Effect of the smeared layer upon dentinal tubule penetration by root canal sealers - A SEM study

Gupta D*, Chandra S**, and Chandra S***

ABSTRACT

The purpose of this study was to find out the effects of the presence and absence of the smeared layer upon penetration of root canal sealers into the dentinal tubules. Penetration of Zinc oxide eugenol, Kalzinol and Sealapex was studied with the help of SEM, in the coronal, middle and apical thirds of the root canal after filling the root canals both in the presence and absence of the smeared layer. Presence of the smeared layer did not allow the sealers to enter the dentinal tubules. After the removal of the smeared layer, Zinc oxide eugenol penetrated the dentinal tubules in coronal and middle thirds and Sealapex in coronal third only. Kalzinol did not display any penetration. No sealer was able to penetrate the apical dentinal tubules.

Introduction

Effective biochemical canal preparation and adequate obturation is essential for successful root canal treatment. As reported by Dow and Ingle1 approximately 60% of the endodontic failures are caused by incomplete obturation of the canal space.

For complete obliteration of root canal space, root canal sealers should come in direct contact with the dentinal tubules, but as reported by McComb and Smith2 it is the smeared layer that comes in between the dentinal tubules and the sealer cement.

The smeared layer is a thin (approximately 1 um thick) layer of amorphous, mostly calcific, debris which is formed during any cutting procedure on dentin3. This layer of debris which obstructs the underlying dentinal tubules is always visible with the help of scanning electron microscope on the instrumented dentin surface.

Though the influence of this layer on the success rate of endodontic treatment has not yet been definitely determined, its removal is currently favoured, as it is an undesirable interface between the filling material and the prepared dentin surface. It is also felt that it provides for an avenue for leakage of microorganism and a source of substrata for bacterial growth. Thus, removal of the smeared layer may increase the penetration of root canal sealers into the dentinal tubules. It could improve the sealing of the root canal system by increasing the surface contact area of sealer cement to the prepared canal walls.

Removal of the varying degrees of dentinal smear layer in the root canal has been
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suggested by many investigators using various combination of solutions. After preparing the root canals a final flush with 10 ml of ethylene diamine tetra-acetic acid followed by 10 ml of 5.25% NaOCl has been found to be the most effective regimen for removing the smeared layer. Scanning electron microscopy of the canals treated in this manner usually show open and patent dentinal tubules.

The aim of this in-vitro study was to find out the effect of smeared layer on the penetration of three root canal sealers, namely, Zinc oxide eugenol, Kalzinol and Sealapex. These materials were chosen specifically because of their antiseptic nature and wide spread clinical use.

Materials and Method

Thirty two sound human, recently extracted, single rooted teeth with relatively straight roots were used in this study. These teeth were stored in 0.9% physiological saline. For easy access, the clinical crowns were removed prior to instrumentation with high speed burs under water spray. Pulp remnants in each tooth was removed with barbed broaches. A size 15 file was then inserted into the canal wall until it was seen at the apical foremen to determine the canal patency and length. One mm was subtracted from this length to determine the working length. Buccal and lingual longitudinal root grooves were also cut to facilitate subsequent splitting for scanning electron microscopic evaluation.

The root canals were instrumented in a serial order with K type files to the working length using a quarter turn pull technique. 1 ml of 5.25% NaOCl was used for irrigation between each instrument. The solution was delivered with a 25 gauge needle placed as far into the preparation as possible without any resistance. After completion of biomechanical preparation, the teeth were randomly divided into two main groups as control and experimental. The teeth in control group were irrigated with 20 ml of normal saline solution, using a 25 gauge needle placed within 1 mm of the end of the preparation. During this final irrigation the needle was continuously moved in and out, while being rotated through a 120° arc. The teeth in the experimental group were irrigated with 10 ml of EDTA (disodium salt of EDTA 17g; 5N sodium hydroxide solution 9.25 ml, distilled water 100 ml), followed by 10 ml of 5.25% NaOCl in the same manner as described for the control group.

After irrigation the root canals were dried with paper points. One tooth from both the main groups was kept unfilled to verify the removal of the smeared layer. Remaining 15 teeth of each main groups were divided into three subgroups according to the root canal sealers used. Each subgroup contained 5 teeth.

![Comparison of Mean Penetration of Different Sealers into the Dentinal Tubules at Various Thirds of Root Canal](chart.png)

Bar chart 1: Comparison of mean penetration of different sealers into the dentinal tubules at various thirds of the root canal.

The canals in subgroup 1 were filled with Zinc oxide eugenol paste (Dental Products of India, India), subgroup 2 with Kalzinol (Dental Products of India, India) and subgroup 3 with Sealapex (Kerr Manufacturing Company, U.S.A.), using root canal reamers. Manufacturers recommendations were followed during mixing and filling of the root canal sealers. Access cavities were closed with silver amalgam and the filling materials were allowed to set for 48 hours at 37°C and 100% humidity. Both filled and unfilled teeth were then split carefully into two halves with a hammer and a sharp chisel. These paired
halves were prepared for examination by scanning electron microscope.

Specimens were mounted on stubs and were then transferred to a sputter coating machine (Polaron Equipment Ltd., SEM Coating Unit, E-5000). Metal coating of gold-palladium alloy was carried out at a vacuum pressure of $1 \times 10^{-1}$ Torr, 1 KV voltage and 10 m.a. of current for 10 minutes under dry nitrogen gas. Thickness of gold-palladium coating was 100-150 Å for each specimen. The specimens were viewed with a scanning electron microscope (Philips 515) operating at 15 KV. All specimens were completely examined at coronal, middle and apical thirds and representative photomicrographs were taken at x 1000 magnification.

The penetration of root canal sealers into the dentinal tubules in each third of the root canal was graded as follows:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Penetration</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No penetration</td>
</tr>
<tr>
<td>I</td>
<td>1-5 microns</td>
</tr>
<tr>
<td>II</td>
<td>6-10 microns</td>
</tr>
<tr>
<td>III</td>
<td>11-15 microns</td>
</tr>
</tbody>
</table>

**Results**

**Control Groups**: In unfilled specimen the smeared layer was present all over the root canal surface (Fig. 1) and its density increased from coronal to the apical third. Penetration was absent in all the thirds of the root canal with all the sealers used in filled specimens. Dentinal tubules were empty in all the thirds of the root canal. In some areas smear material was packed into the dentinal tubules. Sealer cements could not even well adapt to the dentinal tubules because of the presence of the smeared layer (Fig. 2).

![Fig. 2](image)

*Fig. 2*: Photomicrograph showing the smeared layer in between the root canal sealer and dentinal tubules in the coronal third of the control group. (SEM Magnification 1000 X).

S Sealer, Dt = Dentinal tubules.

**Experimental Group**: In unfilled specimen root canal surface topography showed open and patent dentinal tubules. Coronal third (Fig. 3) was totally free of the smeared layer, but towards the apical third tubular opening became comparatively occluded with smear material. In filled specimens after removal of

![Fig. 1](image)

*Fig. 1*: Photomicrograph showing coronal third of root canal surface of unfilled control specimen. Dentinal tubules are partially covered with the smeared layer. (SEM Magnification 1000 X).

![Fig. 3](image)

*Fig. 3*: Patent dentinal tubules are visible in the coronal third of root canal surface of unfilled experimental group specimen. (SEM Magnification 1000 X).
Fig. 4: Photomicrograph showing grade 2 penetration of Zinc oxide eugenol into the dentinal tubules in the coronal third of experimental group specimen. (SEM Magnification 1000 X).
S = Sealer, Dt = Dentinal tubules, m = Missing sealer after penetration, - > showing penetration.

Fig. 5: Photomicrograph showing diffuse penetration of Sealapex into the dentinal tubules in the coronal third of the experimental group.
S = Sealer, Dt = Dentinal tubules.

Fig. 6: No penetration of Kalzinol into the dentinal tubules in the coronal third of the experimental group (SEM Magnification 1000 X).
S = Sealer, Dt = Dentinal tubules.

the smeared layer, Zinc oxide eugenol penetrated the dentinal tubules in coronal (Fig. 4) and middle thirds and Sealapex in the coronal third only (Fig. 5). Kalzinol could not penetrate the dentinal tubules (Fig. 6).

Distribution of total samples of the experimental group filled with different sealers showing different penetration grades is shown in Table No. 1.

Table No. 2 shows the mean penetration + standard deviation shown by different root canal sealers in the experimental group.

The mean penetration differed significantly (p < 0.001) in coronal thirds of root canals with different sealers. It was maximum with Zinc oxide eugenol and was minimum i.e. zero with Kalzinol.

In middle third also penetration was maximum with zinc oxide eugenol. No other sealer could penetrate the dentinal tubules in the middle third.

No sealer was able to penetrate the apical dentinal tubules (Fig. 7).

Comparison of mean penetration with various sealers into dentinal tubules in different thirds of the root canal is shown in bar diag. I

Discussion

Smeared layer is not apparent on routinely processed specimens examined under the light microscope as it is a very thin layer and
TABLE NO. 1

DISTRIBUTION OF SAMPLES OF EXPERIMENTAL GROUP SHOWING VARIOUS PENETRATION GRADES IN DIFFERENT THIRDS OF THE ROOT CANAL

<table>
<thead>
<tr>
<th>Subgroups</th>
<th>Total No. of Samples</th>
<th>Penetration Grades in microns</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Coronal third</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>ZnO</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Kalzinol</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Sealapex</td>
<td>10</td>
<td>5</td>
</tr>
</tbody>
</table>

Grade 0 - No penetration
Grade I - 1-5 microns
Grade II - 6-10 microns
Grade III - 11-15 microns

*no sample in this grade

TABLE NO. 2

MEAN OF PENETRATION (IN MICRONS) SHOWN BY DIFFERENT ROOT CANAL SEALERS AT DIFFERENT THIRDS OF ROOT CANAL IN EXPERIMENTAL GROUP

<table>
<thead>
<tr>
<th>Sealer</th>
<th>Mean penetration (in microns) + standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coronal third</td>
</tr>
<tr>
<td>ZnO</td>
<td>7.20 + 3.96</td>
</tr>
<tr>
<td>Kalzinol</td>
<td>0</td>
</tr>
<tr>
<td>Sealapex</td>
<td>2.6 + 2.79</td>
</tr>
</tbody>
</table>

0 = Penetration is absent

Soluble in acids\(^5\). So, SEM is required to observe the smeared layer. Zinc oxide eugenol, Kalzinol and Sealapex were used as root canal sealers for this study.

Single rooted teeth with relatively straight roots were used, as root canal anatomy in curved roots might affect the biomechanical preparation in confines of the root canal\(^3\). Clinical crowns were amputated for easy access. Buccal and lingual longitudinal root grooves were cut to facilitate subsequent splitting for SEM evaluation. These were cut before starting the root-canal preparation so that debris produced during cutting the grooves might not get deposited on the prepared canal surface\(^6\). Irrigation of root canals was done to the complete length for creation of open apical tubules.

Preparation of the canals was done under irrigation of 5.25% sodium hypochlorite, which is the most widely recommended method of root canal preparation\(^10\). To obtain maximum effect after instrumentation, a final flush with 10 ml of EDTA followed by 10 ml of 5.25% NaOCl is recommended by many investigators\(^5,6\). NaOCl was specifically used as the last irrigant because superior results have been observed when chelating agent was followed by NaOCl for removal of the smeared layer. Direct high volume flush combined with chemical activity is required for removal of the smeared layer\(^6\). In the control
group a final flush with 20 ml of physiological saline solution, which has no chemical activity was used as irrigant instead of combination of EDTA and NaOCl.

None of the sealers used in the present study penetrated the dentinal tubules in the control group. This was due to the presence of the smeared layer which occluded the dentinal tubules. Results are in agreement with those reported by Lester and Boyd\textsuperscript{11} and White et al.\textsuperscript{5,12}.

In the experimental group, after removal of the smeared layer Zinc oxide eugenol was able to penetrate the dentinal tubules in the coronal and middle thirds of the root canals. No penetration was observed in the apical third. Similar results are also reported by others. White et al.\textsuperscript{12} observed penetration of Zinc oxide eugenol sealer into the dentinal tubules when it was used along with laterally condensed gutta-percha. Alacam\textsuperscript{13} reported penetration of Zinc oxide eugenol into the dentinal tubules in the primary teeth after removal of the smeared layer.

Fig. 4 shows that some of the packed Zinc oxide eugenol has been dislodged from the dentinal tubules, presumably while splitting the tooth. Zinc oxide eugenol is a notably weak aggregate of Zinc oxide crystals, hydrogen bonded about the eugenol\textsuperscript{12}. So, because of its less physical integrity it might have fallen out of some tubules while splitting the samples.

Kalzinol did not penetrate the dentinal tubules in any part of the root canal inspite of removal of the smeared layer. As it was well adapted to the dentinal tubules, it was considered that flow of this material was insufficient and its surface activity was not high enough to enter into the dentinal tubules. Aktener et al.\textsuperscript{14} concluded that root canal filling materials should have low surface activity, or a surface active reagent should be added to them to obtain maximum penetration. An additional reason for the lack of sealer penetration into the dentinal tubules could be the basic size of the particles of Kalzinol, as for penetration into wide open tubules, basic particle size of sealer should be about 1 um in diameter.

Sealapex could just penetrate the dentinal tubules in the coronal thirds of the root canals only after removal of the smeared layer. Mean penetration was 2.6μm. No penetration was seen in middle and apical thirds of the root canal.

Gutmann\textsuperscript{15} reported a better degree of penetration of Sealapx in the coronal and middle thirds of the root canal and to a lesser degree in apical dentinal tubules. Better results in all the thirds of the canals could be explained on the basis that thermoplasticized gutta-percha along with vertical condensation was used with the root canal sealer. So movement of the gutta-percha and sealer into the dentinal tubules could be due to the condensation force.

If lateral or vertical condensation forces along with gutta-percha had been used in this study, the penetration of all the sealers into dentinal tubules might have improved.

None of the sealers used was able to enter the apical dentinal tubules of root canals in this study. Lack of penetration in apical tubules was also reported by Michanowicz et al.\textsuperscript{16}, Gutmann\textsuperscript{15} and Oksan et al.\textsuperscript{17}. Absence of tubular penetration in the apical third may be due to the lack of tubular patency in the apical area, since these tubules are inherently smaller, less numerous and often sclerosed\textsuperscript{18}. In addition to this, condensation forces also became less in the apical area.

Thus, even after the removal of the smeared layer there was a significant difference in the penetration score of various sealers at different thirds of the root canals. The results of this study suggest that the chemical and physical properties of root canal sealers may affect tubular penetration and adaptation of filling materials to the root canal wall following the removal of the smeared layer.
Conclusions

1. The presence of the smeared layer prevented the penetration of the root canal sealers into the dentinal tubules.

2. After the removal of the smeared layer, root canal sealers were able to penetrate the dentinal tubules with the difference in their degree of penetration. It was maximum with Zinc oxide eugenol followed by Sealapex. Kalzinol did not display any penetration.

3. None of the sealers penetrated the apical dentinal tubules, even after the removal of the smeared layer.

References