

Effects of zinc oxide-eugenol and calcium hydroxide/ iodoform on delaying root resorption in primary molars without successors

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The purpose of this study was to compare the effects of zinc oxide-eugenol (ZOE) and calcium hydroxide/iodoform paste (Vitapex), as root canal filling materials in pulpectomy, on delaying the root resorption of primary molars without permanent successors. Animal models without permanent successors were surgically established in beagle dogs. Root resorption was observed *via* periapical radiographs. The onset of root resorption of primary mandibular molars without successors occurred later ($p < 0.05$) than physiologic resorption. ZOE pulpectomy clearly delayed the root resorption of primary molars without permanent successors ($p < 0.05$), whereas resorption of primary molars with Vitapex pulpectomy started at almost the same time as physiologic resorption. Compared with Vitapex, ZOE was a more effective root canal filling material in delaying the root resorption of primary molars.

Keywords: Zinc oxide eugenol, Vitapex, Root resorption, Primary molars without successors

INTRODUCTION

Tooth agenesis is a prevalent craniofacial congenital malformation in humans. The incidence of agenesis of permanent teeth, excluding third molars, ranges from 3.4% to 10.1%, depending on the population studied¹. Mandibular second premolar, maxillary lateral incisor, and maxillary second premolar have the highest susceptibility.

In growing individuals, tooth agenesis may result in dental malpositioning, periodontal damage, and lack of maxillary and mandibular bone height development; it also has significant aesthetic and functional consequences². Clinical management of these children requires maintaining deciduous teeth that will facilitate the final phase of corrective therapy. Primary molars with missing permanent successors must also be retained since they retain bone in an area which may be a site for future transplantation or implant therapy³.

Clinically, there are no accurate predictors for the survival of primary teeth without successors. It was reported that only the primary canines—but not molars—can provide many years of service⁴. Though exfoliated later than normal primary molars, the roots of primary molars without successors are eventually resorbed. The outbreak of pulpitis or apicitis can further lead to early tooth loss. Previous study showed that the dental pulp of primary molars might play an important role in the root resorption of primary molars without permanent tooth germs. A pulpectomy technique has been advocated to retain these diseased primary teeth that would otherwise be lost⁵. A mixture of zinc oxide and eugenol (ZOE) with or without formocresol or Vitapex paste (a mixture of 40.4%

iodoform, 30.3% calcium hydroxide, 22.4% silicone oil, and 6.9% inert ingredients)⁶ are commonly used as root canal filling materials for primary teeth. While much has been reported about root canal filling materials used in normal primary teeth, information is scarce concerning root canal filling materials used in primary teeth without permanent successors.

The purpose of this study was to compare the effects of ZOE and Vitapex on delaying the root resorption of primary molars without permanent successors.

MATERIALS AND METHODS

Animal model

All the 14 dogs used in this study were purebred male beagles (Beijing Marshall Biotechnology Co., Beijing, China). They were housed in light- and temperature-controlled rooms and allowed *ad libitum* access to food and water. Their care and the experimental procedures employed in this study were in accordance with the guidelines of the US National Institutes of Health regarding the care and use of animals in research and those of the Administration Regulations on Laboratory Animals of Beijing Municipality. The research protocol of this study was reviewed and formally approved by the Biomedical Institutional Review Board of Peking University (No. LA2010-018).

Using 10-week-old male beagles each weighing 3.5 kg, 14 animal models without permanent tooth germs were established by surgically removing permanent premolar germs, as described in previous reports⁷⁻⁹. For all experimental procedures, the dogs were anesthetized by intravenous injection of pentobarbital sodium (30 mg/kg body weight; Sigma-Aldrich, St. Louis, MO, USA). The intraoral surgical removal of bilateral mandibular and/or maxillary premolar germs was approached via the full-thickness mucoperiosteal

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Received Feb 5, 2014; Accepted Mar 18, 2014

doi:10.4012/dmj.2014-036 JOI JST.JSTAGE/dmj/2014-036

flaps on the lateral aspect of respective jaws. After flap reflection, locations of the premolar germs were determined from preoperative periapical radiographs (Figs. 1A, B). The overlying cortical bone was gently removed with a water-cooled fissure bur at high speed. Special care was exercised to protect the primary molar roots. Dental follicles were revealed after pieces of bone were gently removed.

Periapical radiographs taken after the procedure confirmed that the tooth buds and dental follicles were completely removed (Figs. 1C, D). The surgical wound was then washed with normal saline and the flap was closed. All operations were performed by the first three authors.

Pulpectomy and root canal filling

To compare the effects of different root canal filling materials (ZOE and Vitapex) on the root resorption of primary teeth without successors, the primary mandibular and maxillary second molars of 12 beagles were chosen because these teeth have two roots and their successors can be easily removed. Furthermore, their physiologic root resorption starts at the same time. The primary maxillary third and fourth molars of beagles have three roots; their permanent tooth germs cannot be surgically removed and there were insufficient tooth samples for statistical analysis. Therefore, the primary mandibular and maxillary second molars of each dog were evenly distributed for the test and control

groups in this study.

Pulpectomy of primary molars was performed on the 10th postnatal week, before the onset of physiologic root resorption. For the test groups (ZOE and Vitapex), pulpectomy was performed on the test teeth of 12 beagles. In the control group, the chosen teeth of two remaining dogs were left untreated.

After isolation with cotton rolls, pulp chambers of the primary teeth were accessed and pulp extirpation was performed using Mani barbed broaches (Mani Inc., Tochigi, Japan). Working length of the root canals was estimated from the preoperative periapical radiographs and determined to be 2 mm short of the radiographic apex. Root canals were gently debrided with Kerr files (Mani Inc.) from #20 to #40 and thoroughly irrigated with normal saline. After drying with paper points, the root canals were filled with one of these filling materials according to manufacturers' instructions: ZOE (Dental Materials Factory of Shanghai Medical Instruments Co., Shanghai, China) or Vitapex (NEO Dental Chemical Products Co., Ltd., Tokyo, Japan).

The paste was gently injected into each root canal using the manufacturer-supplied syringe, and postoperative periapical radiographs were taken. Access cavity was sealed with ZOE cement and glass ionomer cement before definitive restoration with Filtek P60 posterior light-cure composite resin (3M ESPE, St. Paul, MN, USA) and bonding by One Coat

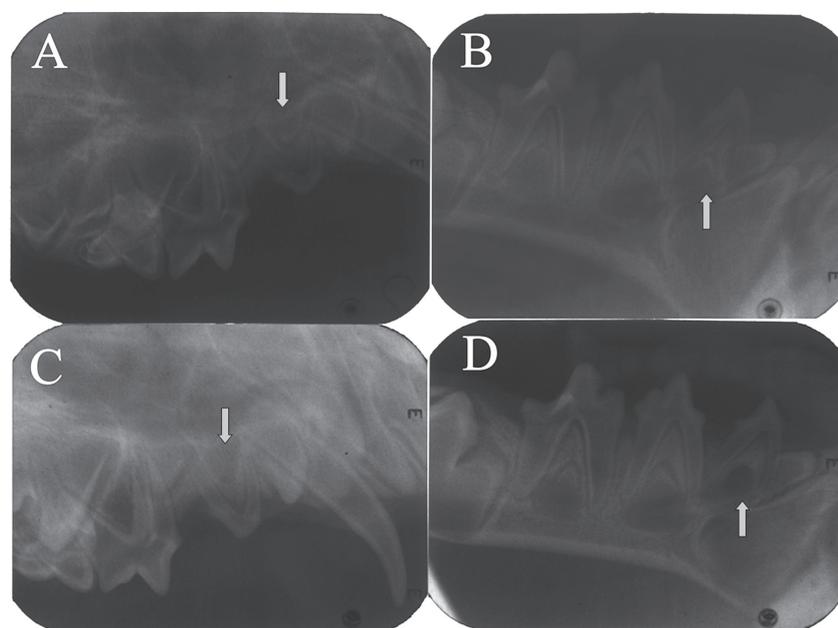


Fig. 1 Animal model without permanent tooth germs was established in a 10-week-old male beagle. A, C: Right primary maxillary second molars. B, D: Right primary mandibular second molars. A, B: Periapical radiographs taken before intraoral surgery. C, D: Periapical radiographs taken after surgery to confirm complete removal of tooth buds and dental follicles of permanent premolars. Tooth buds and dental follicles of permanent mandibular and maxillary second premolars were surgically removed (arrows).

Bond (Coltène/Whaledent, Altstätten, Switzerland). Occlusal adjustment was performed after restoration was cemented. All procedures were carried out by the first three authors.

Radiographic observation and determination of root resorption

All periapical films were taken by the same technician using the bisecting angle technique with projection angles of -37° (mandibular) and $+37^\circ$ (maxillary) and an exposure time of 0.10 s. Periapical films were taken every week postsurgery until all the primary molars had exfoliated. Early resorption was indicated by a blurring of the root and periapical tissue, and complete root resorption occurred during exfoliation.

The periapical films were independently read by four experienced clinicians (the authors) to determine the onset time and time span of root resorption of each primary tooth. In case of disagreement, final consensus was arrived at by a joint decision of all the authors. Kappa coefficients for intra- and inter-examiner reproducibility were 0.76–0.91 and 0.64–0.89 respectively.

Statistical analysis

Mann-Whitney's U test was used to compare the root resorption onset times between primary molars and primary molars without permanent successors. Wilcoxon signed-rank test was applied to evaluate the effects of different root canal filling materials in delaying root resorption of primary molars without permanent successors. All statistical analyses were carried out using SPSS software (version 17.0; SPSS Inc., Chicago, IL, USA). Differences were considered statistically significant when the critical value reached a level of $p < 0.05$.

RESULTS

With ZOE pulpectomy, mean root resorption onset time of primary second molars without permanent successors was 23.75 weeks postnatal, which was later than that of the control teeth (Table 1, Fig. 2). The difference was statistically significant ($p < 0.05$).

With Vitapex pulpectomy, the mean root resorption onset time was 18.75 weeks postnatal, which was

Table 1 Onset times and time spans of root resorption in ZOE, Vitapex and Control groups

	ZOE (n=12)		Vitapex (n=12)		Control (n=12)	
	Onset time	Time Span	Onset time	Time Span	Onset time	Time Span
Mean	23.75	1.83	18.75	1.25	20.17	1.58
Median	24.00	2.00	18.50	1.00	20.00	2.00
Std.deviation	0.9653	0.3893	1.7123	0.4523	0.7177	0.5149
Test Statistic ^a -----Onset Time of Root Resorption						
	ZOE-Control		Vitapex-Control		ZOE-Vitapex	
P value	0.002		0.022		0.002	

^a Wilcoxon signed rank test.

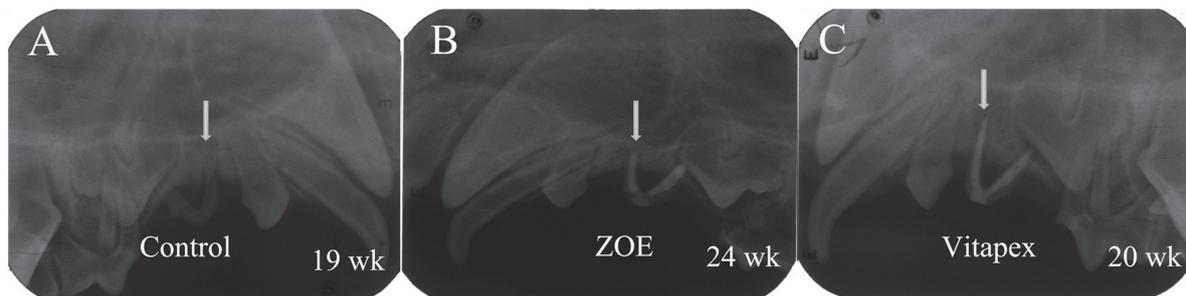


Fig. 2 Root resorption of primary molars with ZOE pulpectomy and Vitapex pulpectomy in the absence of permanent tooth germs, with arrows showing root resorption sites.

A: Root resorption of control tooth (without pulpectomy), right primary maxillary second molar, started at 19th week.

B: Root resorption of right primary mandibular second molar started at 24th week after ZOE pulpectomy.

C: Root resorption of left primary maxillary second molar started at 20th week after Vitapex pulpectomy.

almost the same as that of the control teeth (20.17 weeks postnatal) ($p>0.05$). Root resorption of primary molars with ZOE pulpectomy took place later than with Vitapex pulpectomy, and the difference was statistically significant ($p<0.05$; Table 1).

Exfoliation of primary second molars in the ZOE, Vitapex, and control groups occurred at 1.83 weeks, 1.25 weeks, and 1.58 weeks respectively after the onset of root resorption. There were no statistically significant differences among these three groups ($p>0.05$).

DISCUSSION

Most primary molars with missing permanent successors show delayed root resorption. However, they would be lost finally^{4,10}, especially those with pulpitis and apicitis. These primary molars may play an important role in occlusal and maxillofacial developments, and the retention of these teeth is essential to the treatment plan in clinical practice. Therefore, it is important to protect young people's teeth by treating them when affected by deep caries, pulpitis, or apicitis.

Results of this study showed that ZOE—but not Vitapex—as a root canal filling material clearly delayed the root resorption of primary molars without successors. Although the root resorption time span was shorter in the Vitapex group, there were no statistically significant differences among the three groups.

An ideal root canal filling material for primary teeth should possess these properties: harmless to the periapical tissue and permanent tooth germ, readily resorbs if pressed beyond the apex, easily fills the canal and adheres to root canal walls, radiopaque, strongly antiseptic, and presents minimum shrinkage^{11,12}. However, if permanent tooth germs are absent, the ideal root filling material should prevent root resorption in order to prolong the tooth's survival.

By virtue of its high success rates for primary pulpectomy through clinical and radiographic evaluations, Vitapex has reportedly been suggested as a nearly ideal root canal filling material for primary teeth⁹. In the present study, root resorption of primary teeth with Vitapex pulpectomy started at almost the same time as the control teeth. In some primary molars, root resorption was initiated even earlier than the control. This could be attributed to the bioavailability of Vitapex and in meeting the requirements of an ideal root canal material for primary teeth, Vitapex was readily resorbed^{13,14}.

The major goal of a root canal treatment is to prevent re-infection of the root canal via leakage of microorganisms and their by-products. Treatment outcome may be influenced by the quality of root canal fillings and coronal restorations¹⁵. The sealing ability of a root canal filling material is, therefore, an important factor in achieving this goal. Once the resorption of root canal filling material starts, the apical seal will quickly break down. Subsequently, tissue fluid and blood infiltrate the root canal, leading to further

resorption of the filling material. Finally, the root canal will be empty and root resorption will accelerate. These phenomena might explain why the resorption time span of the Vitapex group was shorter than that of the control group. Therefore, despite its strong bactericidal properties, Vitapex might not be suitable for preserving primary teeth without permanent successors, although it is nearly an ideal root canal filling material for normal primary teeth⁹.

ZOE, as the first recommended root canal filling material, was introduced since the early 1930s¹⁶. Several authors have reported moderate to high success rates in using this material to preserve chronically infected teeth¹⁷. For many years, ZOE was the material of choice. Previous *in vitro* studies showed that ZOE had strong antibacterial activity against all test microorganisms^{18,19}. However, some studies showed that ZOE could cause chronic inflammatory reactions and slow resorption²⁰⁻²². Coll and Sadrian²³ found that after the shedding of primary teeth, ZOE remnants in the alveolar bone altered the eruption paths of permanent teeth in 20% of cases. In the present study, ZOE as a root canal filling material obviously delayed the root resorption of primary molars without permanent tooth germs. This effect could stem from its apical sealing ability, resistance to resorption, and antibacterial property. Therefore, ZOE might be a good choice for preserving primary teeth without permanent successors.

The present study, using animal models, discussed only the use of root canal filling materials in caries-free primary teeth without successors. This might not match the situation clinicians encounter in practice, as factors such as bacteria and inflammation were not fully considered. Actually, we tried to establish an animal model of apicitis in primary molars without successors. However, the rate of root resorption was too high (some primary teeth were lost within a week) to do any further research. Moreover, the animal model established by surgically removing permanent tooth germs was different from congenital absence of permanent tooth germs in humans. The intraoral surgery might modify the histological environment of the primary roots, with some risk of inducing root resorption. To avoid these problems, the surgery was performed at the 10th postnatal week. This was markedly earlier than the onset time of root resorption of primary molars in beagles, thus allowing sufficient time for bone healing, and that signals from the dental follicle of permanent tooth germ might not be released to initiate the root resorption of primary molars.

Results showed that after the surgery, the onset time of primary molars without permanent tooth germs was later than that of normal primary molars. This suggested that the contribution of the dental follicle of permanent tooth germ to root resorption was reduced. Besides, the effects of these factors were equally borne by the test groups and control group. Therefore, the results obtained using animal models might still be useful for pediatric dentists, considering the difficulties of

carrying out such a clinical experiment. Further research should be carried out on infected human primary teeth without successors.

CONCLUSION

Results of this study with beagles showed that ZOE, as a root canal filling material, might be efficacious in delaying the root resorption of primary teeth without successors. Vitapex had no obvious effects in delaying the root resorption of these primary teeth.

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