# Stereomicroscopic evaluation of apical leakage after root canal obturation with zinc oxide eugenol sealer, resin, and mineral trioxide aggregate

**Introduction**

After root canal preparation and the chemical disinfection of the root canal system, obturation is necessary to maintain healthy periradicular tissue by creating a hermetic seal at the apical terminus (1). Ideally, the material employed for obturation should provide a liquid-tight seal while effectively penetrating into the many irregularities inherent in the root canal system, providing apical constriction while filling the discrepancies between the dentinal walls of the root canal system and obturation materials (2).

Gutta-percha is the most commonly used solid core-filling obturation material owing to its inert nature, excellent biocompatibility, superior sealing capabilities, and amenability to retreatment in the case of endodontic failure (3). Despite these advantages, gutta-percha cannot chemically adhere to the root canal walls, and as such, it has the potential to allow for microbial penetration or leakage through the interface of the root filling material and the canal wall, leading to the development of a periradicular infection [4]. Given these limitations, endodontic sealers are used to fill the voids between gutta-percha and the root canal walls. Even so, the formation of gaps within the sealer may allow for the leakage of bacteria and their byproducts, and so the success of treatment is compromised [5,6].

In general, root canal sealers vary in composition and may contain zinc oxide eugenol (ZOE), calcium hydroxide, resins, glass ionomers, silicone, or bioceramics, and no optimal sealer material has been identified to date (7). Advances in adhesive technology in this research space seek to minimize apical leakage by improving or complementing the bond between the obturation material and the root canal walls.

EndoREZ is a resin-based sealer consisting of nonacidic, hydrophilic resin monomers reported to yield superior sealant penetration into the dentinal tubules after smear layer removal (8). This sealer exhibits advantages including minimal shrinkage, good biocompatibility, radioopacity, low solubility, and better periapical repair (9). ZnO-based sealers have also long been employed in clinical contexts owing to their ease of handling, non-toxic composition, antimicrobial activity, radiopacity, low solubility, and ability to mediate periapical repair (10, 11). Mineral trioxide aggregate (MTA)-based root canal sealers have also recently emerged and risen to prominence owing to their ability to promote periodontal ligament regeneration and to form cementum in the root canal space and accessory canals (12, 13).

Irrespective of the material selected for root canal filling in the context of endodontic treatment, endodontic failure may occur as a consequence of persistent microbial infection (14). Factors that can contribute to the incidence of apical microleakage include the physical and chemical properties of the selected sealer, root canal preparation techniques, smear layer, and obturation techniques (15).

Several approaches have been developed to evaluate the ability of different materials to effectively seal the root canal system, with the linear dye microleakage technique being the approach most commonly employed in endodontic studies (16, 17). The present *in vitro* study was therefore developed to compare apical leakage following stepback preparation, smear layer removal, and root canal obturation with Canason, EndoREZ, and MTA sealers.

**Material and Methods**

For this study, 80 extracted single-rooted human teeth that had been extracted for periodontal and orthodontic reasons were used to conduct all experimental analyses. The crowns of these teeth were removed at the cement-enamel junction. Root canal working length was then determined using a K-file #15 (Dentsply Maillefer, Ballaigues, Switzerland), with the file tip being retracted back 1 mm when visible at the apical foramen. Root canals were instrumented according to the step-back technique, with a K-file #30 serving as the master apical file and root canals being recapitulated after each tile use. Root canals were irrigated with 5.25% sodium hypochlorite and 17% EDTA for smear layer removal (5 mL).

After preparation, sample teeth were separated into three experimental groups (n = 20/group) based on the root canal sealer used, while 10 teeth were assigned to each of the negative and positive control groups. Root canals in the positive control group were obturated with gutta-percha and no sealer, while the root canals in the negative control group were obturated with gutta-percha and sealer. Root canals in the first experimental group were obturated with Canason (Voco) sealer and lateral cold gutta-percha compaction. Root canals in the second experimental group were obturated with EndoREZ (Ultradent Products, South Jordan UT, USA) and lateral cold gutta-percha compaction. Root canals in the third experimental group were obturated with ProRoot MTA (Dentsply, Maillefer, Switzerland) in combination with cold gutta-percha.

Root canals were filled with sealer using a Lentulo spiral and were then fitted with a master gutta-percha cone (No. 25), after which lateral compaction was continued using a spreader until the spreader could not be inserted more than 3 mm into the root canal. After obturation, all samples were sealed with Cavit temporary filling material (3M ESPE, Seefeld, Germany).

After this procedure, samples were stored for 7 days in a 37°C incubator until the sealers were set. Teeth were then dried and coated with nail polish, leaving 2 mm of the apical region uncoated for samples in the experimental groups. Samples in the positive control group were left uncoated, while those in the negative control group were fully coated. The apical regions of all teeth were then submerged in 2% methylene blue for 48 h (Fig.1). Samples were then rinsed with water, dried, and longitudinally sectioned using a diamond disk. A stereomicroscope (Brunel Microscope MX6T, Wiltshire, UK) was used to measure apical linear microleakage (Fig. 2-5).

All data in the present study were reported with mean, standard deviation, standard error, and 95% confidence interval (95% CI) values. Dye leakage was compared among groups using Student’s t-tests, with a P-value < 0.05 being indicative of statistical significance. A logistic regression analysis was additionally used to assess the probability of microleakage occurrence.

**Results**

Probability calculations revealed that the odds of dye leakage following root canal preparation with the step-back technique, smear layer removal, and canal obturation with Canason, MTA, and EndoREZ sealers were 99.55%, 93.85%, and 85.07%, respectively. Mean values corresponding to dye microleakage when using different sealers are reported in Table 1 along with corresponding standard deviations. The maximum dye leakage observed for samples sealed with Canason paste in combination with lateral gutta-percha compaction was 0.44 mm, while the minimum was 0.03 mm. The maximum dye leakage in root canals filled with MTA in combination with gutta-percha compaction was 1.07 mm, while the minimum was 0.09 mm. In the experimental group filled with EndoREZ paste in combination with lateral gutta-percha compaction, the respective maximum and minimum dye leakage values were 1.01 mm and 0.00 mm. Differences in average dye leakage values in these different experimental groups are shown in Table 2.

In root canals filled with MTA in combination with lateral gutta-percha compaction dye leakage was significantly increased relative to that observed in root canals filled with EndoREZ (average difference = 0.19 mm, 95% CI: 0.004 - 0.38 mm, P < 0.001). Dye microleakage was higher for root canals filled with MTA (0.31 mm) relative to the group filled with Canason, with the average between these two groups being significantly different (average difference = -0.31 mm, 95% CI -0.47 to -0.15 mm, P < 0.001). Samples in the negative control group exhibited no dye leakage, while all samples in the positive control group exhibited dye leakage, thus validating these study findings.

**Discussion**

A range of root canal preparation and obturation techniques have been developed and studied over time. In the present article, we explored these different techniques using the step-back preparation technique, as it has been shown to be superior to standardized serial filing and reaming techniques in debridement and maintaining the canal shape (18). We additionally selected lateral gutta-percha condensation as a root canal obturation technique in the present study given that it is a standard approach that is generally used for comparison when studying other techniques (19).

We selected methylene blue dye leakage as a means of evaluating the quality of root canal fillings owing to the simplicity of this technique and the availability of sufficient data regarding linear dye penetration. Ballullaya et al. (2017) previously noted that the methylene blue dye technique is frequently used owing to its low molecular weight and good penetration, similar to many bacterial toxins (20).

In our study, when samples were prepared with a step-back technique and obturated with EndoREZ sealer or ProRoot MTA, similar levels of dye leakage were observed, with only slightly lower levels of leakage for the EndoREZ sealer (0.26 mm vs. 0.34 mm). This may be attributable to the fact that EndoREZ sealer is hydrophilic in nature and can create long resin tags with a hybrid layer (21). In addition, MTA cement becomes porous after mixing, which may contribute to apical leakage (22).

In line with our results, Gillespie et al. (23) reported that EndoREZ root canal sealer exhibited good sealing ability attributed to an adhesive filling technique, with De-Deus et al. (24) similarly concluding that reduced bacterial leakage was observed during a 9-week period following root canal filling with gutta-percha and EndoREZ. Moreover, Tay et al. (25) found that MTA was associated with similar levels of leakage to those observed for resin-based root canal sealers, although these sealers do not bond to gutta-percha or root canal walls.

Many studies have previously reported MTA to exhibit excellent sealing ability and biocompatibility (26), and it has been suggested to be an ideal material for obturating the entirety of the root canal system (27). However, in the present study, we found ZOE canal sealer use was associated with reduced apical methylene blue dye leakage as compared to that observed when MTA was used as a root canal sealer, in contrast to other *in vitro* study findings (23, 28, 29). When comparing the sealing ability of MTA to that of ZOE, Nikhade et al. (30) found that a single-cone technique using MTA was associated with superior sealing to that observed when using ZOE paste. In their study, Ballallaya et al. (2) found that ZOE exhibited poor adhesion to root canal walls and limited sealing activity when used as a root canal sealer, although reduced apical leakage was observed when it was placed in an extremely well-dried root canal (31), because there can not dissociate zinc eugenolate into zinc hydroxide and eugenol (32).

The differences between the above results and our findings may be attributable to differences in sample number, methodology, or the invasive method by which roots were longitudinally sectioned during which the gutta-percha may be disconnected from the sealer, thus altering study results. However, many additional *in vitro* and *in vivo* studies will be necessary to conclusively determine which root canal sealers are associated with a more favorable long-term root canal prognosis.

**Conclusions**

In conclusion, the results of this *in vitro* study indicated that all root canal sealers used in combination with lateral cold gutta-percha in this study resulted in apical dye leakage. Moreover, EndoREZ and MTA were found to exhibit similar sealing performance, while ZOE root canal sealers outperformed both EndoREZ and MTA with respect to their sealing activity.

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