Comparison of Electrosurgical Pulpotomy with Zinc Oxide Eugenol or Zinc Polycarboxylate Cements Sub-Base

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Purpose: *The aim of this study was to compare the clinical and radiographic success rates of electrosurgical pulpotomy of human primary molars with zinc oxide eugenol (ZOE) and zinc polycarboxylate (ZPC) cements.* ***Methods:*** *In this randomized clinical trial study, 120 primary second molar teeth were treated by electrosurgical pulpotomy. Teeth were randomly assigned to two groups according to whether ZOE or ZPC cement was used as a sub-base. Teeth were restored with stainless steel crowns and were evaluated clinically and radiographically after 3, 6, and 12 months by two independent examiners. Clinical treatment outcomes and radiographic findings were statistically analyzed using Fishers' exact test with statistically significant differences defined for $P < 0.05$.* ***Results:*** *At 12 months, the clinical and radiographic success rates in the ZOE group were 98.2% and 84.2% and in the ZPC group were 96.2% and 75%, respectively ($P > 0.05$ for all).* ***Conclusions:*** *The outcomes of this study suggested that either ZPC or ZOE sub-base have similar clinical and radiographic success in electrosurgical pulpotomy.*

Keywords: *Pulpotomy; Tooth; Molars; electrosurgical pulpotomy; Zinc Oxide Eugenol cement; zinc polycarboxylate cement*

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INTRODUCTION

Pulpotomy is the most common primary tooth pulp treatment in children under 6 years of age.[1] Buckley's formocresol was first introduced as a pulp medicament in 1904, and since 1930 has been the drug of choice for primary molar vital pulpotomies due to its ease of use and high clinical success rate (55-98%).[2,3,4] However, formocresol and formaldehyde (a formocresol constituent) are potentially mutagenic and carcinogenic according to some animal studies[5,6] and has been shown to be distributed systemically after pulpotomy.[7]

In 2004, the IARC (International Agency for Research on Cancer) issued a press release classifying formaldehyde as carcinogenic to humans.[3] This information was circulated to all pediatric dentistry consultants, resulting in the withdrawal of Buckley's formocresol and all paraformaldehyde containing devitalizing pastes from most teaching hospitals in the UK,[3] however, some researchers believe that formocresol, when used judiciously, is unlikely to be genotoxic, immunotoxic, or carcinogenic in children when used in pulpotomy procedures.[8]

To identify a biologically acceptable and effective alternative to formocresol, other agents and techniques have been examined. After amputation of the inflamed coronal pulp, a non inflamed radicular pulp can be altered through devitalization (e.g., with formocresol or electrosurgery), preservation (e.g., with ferric sulfate), or regeneration (e.g., with bone morphogenetic proteins).[9,10] Electrosurgery is a nonpharmacological, hemostatic technique for pulpotomy prior to placing a lining material. It is a time-efficient method that is relatively free from postoperative complications, with a high success rate similar to formocresol pulpotomy.[4, 11-15]

Currents producing various amounts of heat are used to produce a surgical incision, coagulation, or electrofulguration. The procedure carbonizes and denatures the pulp tissue, producing a layer of coagulative necrosis that protects the healthy radicular tissue beneath the lining base material.[1]

Despite many positive results for electrosurgery, some studies indicate less radiographic success using this technique compared to formocresol pulpotomy[4]

Such failures may be related to the stimulating and harmful effects of eugenol. Therefore, the purpose of this study was to assess the clinical and radiographic success rate of electrosurgical pulpotomy of primary molars with zinc oxide eugenol (ZOE) or zinc polycarboxylate (ZPC) cements, to identify the most suitable pulp-capping material.

MATERIALS AND METHOD

Patients: Healthy and cooperative 110 boys and girls (mean

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age 48.± 12 months) were selected from among patients referred to the dental clinic of the School of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran. Selection was based on the patient having one or two second primary molars requiring pulpotomy. This study was approved by the Research Ethics Committee of the Mashhad University of Medical Sciences. Full detailed treatment plans were explained to the parents or guardians of each child. After obtaining written consent, periapical radiographs of the teeth to be treated were obtained.

Inclusion criteria: The 120 primary mandibular second molars included in our study were selected according to the following criteria: 1) Being symptom free, 2) carious exposure of vital pulp, 3) no radiographic evidence of physiologic root resorption, 4) no clinical or radiographic evidence of pulpal degeneration, 5) possibility to fit a proper restoration, 6) enjoying complete medical health.

Experimental Groups: Primary mandibular second molars were randomly assigned to one of two treatment groups (n = 60 teeth each) using random allocation table generated by the method block of random permuted (Fliess 1986), depending on whether electrosurgical pulpotomy was performed with a ZOE or ZPC cement sub-base. When a patient presented with two teeth requiring pulpotomy, each tooth was assigned randomly to one of the two treatment groups. Each tooth was assigned a numerical code, which was available only to the operator.

Clinical and recent radiographic examinations were considered in the selection of teeth for vital pulpotomy, but final case selection was based on the direct evaluation of pulp tissue after coronal amputation. If the nature of the bleeding from the amputation site was normal (red color and hemostasis evident in < 5 min with mild cotton pellet pressure), the pulp tissue in the canals was assumed to be normal. This ensured a similar pulp tissue quality in all cases. If bleeding recommenced afterward, the tooth was excluded for the study. After performing local anesthesia, all teeth were isolated with a rubber dam and dental caries were removed with a large slow-speed round bur before pulpal exposure. The entire roof of the pulp chamber was then removed. This procedure was accomplished using a No. 330 bur mounted in a water-cooled high-speed turbine. The coronal pulp was amputated using a slowly revolving round bur, and the pulp chamber was irrigated with a light flow of normal saline. Initial hemorrhage control was achieved using one or more sterile, moistened cotton pellets over the pulp stumps with pressure for a few minutes. Complete hemostasis was achieved using electrocoagulation. During the procedure, the active burnisher from the electrode tip was positioned ~ 1 mm above the orifice pulp tissue and closes enough for electrical arcing. A current was applied for 1-2 s over each pulpal stump followed by a cool-down period of 5 s. Heat was minimized by keeping the electrode as far away from the pulpal stumps and tooth structure as possible while still allowing electrical arcing to occur. This procedure was repeated up to a maximum of 3 times at each pulpal orifice.

To avoid heat build-up in any one area of the tooth, single current applications of 1 s were performed to each orifice in a rotational sequence. After each application, a new large sterile cotton pellet was placed with pressure on the next pulpal orifice to be electrosurgically treated to absorb any blood or tissue fluids. A Perfect TCS (A Colten/Whaledent Inc.) electrosurgery device was used, with power set at 40%.

After irrigation with normal saline and observation of hemostasis (i.e., pulpal stumps appeared dry and completely blackened, the treated pulpal stumps were covered with a ZOE (IRM, Dentsply, USA) or ZPC cement (Poly F Plus, Dentsply,USA) sub-base according to the manufacturer's instructions. Teeth were restored with stainless steel crowns (3M ESPE, USA). If hemorrhage was not controlled, pulpectomy was performed and the tooth was eliminated from the study. All pulpotomies were performed by an unblinded operator (second author) who was not a radiographic interpreter in the follow-up periods.

Clinical and Radiographic Evaluations

Teeth were evaluated clinically and radiographically at 3, 6, and 12 postoperative months. Two blinded examiners compared the lamina dura of pulpotomized teeth on high-quality size 1 periapical radiographs before and after treatment. The success or failure of each tooth was determined according to clinical and radiographic criteria. "Clinical success" was defined as the absence of spontaneous or nocturnal pain, excessive tooth mobility, subjective symptoms of pain, tenderness to percussion, abscess, swelling, or fistula according to previous studies.[16-18] "Radiographic success" was recorded for samples that did not show any pathological defect or lesion progression and for samples that demonstrated healing of the former defects. "Radiographic failure" was recorded if any of the following were observed: partial loss of the lamina dura; widening of the periodontal ligament (PDL); any sign of pathologic external or internal root resorption; periapical or interradicular radiolucency; and new pathological findings or progression of the former lesions from the last follow-up.

Calcification metamorphosis results from the extensive activity of odontoblast-like cells and indicates that the tooth retains some degree of vitality. Therefore, pulp canal obliteration (PCO) indicated that the pulp was vital and active, and was not regarded as a failure.[11, 19, 20]

Statistical Analysis: Clinical treatment outcomes and radiographic findings were evaluated using the Fisher's exact test with the Statistical Package for Social Science (SPSS) software. The level of significance was set at $P < 0.05$.

RESULTS

Of the 120 teeth of 110 children, 108, 110, and 109 teeth were available for follow-up at 3, 6, and 12 months, respectively. Fisher's exact test revealed no significant difference between the clinical and radiographic success rates of the two groups at 3, 6, or 12 months (Table 1). The most common pathologic radiographic finding was internal resorption, which was seen in 3 (5.6%), 13 (22.8%), and 18 ZOE

Table 1. Clinical and radiographic assessment at 3, 6, and 12 months

Sub-base	Success/Failure	No. (%)					
		3 Months		6 Months		12 Months	
		Clinical	Radiographic	Clinical	Radiographic	Clinical	Radiographic
ZOE	Success	54 (100)	51 (94.4)	57 (100)	47 (82.5)	56 (98.2)	48 (84.2)
	Failure	0 (0)	3 (5.6)	0 (0)	10 (17.5)	1 (1.8)	9 (15.8)
	Unavailable for Recall	6 (10)	6 (10)	3 (5)	3 (5)	3 (5)	3 (5)
ZPC	Success	54 (100)	45 (83.3)	53 (100)	38 (71.7)	50 (96.2)	39 (75)
	Failure	0 (0)	9 (16.7)	0 (0)	15 (28.3)	2 (3.8)	13 (25)
	Unavailable for Recall	6 (10)	6 (10)	7 (11.7)	7 (11.7)	8 (13.3)	8 (13.3)
	Results of Fisher's exact tests:	*P = 0.6*	P = 0.123	*P = 0.6*	P = 0.255	*P = 0.6*	P = 0.340

Table 2. Pathological radiographic findings at 3, 6 and 12 months

	No. (%)					
	3 Months		6 Months		12 Months	
	ZOE	ZPC	ZOE	ZPC	ZOE	ZPC
External resorption	0 (0)	2 (3.7)	1 (1.8)	3 (5.7)	3 (5.3)	18 (31.6)
Internal resorption	3 (5.6)	7 (13)	13 (22.8)	12 (22.6)	18 (31.6)	17 (31.5)
Widening of the PDL	0 (0)	1 (1.9)	1 (1.8)	3 (5.7)	2 (3.5)	7 (13)
Periapical radiolucency	0 (0)	1 (1.9)	0 (0)	1 (1.9)	0 (0)	2 (3.7)
Furcal radiolucency	0 (0)	2 (3.7)	1 (1.8)	4 (7.5)	3 (5.3)	8 (14.8)
Replacement resorption	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

group teeth (31.6%) and in 7 (13%), 12 (22.6%), and 17 ZPC group teeth (31.5%) at 3, 6, and 12 months, respectively (Table 2). Pulp canal obliteration was common in both groups at all follow-up periods, but was more frequent in the ZOE than in the ZPC group at 12 months (Table 3). Table 4 summarizes the radiographic internal resorption results during the 6- to 12-month follow-up period.

Table 3. Radiographic assessment of pulp canal obliteration at 3, 6, and 12 months

Sub Base	PCO	No. (%)		
		3 Months	6 Months	12 Months
ZOE	PCO^+	5 (9.3)	7 (12.3)	15 (26.3)
	PCO-	49 (90.7)	50 (87.7)	42 (73.7)
ZPC	PCO^+	1 (1.96)	2 (3.8)	4 (7.4)
	PCO-	53 (98.0)	51 (96.2)	50 (92.6)
Results of Fisher's exact tests		*P = 0.2*	*P = 0.164*	*P = 0.008*

Table 4. Radiographic assessment of internal resorption during the 6- to 12-month follow-up period

Sub Base	No. (%)			
	No Change	Healing	Progression	Total
ZOE	8 (61.5)	2 (15.4)	3 (23.1)	13 (100)
ZPC	5 (41.7)	4 (33.3)	3 (25)	12 (100)
Result of Fisher's exact test P = 0.67				

DISCUSSION

The observed one-year clinical and radiographic success rates of electrosurgical pulpotomy with a ZOE cement sub-base (98.2% and 84.2%, respectively) were higher than Dean *et al* [4] and *Fishman et al,* [21]. While our rates were lower than those reported by Mack *et al*.[11] Because electrosurgical pulpotomy is a safe, easy, and effective nonpharmacological method with no evidence of any adverse effects, we recommend electrosurgical pulpotomy in primary teeth as a substitution for formocresol.[4, 22, 23]

Because the electrosurgical process cannot eliminate inflammation of the radicular pulp, the success of the electrosurgical pulpotomy depends on the initial pulp status.[23] In the present study, 1 ZOE group tooth (0.8%) and 3 ZPC group teeth (4.7%) were deemed clinically unsuccessful at 12 months, although these results were not statistically significant. Radiographic assessment at 12 months revealed a non-significantly increased success rate in the ZOE group (84.2%) compared to the ZPC group (75%). No significant differences were noted between the success rates using the two different cements.

A prospective human study of electrosurgical pulpotomies revealed no significant differences between using ZOE or calcium hydroxide as sub-base materials in terms of

the clinical and radiographic success rates at 6 months.[21] However, because they compared two pulpal medications rather than the success rates of electrosurgical vs. formocresol pulpotomy, we disagree with their non-recommendation of electrosurgical pulpotomy.

Electrosurgery has no antiseptic or fixative properties. In electrosurgical pulpotomy, the sub-base cements are placed adjacent to the carbonized pulpal tissue. We addressed whether placing a particular base over the remaining pulpal stump had a significant effect on the clinical or radiologic success. Following hemostasis due to electrosurgery, there is no physical barrier to protect healthy normal radicular pulp from the toxic effects of the sub-base medicaments or dressing materials. The presence of carbonized pulp after electrosurgery application can prepare the way for eugenol penetration from the sub-base ZOE cement and subsequent inflammation. However, if the vital pulp tissue is fixed with formocresol medicament, fixed tissue may acts as a barrier to eugenol.[16, 24]

Our hypothesis was that the ZPC cement is less irritating than ZOE. Ultrastructurally, ZOE consists of grains of ZO embedded in a zinc eugenolate matrix. When exposed to aqueous media such as saliva, dentinal fluid, or pulp fluid, the zinc eugenolate is hydrolyzed yielding eugenol and zinc hydroxide.[14] The eugenol released from ZOE cement in direct contact with radicular pulp tissue fixes cells, decreases cellular respiration, and reduces neural transmission *in vitro*[21] Zinc oxide eugenol can cause pulp inflammation and potential internal resorption when used as a pulpotomy base.[25] The placement of ZOE directly over the pulp tissue may explain the internal resorption observed in ferric sulfate pulpotomies.[16,26,27]

Eugenol can uncouple oxidative phosphorylation in mitochondria.[28] Watts and Paterson tested the effects of ZOE-containing cements on germ-free rats after sterile pulp exposure. When the ZOE material was separated from the exposed pulp by dentin chips, the pulp exhibited minimal inflammatory changes 28 days after pulp capping. Placement of the ZOE material in direct contact with the pulp tissue resulted in chronic inflammation and necrosis.[29] Eugenol and related compounds reportedly have a high affinity for plasma membranes because of their lipid solubility, which may also contribute to cell damage.[3] Cells cultured with glass ionomer cement display a weaker pulp tissue reaction than cells cultured with ZOE or ZPC, and ZOE shows the strongest cytotoxicity. Thus, it may be that the composition of ZOE cement is different from that of ZPC cement.[30] Polycarboxylate cement powder mainly contains Zinc oxide and magnesium oxide. Zinc oxide powder is decomposed in polyacrylic acid solution, and free zinc ions may be dispersed into the culture medium. Metallic zinc and zinc ion have a pronounced cytotoxic effect in culture medium.[30]

The ZOE group displayed prevalent PCO at 3 months follow-up and had significantly increased PCO compared with the ZPC group at 12 months. Internal resorption was the most prevalent of the pathologic findings, but was not significantly increased in either group, emphasizing that neither of the tested cements was preferable to the other. Previous pulpotomy studies using ZOE as a sub-base demonstrated inflammation and subsequent internal resorption,[3,11] Smith *et al.* attributed internal resorption to eugenol and its direct contact with the vital pulp tissue; however, internal resorption may also result from the inappropriate diagnosis of chronic inflammation in the radicular pulp before pulpotomy.[16]

Failure of the electrosurgical pulpotomy technique may be related to isolation and sterilization conditions. Uncontrolled contaminations during pulpotomy or entrance of dental caries microorganisms from the oral cavity to the pulp can negatively affect prognosis. Thus, the success or failure of pulpotomy depends on an accurate diagnosis at the time of treatment. However, no clinical method is available for determining the pretreatment pulpal status, although correlations between certain inflammatory mediators and the clinical outcome have been examined.[3] Formocresol is a forgiving technique in which teeth can remain in the arch with chronic silent inflammation.[13] Electrosurgical pulpotomy appears to require a more sensitive diagnosis.[4,15,21]

Our study has limitations. Non-matched-pair samples were used, due to the difficulty of finding two teeth with the same pathologic stage in the mandible of the same patient. The materials used were not blinded to the operator who performed the pulpotomies. However, the radiograph assessor was not aware of the material used in each tooth. This study used narrow sample selection criteria, with only the lower molars being used. This was done to eliminate overlap of the permanent tooth buds on the primary molar roots and furcations, as well as to enable the investigator to clearly identify the radiographic pathology.

CONCLUSIONS

Use of ZPC cement as a sub-base in electrosurgical pulpotomy is not preferable to ZOE cement use. Further research is needed to identify a more suitable pulp-capping material.

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