=2). Assessment of clinical and radiographic outcomes done on a schedule set at 3, 6, 12, 24 months and annually thereafter.

Result: The recall rate ranged initially from 81% at 3 months to 100 % thereafter, with overall 100% clinical and radiographic successful outcomes at different recall intervals. One case presented after 24 months with a resolution of the periapical radiolucency, and shared signs of canals narrowing with other one.

Conclusion: Pulpotomy using BECs was a viable treatment option for cariously exposed pulp chamber in selected cases. Clinical signs of irreversible pulpitis together with the existence of radiographic periapical radiolucency should not be excluded from VPT procedures.

INTRODUCTION

Dental caries is a noncommunicable disease of high prevalence globally[1]. Caries is preventable, but if neglected may progress toward the pulp chamber eliciting complex degenerative and inflammatory events that can result in pulp necrosis and apical periodontitis[2]. Data indicates that approximately 55% of previously root treated vital teeth caused by pulpitis as a sequalae of untreated decay[3].

Despite the fact that complete pulp tissue removal by pulpectomy in inflamed vital teeth is of a predictable success rate close to 90%[4], if performed aseptically up to the high technical standards. The global incidence of technically inadequate root fillings and post treatment diseases is high and ranged between 30-60%[5]. Conventional root canal treatment is a complicated, destructive, time-consuming and expensive process, especially in general practice where the outcomes are less optimal[6]. There is an exquisite array of environmental sensory and defensive mechanisms at the odontoblastic layer within dentin-pulp complex. Therefore, preservation of such protective responses will be destroyed in pulpless teeth[7]. Rendering such teeth to be more prone to fracture, further caries and infections, with not as good as vital in survival recording a hazard ratio of 7:1 [8]. It can be postulated that promoting and maintaining pulpal tissue vitality in restorative procedures would ensure prevention of apical periodontitis that stems from nonvital/infected pulp. In other words, the biologic rationale for endodontic treatment is achieved via vital pulp therapy (VPT) treatment modalities[9]. Clinically, VPT is an umbrella term for pulp capping (direct/indirect) and pulpotomy (partial/complete).

Pulpotomy or pulpal tissue excision, is a conservative procedure whereby the inflamed/diseased tissue is surgically amputated from the coronal pulp space of a tooth leaving healthy tissue which is capped with a biomaterial that preserves tissue vitality and encourages repair. It can be either partial (involves removal of 2-3mm of inflamed, irreversibly damaged coronal pulp tissue) or complete (in which total coronal pulp excised)[10]. Traditionally, is indicated in primary teeth as a treatment of reversible pulpitis associated with carious lesion or after traumatic pulp exposure and immature permanent teeth[11]. In mature permanent teeth, the full pulpotomy is reported as an emergency pain relief step proceeding conventional root canal treatment[12]. However, the investigation of pulpotomy as definitive treatment for mature

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asymptomatic curiously exposed teeth is fortified; due to a combination of less technical complexity, development of compatible bioactive endodontic cements (BECs) and enhanced understanding of pulp biology and its regenerative potential[13,14].

Nevertheless, evidence is compromised to properly guide clinicians on treatment decisions in pulpotomy of teeth with closed apices. Multiple studies reported mismatch between signs and symptoms with the histologic picture of the pulp[15,16]. In the mean time, a percentage of 15.4 % in teeth diagnosed clinically with irreversible pulpitis could be still receiving pulp vitality preservation procedures due to the coexistence of healthy tissues in the same pulp at different zones[17]. The deep-rooted professional doctrine that carious exposure, or spontaneous irreversible pulpitis of a permanent tooth contraindicate application of VPT is challenged by demonstration of successful outcomes in recent multiple clinical trials relative to conventional root canal treatment[18-22].

The main aim of this report was to determine success rate of both types of pulpotomy in permanent teeth with variable signs and symptoms of pulpitis. A subsidiary aim is to evaluate the performance of different bioactive materials (MTA, Bioceramics).

METHOD

Recruitment of the 11 cases extended from August 2017 to March 2020 among patients seeking emergency care for symptomatic permanent teeth. Verbal assent and written consent were obtained from either participating patients/ guardian after full explanation of study objectives, benefits of pulpotomy, risks and alternatives if failure occurs.

Participants who fulfilled the following inclusion criteria have been included; noncontributory medical history, cooperative at operation and in attendance of scheduled follow-up visits, of restorable carious permanent tooth involving inner third of dentin regardless of clinical symptoms and presence or absence of apical rarefaction, positive to sensibility tests (cold/electrical), normal limits of pocketing and mobility, absence of signs of pulpal necrosis as sinus tract or swelling and radiographically not presented with signs of external or internal resorptive pathosis. Exclusion criteria applied were; compromised remaining tooth structure after meticulous complete caries excavation, no pulp exposure upon caries elimination, periodontal involvement, teeth required more than 10 minutes to attain hemostasis or no bleeding encountered, and unfavorable characteristic of pulpal tissue as viewed under magnification (either Hyperemic of dark hue red colour or necrotic with pale yellow zones of liquified necrosis[23]).

A thorough history of the chief complaint related to candidate tooth obtained from patients preoperatively. Huskinsson visual analogue scale {VAS} was employed to record preoperative and postoperative pain. A list of routine clinical investigations was carried out including careful visual examination of the carious lesion under magnification, vitality tests including cold test with cold spray **(Endo-Ice; Coltene / IWhaledent, Inc, OH, USA)** to imitate patients' symptoms and electrical pulp test using **(Digitest; Parkell Inc., NY, USA)**, percussion / apical palpation tests, peripheral periodontal examination and periapical radiographs. Documentation of each potential case with digital radiographs taken with a digital sensor **(Kodak 6100, France)** as well as clinical photographs via the same digital camera of same setting later at follow up visits to evaluate noticeable discoloration. All radiographs interpreted with a calibrated endodontist who subjected to test intra-observer reliability by Cohen`s Kappa coefficient of agreement index.

All clinical interventions were performed aseptically under rubber dam and magnification. Witherspoon[24] and Ricucci *et al*[23], clinical protocol of pulpotomy were adopted in all cases. After achieving profound local anesthesia **(lidocaine hydrochloride 2% with 1;100000 epinephrine, Novocol, Canada)**, disinfection of the clinical crown done with 5% NaOCl solution **(Vista, USA)** before caries excavation: initially, caries removed using a sterile round high-speed diamond bur with adequate water coolant, followed by sharp spoon excavator. Once approximating a pulp exposure, the cavity is flushed with 3% NaOCl solution **(Vista, USA)**, and rinsing applied again upon virtual exposure. Tooth allocation for either partial pulpal amputation of 2-3 mm by a sterile round high - speed bur or complete coronal tissue excision to a level of canal orifices according to the following parameters: no dentin chips dislodged in the pulpal wound, reaching to bright red homogenous pulpal tissue, hemostasis achieved after maximum 10 minutes by a sterile dampened cotton pellet in NaOCl. Subsequently, the pulp wound was capped with either white MTA **(Angelus, Londrina, Brazil)** or bioceramic root repair material **(PC, Totalfill, FKG, Switzerland**). The capping materials applied in 1-2mm thickness with a messing gun and adapted gently with a sterile cotton pellet. Another soaked sterile pellet left over the capping material to complete its setting. Intermediate Restorative Material **(IRM, Dentsply)** was used to achieve an interim coronal seal for about 2-3 days. At the second visit, asymptomatic teeth or those of mild discomfort received a definitive restoration in composite resin restoration **(Tetric®N-Ceram Bulk Fill, ivoclar vivadent**) under rubber dam to avoid recontamination. A postoperative periapical radiograph taken as baseline record (Figure 1).

Treatment outcome assessed clinically and radiographically at a periodic recall scheme set at 3 months, 6 months, 1 year and annually thereafter for 5 years. At each follow-up, radiographs, photographs were taken with sensibility tests (thermal and electrical) to determine pulp vitality when applicable. Zanini *et al*[25] and Taha *et. al*[26] criteria for success adopted in this study which include:

Clinical criteria; no spontaneous or lingering pain except for mild discomfort at initial 2 days, functional tooth with no pain on chewing or percussion, positive to sensibility tests if applicable, normal grade 1 mobility without attachment loss, normal soft tissue around the tooth without swelling or sinus tract and negative to apical palpation, good quality coronal restoration, absence of recurrent decay.

Radiographic criteria; absence of radicular resorptive defects (internal/ external), no furcal pathosis, absence of periapical rarefaction. Any object will be offered conventional root canal therapy if signs of failure developed.

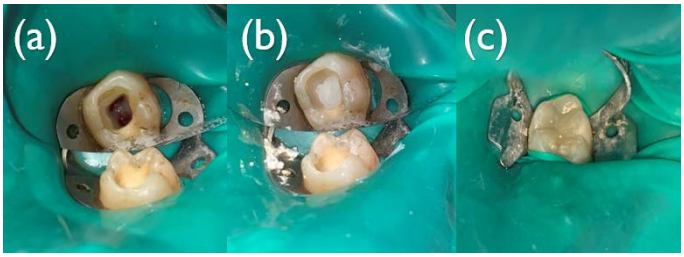

Figure 1: (a) Radicular healthy pulp stumps after achieving hemostasis. (b) Capping the pulp with a uniform MTA thickness of 2mm (C) Final Composite resin restoration

RESULT

Eleven participants (5 males and 6 females) with 11 permanent teeth (1 premolar, 10 molars) were enrolled. The age range as registered at time of pulp therapy was (7-28) years. On initial presentation, about (72.7%) of patients reported high VAS score of preoperative pain and the remainder either scored mild pain (2 cases) or with a provoked pain by cold spray (one case). None of study patients reported the use of analgesics for pain postoperatively neither after placement of the definitive restoration.

Partial pulpotomy only planned for 2 cases, the remainder received full pulpotomy. Majority of cases (72.7%) had incomplete root formation. Overall, average time for attaining control of pulpal tissue hemorrhage was 6 minutes. Full coronal pulpotomy with Bioceramics performed in merely two cases (1 mature, 1 immature root), the remainder received MTA as a pulpotomy agent. Refer to (Table 1)

The range of follow up period was (6-48) months, with ongoing schedule planned for all the cases up to 5 years.

Recall rate was (80%) at 3 months period, but dramatically rose to 100 % at the next follow-up intervals.

All cases demonstrate extremely high successful outcome (100%) clinically and radiographically at examination on follow-up intervals. Molars with immature roots showed signs of continued root development, notably after 6 months postoperatively. About (27%) of open apices molars showed signs of complete root maturation as detected radiographically. Canal narrowing was discernible in radiographs for two cases after follow up period of 24 months. In one immature root with signs of preoperative periapical radiolucency, lesion has resolved completely at 48 months. None of the cases showed radiographic signs of new emerging rarefaction nor resorptive pathosis

Table 1 Preoperative characteristics of study cases

Case number	Gender	Age (years)	Tooth	Pulpal diagnosis	Apical diagnosis	Investigation				Pre -operative. Pain -VAS- score	Root maturation
						EPT	Cold test	Percussion	Palpation		
Case 1	Female	14	16	SIP	NAT	+	++	-	-	Spontaneous (8)	Mature
Case 2	Female	13	46	RP	NAT	+	+	-	-	mild pain (2)	Mature
Case 3	Female	28	24	RP	NAT	+	+	-	-	Provoked (3)	Mature
Case 4	Male	13	37	SIP	SAP	+	++	+	+	Spontaneous (8)	Immature
Case 5	Female	12	36	SIP	NAT	+	++	-	-	Spontaneous (7)	Immature
Case 6	Male	14	47	SIP	NAT	+	++	-	-	Spontaneous (7)	Immature
Case 7	Male	9	36	SIP	SAP	+	++	+	-	Spontaneous (7)	Immature
Case 8	Male	13	37	RP	NAT	+	+	-	-	mild pain (2)	Immature
Case 9	Male	8	36	SIP	NAT	+	++	-	-	Spontaneous (6)	Immature
Case 10	Female	7	46	SIP	NAT	+	++	-	-	Spontaneous (7)	Immature
Case 11	Female	15	37	SIP	NAT	+	++	-	-	Spontaneous (8)	Immature

Table 2: A summary of the outcome among participants

Case number	Type of pulpotomy	3 months follow up		6 months follow up		12 months follow up		24 months follow up		36 months follow up		48months follow up	
		Clinical	Radio-graphic	Clinical	Radio-graphic	Clinical	Radio-graphic	Clinical	Radio-graphic	Clinical	Radio-graphic	Clinical	Radio-graphic
Case 1	Complete ●	✓	✓	✓	✓	✓	✓	✓	✓				
Case 2	Partial ▓	✓	✓	✓	✓	✓	✓	✓	✓↓				
Case 3	Partial ▓	✓	✓	✓	✓	✓	✓						
Case 4	complete ▓	✓	✓	✓	✓	✓	✓↻	✓	✓↻	✓	✓↓⌄	✓	✓↓⌄
Case 5	complete ▓	✓	✓	✓	✓↻	✓	✓↻						
Case 6	complete ▓	A	A	✓	✓↻	✓	✓⌄						
Case 7	complete ●	✓	✓	✓	✓↻								
Case 8	complete ▓	✓	✓	✓	✓⌄								
Case 9	complete ▓	A	A	✓	✓↻								
Case 10	complete ▓	✓	✓	✓	✓↻								
Case 11	complete ▓	A	A	✓	✓↻								

●Ceramic ▓ MTA ✓ meets the criteria of success A: absent ↻ continued root formation ⌄ complete root formation
↓ canal narrowing or obliteration ■ not due to follow up

(internal or external). Perceptive coronal discoloration was absent. All restorations were adequate except for one after 3 years, where incomplete composite fracture had been repaired. Refer to Table 2, figures (2-5)

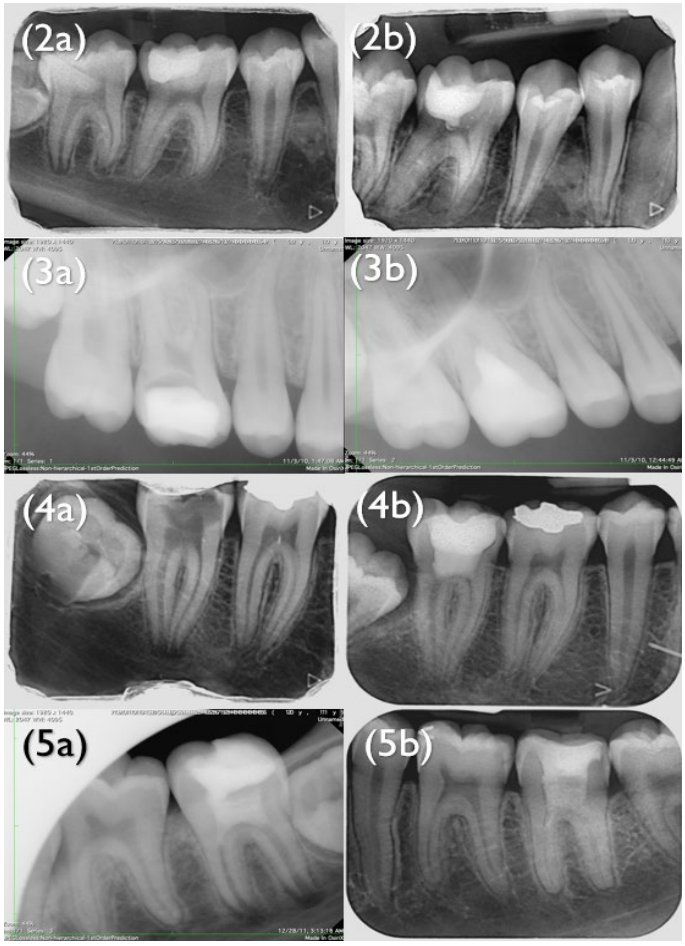

Figure 2. 13-years-old female presented with symptoms related to lower right first permanent molar after receiving direct pulp capping with (calcium hydroxide). The tooth was diagnosed with reversible pulpitis. (a) preoperative radiograph. (b) The 24-month follow up after MTA partial pulpotomy, signs of canal obliteration but normal periapex

Figure 3. 14-years- old female presented with symptoms related to upper right first permanent molar, dressed by Eugenol-soaked cotton pellet and restored by Glass ionomer. The tooth was diagnosed with irreversible pulpitis. (a) preoperative radiograph. (b) The 24- month follow up after MTA complete pulpotomy.

Figure 4. 14-years-old male presented with severe pain related to lower right second permanent molar. The tooth was diagnosed with irreversible pulpitis and normal apical tissue. (a) preoperative radiograph. (b) 12 months follow up radiograph showing complete root maturation after MTA complete pulpotomy

Figure 5. 13-years-old male presented with severe pain related to lower left second permanent molar. The tooth was diagnosed with irreversible pulpitis and symptomatic apical periodontitis. (a) Immediate postoperative radiograph with MTA complete pulpotomy. (b) 48-month recall radiograph revealing healed periapical rarefaction and signs of canal narrowing at distal canal, concomitant with obliteration of mesials and normal periapex.

DISCUSSION

Approaching a clinical problem should be based on updated robust evidence, and up to date, there are no definite consensus regarding the management of cariously exposed pulps that is common among adults and adolescence (age group of this study). An accurate diagnosis of the pulpal status upon exposure to an insult as caries is critical for arriving at a satisfactory treatment decision[16]. It is equally important to be able to determine whether the pulp is reversibly or irreversibly inflamed, as degree of pulpal inflammation will immensely impacts the healing or biological regeneration. Practically, the distinction is questionable and such classification is not biological and considered only as clinical labels to determine outcome of treatment[27]. Additionally, unreliability of diagnostic accuracy of clinical signs/symptoms and available tests to distinguish true depth of the disease progression into the pulp. clinicians have long faced a difficulty in correlating clinical symptoms with actual histologic picture of an inflamed pulp[15,16]. Classical histological studies reported that vital pulp with carious exposure not always completely infected, depending on the extent and duration of the carious attack[28]. Occasionally, inflammation was extended to 2mm subjacent to exposure site without involving the whole coronal and radicular pulp; imply the diagnostic category of partial necrosis[28]. Considering that major cause on inflammation is an infection, pulpal tissue should be able to heal with conservation of remaining healthy pulp if the source of infection is eradicated[15]. On other word, pulpitis induced by caries should be reversible, especially with the eradication of the caries-related infectious elements[15]. Due to factors of technical ease, short chair time, preserving proprioception, hydration of tooth structure, preserving pulp vitality in immature root to complete apexogenesis, development of new bioactive endodontic cements that facilitate release of dentin growth factors, VPT procedures including pulpotomy of permanent tooth may provide a hope as an alternative to root canal treatment in teeth with vital pulp either of open or closed apices[13].

This study reported extremely high successful outcome of pulpotomy in permanent teeth with various clinical presentations. These preliminary results lend support for a more extended randomized clinical trial of the application of pulpotomy in irreversible as well reversible pulpitis. No incidence of failure among the cases reported. The overall success rate clinically and radiographically was superior to other investigators[18-20,26,29].

It is vital to highlight that actual progress of pulpal connective tissue degeneration or inflammation cannot be deduced from clinical signs and symptoms[28]. Accordingly, in this study the authors have followed guidelines proposed by Ricucci *et al*.[23] in deciding the level of pulpal tissue amputation in each case, which is based on detailed inspection of the affected tissues under magnification together with hemostasis attainment within reasonable range of time and hard mineralized dentin surrounding the wound. This is applied for case No 8 where he presented initially with clinical signs of reversible pulpitis, but upon intervention the decision to shift from partial to complete pulpotomy dictated by encountering a healthy surgical wound. Absence of immediate failures may indicate that pulpal inflammatory conditions was correctly inferred by direct clinical examination. In total, high scores of preoperative pains was not a negative prognostic factor in this report and it is in agreement with other recent studies[18,20.]

One of the benefits in considering pulpotomy of symptomatic vital pulp, is the prompt pain relief among patients, for instance, approaches about 95% in a study of Galani *et al*[30]. This is attributed to the dramatic reduction in concentration of molecular inflammatory mediators with associated local tissue pressure and severing the nociceptive sensory terminals. It is reported that higher incidence of postoperative pain

related to the intensity of preoperative clinical symptoms, specially up to 24 hours. In this report none of the cases reported a need for non-steroidal inflammatory drugs postoperatively.

The overall performance of both BECs namely MTA and Bioceramic was not different even with limited number of clinical cases represented ceramic at period of time ranged from 6-24 months post-treatment. Both materials are based in composition on the bioactive hydraulic calcium silicate, that explained the similar biological features for vital pulp therapy, including excellent biocompatibility, odontogenic outcomes, biomineralization potential, minimal inflammatory response, angiogenesis and antibacterial properties[31].These cements should be applied in sufficient thickness under stringent aseptic rubber dam isolation to protect fresh pulp wound till the physiologic calcified hard-tissue barrier completely matured.

Development of periapical pathology may be associated with varying portions of vital pulp, periapical reaction to bacterial products may precede the process of full pulp necrosis. It reflects the neurogenic inflammation caused by the release of neuropeptides such as substance P from afferent nerves supplying the area. Therefore, once the insult is removed and the remaining tissue not of an advance damage, the radiolucency will be amenable to heal[32]. In this study, one case presented initially with a radiolucency that is healed completely by 48 months. This finding is also repeatedly reported in multiple clinical trials [2,29].

Despite the concerns of accuracy in visualization at overlapping two-dimensional radiographs, two cases judged to have canals narrowing without full obliteration. Therefore, subsequent, root canal treatment (in case of clinical symptoms and/or definitive radiographic finding of an apical disease) is less likely to be technically complicated specially under magnification and with the aid of cone beam computed tomography (CBCT). Pulp obliteration due the uncontrolled hard tissue deposition is a common sequala specially in immature roots[20], however the incidence of pulpal and periapical disease emanating from an obliterated pulp canals is low[33]. Interestingly, both cases presented with different root maturity, apical diagnosis and type of pulpotomy provided.

Young age group of patients are considered perfect candidates for VPT due to abundant apical blood supply, freedom of age-related changes and enhanced anti-inflammatory capacity[34]. Meanwhile, Pulpotomy after pulp exposure in retrospective studies[2,19] and randomized clinical trials[18,29], shows an equal distribution of success and failure outcomes regardless the age. The oldest patient shared (case No 3) sustained successful outcomes up to 12 months comparable with younger age groups. Undeniably, most of our cases are below age of 20, so the mature teeth were still young with excellent regenerative and reparative capacities.

A retrospective study concluded a significant positive association between coronal seal quality and clinical success of pulpotomy[35]. As any bacterial microleakage and recolonization of the pulpal tissue, eventually results in degeneration[23]. A case received repair of the coronal restoration after 36 months.

There is no study reports a time frame and risk analysis for the development of apical diseases in teeth received pulpotomies well as exact period necessary for follow up[18]. Matsuo et al. recommended a period of 3 months for tentative evaluation of the outcome[36], long-term follow is needed to detect latent adverse events due to post-operative contamination or even in cases of signs of pulpal obliteration[25]. The frame time of this study was in accordance to ESE statement[27]. Zanini et al. described the periapical health as a clinically relevant measure of pulpotomy outcome, as clinician may struggle with vitality tests in pulpotomised teeth[25]. High quality radiographs are of paramount importance in detecting early periapical changes. CBCT may offer a lot in this aspect as well.

The finding of this preliminary study should be taken in caution as it suffers certain limitations among which; low number of recruited patients and variable follow up periods between them, mostly young age group included, lack of histological evaluation that is accurately representing the pulpal tissue picture to minimize invasiveness of pulpotomy itself. Results do not provide a definitive reply to which factors influence the outcome, however, may provide some information that may be useful for highly evidenced, longer term prospective future studies.

CONCLUSION

Vital pulp pulpotomy should be revisited and considered as a reliable alternative to root canal therapy in meticulously selected permanent teeth with carious exposure. Provided that criteria such as stringent isolation, pulpotomy agents of bioactive ability, optimal quality of coronal restoration and patient cooperation, are met. Within limitations of this report, MTA and Bioceramics were of comparable successful rate as pulp capping agents. Vital permanent teeth have the potential to heal following pulpotomy regardless pulpal or periapical diagnosis.

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