Apical Microleakage of Primary Teeth Root Canal Filling Materials

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ABSTRACT

Objective: The objective of this study was to evaluate in vitro apical microleakage of root canal filling materials for primary teeth.
Methods: Fifty extracted primary anterior teeth were distributed into 6 groups: 4 experimental groups; 1 negative control group; and 1 positive control group. Zinc oxide and eugenol (ZOE), Kri paste, calcium hydroxide ($Ca(OH)_2$), and Vitapex were inserted into the canal using a lentulo spiral mounted in a slow-speed handpiece. All teeth were then subjected to a dye leakage test using 2% methylene blue as the tracer.
Results: The highest dye penetration was recorded for teeth filled with ZOE, with mean values of 9.01±1.23 mm. Vitapex showed the lowest dye penetration, with mean values of 4.02±1.79 mm. Comparison between groups showed significant difference when the Vitapex and Kri paste groups were compared to the ZOE group ($P<.0001$). Also, a significant difference between the Vitapex and Ca(OH)2 group ($P=.014$) was detected. The result showed no difference between Vitapex and Kri paste ($P=.658$) nor between Kri paste and $Ca(OH)_2$ ($P=.185$).
Conclusions: All the resorbable root canal filling materials used in primary teeth showed apical leakage. The highest apical leakage was recorded for ZOE, while Vitapex showed minimum dye leakage. (J Dent Child 2007;74:46-51)

KEYWORDS: PULPECTOMY, ZINC OXIDE AND EUGENOL, KRI PASTE, CALCIUM HYDROXIDE, VITAPEX

Pulpectomy can be one option for treatment of severely infected primary teeth.[1] Pulpectomy is defined as a procedure involving removal of the roof of the pulp chamber to gain access to the root canals which are debrided, enlarged, disinfected and filled with a resorbable material.

The most popular root canal filling materials for primary teeth are: ZOE,[2] calcium hydroxide ($Ca(OH)_2$) and (3) iodoform paste.[3] ZOE is probably the most commonly used filling material for primary teeth in the United States.[4]

The criteria for an ideal root-canal filling material for primary teeth have been named by several authors. The material should:

1. resorb as the primary tooth root resorbs;
2. be harmless to the periapical tissues and permanent tooth germ;
3. readily resorb if pressed beyond the apex;
4. be antiseptic;
5. easily fill the root canals;
6. adhere to the walls of the canal;
7. not shrink;
8. be easily removed, if necessary;
9. be radiopaque; and
10. not discolor the tooth.[5,6]

At the present time, no material meets all these criteria.[4]

In permanent teeth, it is important that materials used to fill the root canal possess good sealing properties, since inadequate seal at the apex is said to account for 59% of failures of root canal therapy.[7] It is well known that microleakage between the root canal filling material and canal walls may adversely affect the results of root canal therapy.[8]

In the search to find data that investigated the sealing ability of root canal filling materials used in primary teeth, little knowledge was present. Alacam (1992)[9] investigated the adaptation of ZOE after irrigating the canals of extracted primary canines with different irrigation solutions and reported insufficient adaptation of the filling material at

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different levels of root canal. By using clearing technique and Indian ink as a tracer, Ayhan et al (1996)[10] carried out an in vitro study in primary teeth to evaluate the apical microleakage of: (1) ZOE; (2) ZOE combined with gluteraldehyde (GA); (3) Kri paste; and (4) $Ca(OH)_2$. They reported no significant difference between ZOE, Kri paste, and $Ca(OH)_2$ compared to the dye penetration level.[10]

The aim of this study was to assess the apical microleakage of primary teeth root canal filling materials using 2% methylene blue as the tracer.

METHODS

SAMPLE

This study was approved by the Human Ethics Review Committee, College of Dentistry, King Saud University, Riyadh, Saudi Arabia. Fifty newly extracted primary maxillary incisors and canines—with at least two thirds of the root intact and a length range from 15 to 22 mm measured between the incisal edge and the root apex—were selected and preserved in normal saline obtained from several dentists. The teeth were selected after careful radiographic and microscopic examination from a large sample of primary anterior teeth. The dentists reported having extracted the teeth for a variety of reasons, including: (1) abscess formation; (2) pulpitis; (3) trauma; and (4) orthodontic consideration. An anterior/posterior (AP) baseline standardized radiograph was taken for each tooth to determine: (1) fracture; (2) resorption; (3) working length; and (4) anatomy of the root canal. The teeth were then examined by stereomicroscope to:

1. determine the position of the apical foramen;
2. be sure the position was not affected by resorption; and
3. ensure that the size of apices is less than size 50 file.

These teeth were stored in 2.5% sodium hypochlorite for 48 hours to remove the organic debris. They were then cleaned under running water using a small toothbrush.

TECHNIQUE

All the teeth received standardized instrumentation procedures. The clinical crown was maintained to assist hand holding each tooth. Access to the pulp was obtained with no. 2 and no. 4 high-speed round carbide burs. Working length was measured from the radiograph and kept 1 mm short of the apex, followed by canal preparation using a Hedstrom file (Dentsply, Maillefer CH- 1338 Ballaigues, France) in pull-back action. Each canal was enlarged up to size 50. After each instrument size, irrigation was performed with 5.25% sodium hypochlorite. Irrigation was carried out with a 21-gauge needle attached to a 10-ml syringe. The final irrigation was performed using 10 ml of physiological saline. Finally, the canal was dried by paper points and an oil free air syringe was used to apply positive pressure to force air bubbles or fluid out of the canal. After instrumentation, the teeth were randomly divided into 6 groups of 10 teeth each, except group 5 and group 6, which contained 5 teeth each used as a negative and positive control, respectively.

Group 1 teeth were filled with ZOE, while group 2 teeth were filled with Kri paste. Teeth in groups 3 and 4 were filled with $Ca(OH)_2$ and Vitapex, respectively. The materials used in the present study, with corresponding manufacturers, are presented in Table 1.

Table 1. Materials and Methods of Obturation in the Laboratory Study and Dye Penetration in mm for Various Experimental Groups

Groups	Obturation material used	Manufacturer	Mean±(SD)
1	ZOE	Temrex, Freeport, New York, NY	9.01±1.23
2	Kri paste	Pharmachemie AG, CH-8053, Zurich, Switzerland	5.00±1.78
3	$Ca(OH)_2$	Pulpdent, TempCanal, Watertown, Mass	6.75±2.55
4	Vitapex	Diadent Group International Inc, Burnaby, BC, Canada	4.02±1.79

Using a lentulo spiral (MANI INC, Tochigi, Japan) mounted in a slow-speed handpiece, the filling materials were inserted into the canal, rotated and withdrawn gently from the canal while still rotating.

A rubber stopper was used to keep the lentulo spiral 1 mm short of the working length. The process was repeated 5 to 7 times for each tooth until the canal orifice appeared completely filled.

Group 5 teeth were filled with ZOE by using the lentulo spiral mounted in a slow-speed handpiece. The root surfaces of these teeth were painted with 2 layers of nail polish covering the entire root length, which served as the negative control. Group 6 was left unfilled and served as the positive control.

The materials used in this study came in ready-made standardized preparations, except for ZOE. To standardize ZOE's consistency and quantity, it was mixed according to the manufacturer's instructions. A cement mix was obtained from mixing 1 volume unit of powder with 2 volume units of liquid.

The access opening was sealed with Cavit-G (3M ESPE, Seefeld, Germany), then wrapped in wet gauze to maintain a humid environment and stored for 14 days in individual coded glasses at 37°C in an incubator to ensure setting of the obturation material.

Another anterior/posterior (AP) standardized radiograph with the same setting as the previous one was taken for each tooth to be sure that the filling material filled the apical third.

Root surfaces of experimental groups (groups 1 to 4) were painted with 2 coats of nail polish, except 1 mm from the apical foramen. The root surfaces in group 5 were painted with 2 layers of nail polish covering the entire root length, including the apex, to show that nail polish provides a good barrier against dye penetration. Group 6 teeth were painted with 2 coats of nail polish, except 1 mm from the apical foramen to allow the dye to flow into the prepared root canals, which were not filled. Then, all teeth were suspended into 2% methylene blue dye for 7 days[11] in individual glass vials.

Later, the specimens were removed from the dye solution, washed, and air-dried before cutting the teeth for dye evaluation. Each tooth was split longitudinally in a labiolingual direction by a diamond disk mounted on a KAVO handpiece (Elektrotechniches Werk GmbH, Neuss, Germany) in a direction parallel to the tooth's long axis and through the apical foramen. Both halves of the cut surfaces were examined for dye penetration between the obturation material and the tooth structure using a stereomicroscope (Wild Photomakroskop M400, Heerbrugg, Switzerland). The presence of dye penetration at the interface of the obturation material and the tooth was considered to be an indicator of microleakage.

EVALUATION

Liner dye penetration was measured by Graticule (Graticules Ltd, Tonbridge Kent, England) one tenth of a millimeter from the root's apex to the point where the dye no longer penetrated the filling material. Their interface with the dentinal tubules was in both halves of the root. The tooth half that showed more leakage was selected, and the deepest penetration of the dye on this half was recorded.

Reliability of the linear dye penetration measurements was tested by comparing the results obtained from the same examiner (intraexaminer observation), registering a sample of 40 readings at 2 different occasions. The interval between the 2 occasions was 2 weeks. There was 100% correlation, and the paired *t* test showed no significant difference between intraexaminer readings at the 0.05 significant level.

STATISTICAL ANALYSIS

One–way analysis of variance (ANOVA) was used to establish whether or not there were significant differences in the mean of liner dye penetration between the experimental materials at level 0.05. Tukey's HSD test was used as post-hoc to find the differences between experimental groups at alpha=0.05. The Kruskal-Wallis nonparametric test was used to verify the parametric ANOVA.

RESULTS

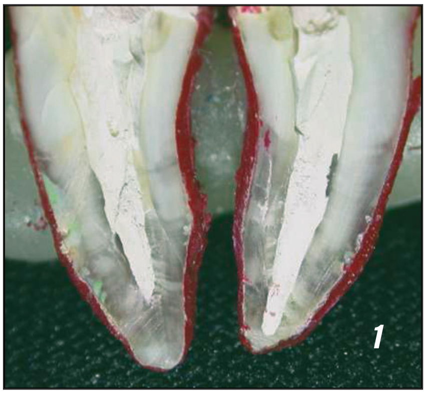
Stereoscopic examination of the sectioned control teeth (2 halves) of the negative control roots (group 5) showed no dye penetration of the root canal (Figure 1). Positive control roots (group 6), meanwhile, showed complete dye penetration along the entire length of the root canal (Figure 2). Microleakage of root canal filling materials used in the present study is presented in Figures 3 through 6.

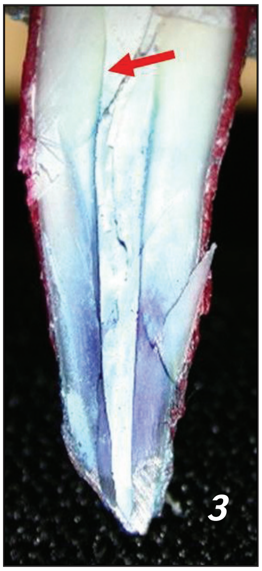
The mean and standard deviation of linear dye penetration measurements of experimental groups are presented in Table 1.

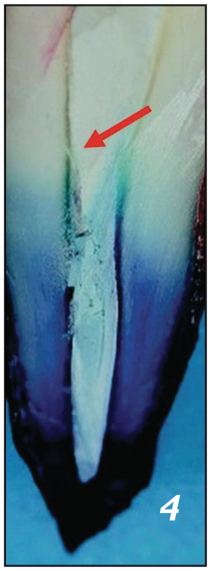
The mean values of dye penetration measurements were:

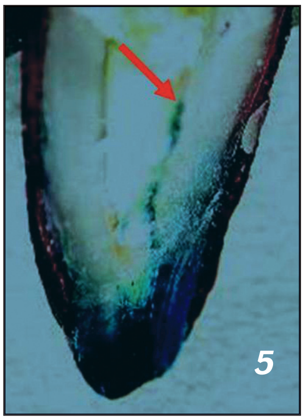
1. 9.01±1.23 mm in the ZOE group, which represents the highest dye penetration;
2. 4.02±1.79 mm in the Vitapex group, which represents the least dye penetration measurements.
3. 5.00±1.78 mm in the Kri paste group; and
4. 6.75±2.55 mm in the $Ca(OH)_2$ group.

The ANOVA results showed a significant difference between the materials at P>.0001. The differences between the materials were identified by Tukey's









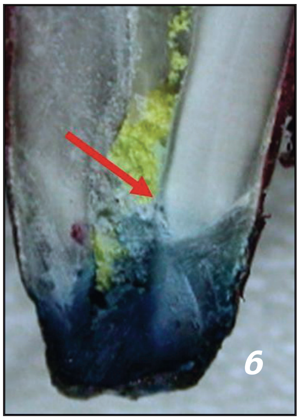


Figure 1. Shows a negative control specimen. Note lack of leakage.

Figure 2. Shows a positive control specimen. Note complete dye penetration.

Figure 3. Shows microleakage of ZOE.

Figure 4. Shows microleakage of $Ca(OH)_2$.

Figure 5. Shows microleakage of VItapex.

Figure 6. Shows microleakage of Kri paste.

HSD test in Table 2. The results showed highly significant differences of the Vitapex and the Kri paste groups compared to the ZOE group (P<.0001). Also, a significant difference between the Vitapex and the $Ca(OH)_2$ group (P=.014) can be detected. The results showed no difference between Vitapex and Kri paste (P=.658) nor between Kri paste and $Ca(OH)_2$ (P=.185). A marginal difference can be detected between the $Ca(OH)_2$ and the ZOE group (P=.053). To confirm these findings, a nonparametric analysis of variance was also used. The Kruskal-Wallis test showed the presence of a significant difference in the amount of leakage between the experimental groups at P<.0001.

Table 2. Tukey Multiple Range to Compare Root Canal Filling Material

Comparison between groups	*P* value
Vitapex vs ZOE	<.0001 *
Vitapex vs $CA(OH)_2$	.014*
Vitapex vs Kri paste	.658
Kri paste vs ZOE	<.0001*
Kri paste vs $CA(OH)_2$	.185
$CA(OH)_2$ vs ZOE	.053

**** The mean difference is significant at 0.05 level***

DISCUSSION

Assessment of sealing ability of root canal obturation materials has included radiographic, volumetric, and visual inspection as well as scanning electron microscope examination. The most popular method was linear measurement of dye penetration along the root surface.[8,12,13] This measurement was made after employing different methods of sample preparation, such as: (1) longitudinal splitting of the root; (2) making cross-sections perpendicular to the root's longitudinal axis; or (3) decalcification and clearing of the root using a special technique.[14] The present study used linear measurement of dye penetration along the root surface after longitudinal splitting of the root.

Even though the main principles used for endodontic therapy of permanent teeth apply also for primary teeth, certain criteria of root canal filling materials are different. These criteria include the resorption of root canal filling material with a similar rate as the physiological root resorption of the primary root. This contraindicates the use of solid or semi-solid core materials used to fill root canals of permanent teeth.[15] Another critical difference is the use of cement for root canal filling. In permanent teeth, the cement is used to fill the gaps between the obturation material and the root canal walls. The pressure and condensation applied to the core material during obturation of the root canal in permanent teeth results in better and closer adaptation of cement and gutta percha to the root canal walls. This condition does not exist in primary teeth, which use a paste as a sole obturation material. Therefore, the sealing ability of the material used to fill a root canal in primary teeth depends mainly on the material's ability to adhere to the root canal walls and the method applied to introduce this material into the root canal.

In the present study, extracted primary anterior teeth were used to decrease anatomic variations. Also, radiographic and microscopic examination of the apical foramen of each selected tooth was performed to ensure that it was not affected by resorption, as the resorption may result in wide variations of the apical foramen's position. No attempts were made to cut clinical crowns of the teeth to facilitate handling during root canal preparation and to simulate the clinical situations. To reduce variability, random distribution of the teeth into experimental groups was performed after complete preparation of the root canal. In this study, immersion in the dye was performed 14 days after obturation to allow complete setting of the root canal filling materials. Ahlberg et al (1995)[16] compared methylene blue to Indian ink dye and reported superiority of methylene blue as a tracer of microspaces and as an accurate method of leakage measurement when used in passive dye penetration. Methylene blue has a smaller molecular weight than bacteria, which may not simulate the clinical situation.[17] Wu and Wesselink (1993),[14] in reviewing 19 studies in permanent teeth using methylene blue, reported an average dye penetration of 0.5 mm to 7.6 mm.

In the present study, teeth were cut longitudinally to measure the dye penetration. Teeth sectioning was performed with a fine diamond disk, which had negligible alteration of the root content. This technique is less destructive than the cross-section, which provides knowledge about the adaptation of filling material but ends up with a destroyed sample. Also, no attempts were made to split the teeth with a chisel, due to the small diameter of primary teeth. Longitudinal sectioning of the teeth demonstrates the pattern of tracer penetration. In contrast, previous investigators used the clearing technique, never completely demonstrating the pattern of tracer penetration. Consequently, part of the tracer was lost during sample preparation.[18] In the present study, the negative control group showed no dye penetration, which represented the ability of nail polish to provide good sealing of the root against leakage of methylene blue. In contrast, the positive control group showed the dye's ability to penetrate to the full length of the canal, which reflects the patency of the root canal.

Apical dye penetration in the experimental groups averaged from 1 mm to 11 mm. This wide range corresponded to the high average reported when methylene blue was used.[14] The high penetration in the present study may be due to less adaptation of the root filling materials to the root canal walls. The high penetration may also be due to the long period of dye exposure (7 days) and low molecular weight of methylene blue.

In the present study, the highest microleakage was reported for the ZOE group, which differed significantly from Vitapex and Kri paste. This finding was similar to the finding of Alacam (1992)[9] who investigated the adaptation of ZOE after irrigating the canals of extracted primary canines with different irrigation solutions. The investigator reported insufficient adaptation of the ZOE at different levels of the root canal, which was attributed to shrinkage of ZOE after setting.[9] This justification seems to be correct, since, in the present study, the other paste materials showed better performance. Also, a significant difference between Vitapex and $Ca(OH)_2$ was noticed. This better performance of Vitapex over $Ca(OH)_2$ may be attributed to the consistency of Vitapex, but could not be attributed to its iodoform content. This is because Kri paste, which contains iodoform, failed to show any significant difference compared to $Ca(OH)_2$. The sealing ability of Vitapex and Kri paste showed no statistically significant difference between the 2 materials. This finding may be due to the presence of iodoform as a main component in both materials or due to their composition—such as silicone in Vitapex—which could favor the this material's performance.

The results in the present investigation disagreed with the results reported by Ayhan et al (1996).[10] They compared apical microleakage of ZOE, iodoform paste, and $Ca(OH)_2$ in primary teeth by using the clearing technique after suspension of teeth in Indian ink for 24 hours. The investigators reported a mean dye penetration 0.57 mm, 0.47 mm, and 0.56 mm for ZOE, iodoform, and $Ca(OH)_2$ groups, respectively, with no significant difference between these materials.[10] The difference between the findings of the present study and Ayhan et al (1996)[10] may be due to the difference in: (1) the dye used; (2) immersion time (24 hours in the 1996 study by Ayhan et al[10]); and (3) the evaluation method.

This difference could be also explained by Wu and Wesselink (1993),[14] who reported in their review that, in 19 studies where methylene blue was used as an indicator, the mean dye penetration varied from 0.5±0.6 mm to 7.6±1.96 mm. Meanwhile, 7 studies using Indian ink showed a mean leakage varying from 0.12±0.31 mm to 1.24±1.10 mm.

In the present study, all materials showed different levels of microleakage. These differences may lead the clinician to prefer one material over the other. Other significant criteria must also be considered, however, such as resorption rate and antimicrobial effect. Excessive solubility of the filling materials could lead to destruction of their sealing ability (Ayhan et al, 1996).[10] In this study's findings, however, the authors discovered that the materials having high solubility provide better sealing than ZOE, which is less soluble. This cannot be explained by this study, and more research is needed.

CONCLUSIONS

Based on this study's results, the following conclusions can be made:

1. The selected resorbable root canal filling materials used in primary teeth and applied in this study showed apical leakage.
2. The highest apical leakage was recorded for the ZOE filling material.
3. Vitapex showed less apical leakage than ZOE and $Ca(OH)_2$.
4. Kri paste showed less apical leakage than ZOE.
5. No significant difference was noted between Vitapex and Kri paste, nor between Kri paste and $Ca(OH)_2$.

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