Original Article

Apical dye leakage of two single-cone root canal core materials (hydrophilic core material and gutta-percha) sealed by different types of endodontic sealers: An *in vitro* study

Mohamed Abdel Aziz Mohamed El Sayed[1,2], Hussam Al Husseini[1]

[1]Department of Restorative Dentistry, Faculty of Dentistry, Ajman University, Ajman, UAE, [2]Department of Endodontic, Faculty of Dentistry, Mansoura University, Mansoura, Egypt

Abstract

Aim of the Study: The aim of this study was to compare the apical sealing ability of two single-cone filling materials when sealed with different types of root canal sealers.

Materials and Methods: Eighty extracted maxillary and mandibular canines were selected and their crowns were cut. The root canals were prepared using ProTaper Universal rotary system until size F4 and then divided into seven experimental groups (n = 10 each) and two control groups (n = 5 each). Samples of Groups 1, 2, and 3 were filled with single-cone gutta-percha and AH Plus, MTA Fillapex, and EndoSequence BC, respectively. Samples of Groups 4, 5, and 6 were filled similar to the previous groups with the exception of using a single-cone CPoint. Samples of Group 7 were filled with cold gutta-percha lateral condensation technique. To assess apical microleakage, the apical linear dye penetration was measured microscopically and data were statistically analyzed.

Results: All experimental groups showed significantly different dye apical leakage values ($P = 0.000$). No significant differences were found between Groups 1, 2, 4, 6, and 7 ($P < 0.05$). The lowest mean leakage value was observed in Group 6 (0.95 ± 0.56 mm) while Groups 3 (2.68 ± 0.71 mm) and 5 (2.61 ± 0.71 mm) showed significantly higher mean leakage values.

Conclusions: The lowest apical leakage value was observed with single-cone CPoint/EndoSequence BC but without significant differences when compared with single-cone gutta-percha/AH Plus, single-cone gutta-percha/MTA Fillapex, single-cone CPoint/AH Plus, and lateral condensation technique. Higher apical leakage values were observed with single-cone gutta-percha/EndoSequence BC and CPoint/MTA Fillapex.

Keywords: Bioceramic root canal sealer; CPoint; microleakage, MTA Fillapex; single-cone obturation technique

INTRODUCTION

A three-dimensional root canal filling prevents reinfection of the canal space and subsequent leakage of fluid and antigenic agents into or from the periapical tissues.[1] Although different obturation techniques are currently available, there is an ongoing interest in developing more effective and simplified materials/techniques. Single-cone obturation technique has become popular with the widespread use of rotary nickel–titanium (Ni–Ti) instruments.[2]

Root canal sealers are important in achieving a three-dimensional filling by reducing apical and coronal microleakage.[3] Different types of sealers based on

Address for correspondence:
Dr. Mohamed Abdel Aziz Mohamed El Sayed, Associate Professor of Endodontic, Faculty of Dentistry, Mansoura University, El Gomhouria Street, Mansoura 35516, Egypt.
E-mail: elsayednada@yahoo.com

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various formulas are available. AH Plus (Dentsply Maillefer, Ballaigues, Switzerland) is the most frequently epoxy resin-based sealer used because of its good physical and chemical properties and good sealing ability.[4] MTA Fillapex is a new MTA-based sealer developed by Angelus (Londrina/Parana/Brazil) and composed of portland cement, bismuth oxide, and dehydrated calcium sulfate. The manufacturer claims that this type of sealer can provide perfect sealing ability and promotes cementum regeneration.[5] EndoSequence BC sealer (Brasseler USA, Savannah, GA) is a newly introduced bioceramic sealer that utilizes moisture inherently present in dentinal tubules for its setting reaction.[6] It consists of nanoparticle size of calcium silicates, calcium phosphate monobasic, calcium hydroxide, and zirconium oxide. It results in a gap-free interface between gutta-percha, sealer, and dentin as it does not shrink on setting.[6] Moreover, it has the ability to form an interfacial apatite layer that causes a chemical bond between the material and radicular dentin.[7]

Besides root canal sealers, the type of core material could play an important role in the success of endodontic treatment. It was demonstrated that the gutta-percha points of ProTaper system (Dentsply Maillefer, Ballaigues, Switzerland) can be used effectively and simply for single-cone obturation technique provided that the root canals are prepared with ProTaper finisher files of similar size and taper.[8] CPoint system (EndoTechnologies, LLC, Shrewsbury, MA, USA) is a newly introduced single-cone obturation system consisting of premade hydrophilic endodontic points (CPoints or ProPoints) of different sizes and taper and an accompanying endodontic sealer (Bioceramic sealer). A CPoint cone consists of a radiopaque polymeric core coated with a radiolucent sheath of a hydrophilic polymer. The inner core is composed of a zirconium oxide/polyamide blend, a mix of two proprietary nylon polymers: Trogamid T and Trogamid CX. The outer sheath of the CPoint is a cross-linked copolymer of acrylonitrile and vinylpyrrolidone. By absorbing the residual water presents inside the root canal, the coat is designed to expand laterally but not axially until the cone comes in contact with the dentinal wall, providing a superior adaptation and seal.[9]

The majority of endodontic failures are caused by the microleakage resulting from incomplete obturation.[10] Therefore, leakage tests are important in evaluating the excellence of the root canal treatment. Passive dye penetration method is the most widely used because of its sensitivity, ease of use, and convenience.[11]

There is a lack of evidence on the apical sealing ability of single-cone obturation utilizing CPoint when combined with different types of root canal sealers. Therefore, the aim of the current study was to compare the apical dye leakage of two single-cone core materials, CPoint and ProTaper gutta-percha, when sealed with different endodontic sealers in root canals prepared with ProTaper Universal instruments. Furthermore, the apical dye leakage of each single-cone obturation system was then compared with that of cold gutta-percha lateral condensation technique.

MATERIALS AND METHODS

Samples selection and preparation

Eighty freshly extracted human maxillary and mandibular canines with sound roots were selected. The crowns were sectioned below the cementoenamel junction so that the length of roots was standardized to 15 mm. The initial file for selected samples was not larger than a #25 K-file. The working length was determined, and the canals were instrumented with ProTaper Universal NiTi rotary files (Dentsply Maillefer, Ballaigues, Switzerland) to size F4 following the manufacturer instructions. Glyde File Prep (Dentsply Maillefer, Ballaigues, Switzerland) was used as a lubricant during the instrumentation. The canals were irrigated after using each file with 5 ml 3% sodium hypochlorite (NaOCl) solution using a 27-gauge Max-i-Probe needle (Dentsply Maillefer, Ballaigues, Switzerland). Eventually, all canals were rinsed for 1 min with 5 ml of 17% ethylenediaminetetraacetic acid (EDTA) solution (MD-Cleanser, META BIOMED Co. Ltd, Korea), followed by 10 ml distilled water as a final irrigant to remove any traces of NaOCl. Canals were dried with ProTaper Universal paper point size F4.

Samples grouping and root canal obturation

Samples were randomly divided according to the obturation technique and materials into seven experimental groups of ten samples each and two control groups of five samples each [Table 1]. Samples in the negative control group did not receive root canal fillings, while in the positive control group, they were obturated with single gutta-percha cone size F4 but without sealer. Samples in Groups 1, 2, and 3 were filled with single one ProTaper gutta-percha size F4 and sealed with AH Plus (Group 1), MTA Fillapex (Group 2), and EndoSequence BC (Group 3). Samples in Groups 4, 5, and 6 were filled with single-cone CPoint size 40/0.06 and sealed with AH Plus (Group 4), MTA Fillapex (Group 5), and EndoSequence BC (Group 6). Samples in Group 7 were filled with standardized gutta-percha size 40 and AH Plus using cold lateral condensation.

All sealers were mixed according to manufacturers' instructions. AH Plus and MTA Fillapex were introduced into the prepared canals using a #30 Lentulo spiral rotated at 300 rpm and 3 mm away from the apex, whereas EndoSequence BC sealer was directly injected into the canals through the intracanal tip supplied by the manufacturer. For single-cone obturation technique (Groups 1 to 6), the tip of each prefitted master cone was slightly coated with its respective sealer and inserted into the prepared canal

Table 1: Experimental sample grouping

Groups	*n*	Obturation system		
		Core material	Root canal sealer	Obturation technique
1	10	ProTaper gutta-percha	AH Plus	SC technique
2	10	ProTaper gutta-percha	MTA Fillapex	
3	10	ProTaper gutta-percha	EndoSequence BC	
4	10	CPoint	AH Plus	
5	10	CPoint	MTA Fillapex	
6	10	CPoint	EndoSequence BC	
7	10	Gutta-percha	AH Plus	Lateral condensation

MTA: Mineral trioxide aggregate, SC: Single-cone

using up-and-down pumping motion until reaching the full working length.

In Group 7, AH Plus was introduced into the canal space with the Lentulo spiral as previously mentioned. The tip of a size 40/0.02 taper prefitted master gutta-percha cone was then coated with a thin layer of sealer and introduced apically to the full working length. Lateral condensation was achieved using size 25/0.02 standardized gutta-percha cones and size C finger spreader (D1 diameter 0.3 mm, 0.04 taper) (Dentsply Maillefer).

After removing excess gutta-percha with a heated endodontic plugger and excess CPoint with a specialized high-speed bur supplied by the manufacturer, each canal orifice was filled with light-cured glass ionomer cement. The quality of obturation was assessed radiographically, and samples with insufficient obturation were excluded from the study and replaced with a new one. All samples were incubated for 1 week at 37°C and 95% humidity to allow complete setting of sealers.

Microleakage measurement

The roots in the experimental and positive control groups were coated with triple layers of nail varnish, except at the apical foramen which was kept open by placing a K-file no. 8 inside it during the application of the nail varnish. The roots including apical foramen in the negative control group were entirely covered with nail varnish.

All samples were immersed in 1% methylene blue dye and stored at 37°C for 72 h, after which they were thoroughly rinsed in running water. The nail varnish was gently removed with a scalpel blade no. 11. The apical 7 mm of each root was longitudinally sectioned in a buccolingual direction, and then, a horizontal cut was made on the mesial or distal surface using a flexible diamond disc under water coolant. The 7 mm proximal portion of each sample was then cut, and the filling material was removed using an endodontic explorer to allow obvious evaluation of dye penetration.

Microleakage in each sample was evaluated under a digital stereomicroscope (Leica EZ4W, Germany) at ×20 magnification. Pictures were captured and saved, and the maximum apical dye penetration leakage was measured using ImageJ software program (National Institutes of Health, 9000 Rockville PikeBethesda, Maryland 20892). To eliminate the operator variable, a single operator completed all preparations and testing procedures.

Statistical analysis

The results were statistically analyzed by one-way ANOVA and Tukey's *post hoc* test using IBM SPSS version 20 (IBM Corporation 1 New Orchard Road Armonk, New York 10504-1722, United States). All the level of statistical significance was set at $P < 0.05$.

RESULTS

The mean values and standard deviations of apical dye penetration for all experimental groups are presented in Table 2 and illustrated in Figure 1. All experimental groups demonstrated apical leakage of variable measurements [Figure 2]. The negative control group showed no leakage while the positive control groups showed complete leakage through the canal space [Figure 2]. The lowest mean leakage value (0.95 ± 0.56 mm) was observed in Group 6 (CPoint + EndoSequence BC) but without significant difference when compared to the other experimental groups ($P > 0.05$) except Groups 3 (gutta-percha + EndoSequence BC) and 5 (CPoint + MTA Fillapex) which showed the highest and significant ($P < 0.05$) mean leakage values of 2.68 ± 0.71 mm and 2.61 ± 0.71 mm, respectively.

DISCUSSION

Apical and coronal leakage has been shown to be the main reasons for root canal treatment failure.[10] Therefore, the root canal filling should seal the canal space both apically and coronally to prevent microorganisms and tissue fluids from entering the canal space and *vice versa*.

Regardless of the obturation technique, the main function of root canal sealers is to achieve immediate and long-lasting seal along the root canal wall. The development of new types of endodontic sealers and/or obturation core materials may overcome the microleakage associated with currently used materials and encourage the use of single-cone obturation technique, especially with canals instrumented with greater taper Ni–Ti rotary files. CPoint is a recent core material and its manufacturer claimed that it has the ability to expand upon exposure to moisture from the root canal irrigants and/or dentinal tubules. This is thought to enhance the sealing ability of CPoint when combined with a root canal sealer. Moreover, the manufacturer recommends the use of EndoSequence BC sealer with this core material to form a single-cone obturation system. Therefore, the current

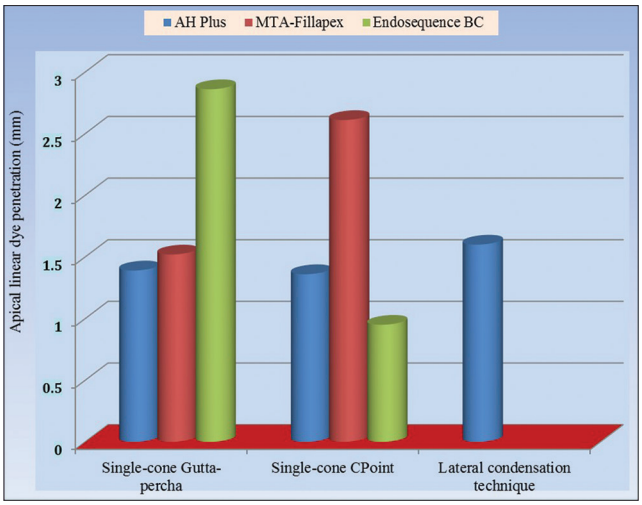

Figure 1: Mean values of apical linear dye penetration for all experimental groups

Table 2: Comparison between dye leakage mean values of matched-taper single-cone obturation systems and lateral condensation technique

Groups	Obturation system	Apical linear dye penetration (mm)		
		Mean±SD**	Maximum	Minimum
Group 1	SC gutta-percha + AH Plus	1.39±0.39[a]	1.88	0.80
Group 2	SC gutta-percha +MTA Fillapex	1.52±0.77[a]	2.88	0.79
Group 3	SC gutta-percha + EndoSequence BC	2.68±0.71[b]	3.95	1.87
Group 4	SC CPoint + AH Plus	1.36±0.50[a]	2.02	0.52
Group 5	SC CPoint + MTA Fillapex	2.61±0.71[b]	3.63	1.79
Group 6	SC CPoint + EndoSequence BC	0.95±0.56[a]	1.65	0.00
Group 7	Gutta-percha lateral condensation	1.60±0.64[a]	2.96	0.67
ANOVA (*P*)		0.000		

**Tukey's HSD test: Means with different superscript letter in the same column are significantly different ($P<0.05$). SD: Standard deviation, SC: Single-cone, HSD: Honest significant difference, MTA: Mineral trioxide aggregate

study aimed to evaluate and compare the apical sealing ability of matched-taper single-cone CPoint and ProTaper gutta-percha when combined with AH Plus, MTA Fillapex, or EndoSequence BC root canal sealers. The cold gutta-percha lateral condensation technique was used in the current study as it is considered a standard obturation technique to which other obturation techniques are compared.[12]

In this study, extracted canines with straight canals were selected and instrumented to # F4 ProTaper Universal Ni–Ti rotary instrument. Therefore, variables such as anatomical variation, canal size, and the diameter of the apical foramen which can affect the apical leakage were minimized. Moreover, the rotary instrumentation was found to be less time consuming, more comfortable, and more efficient than hand instrumentation and provides a standardized root canal preparation.[13] During instrumentation, the

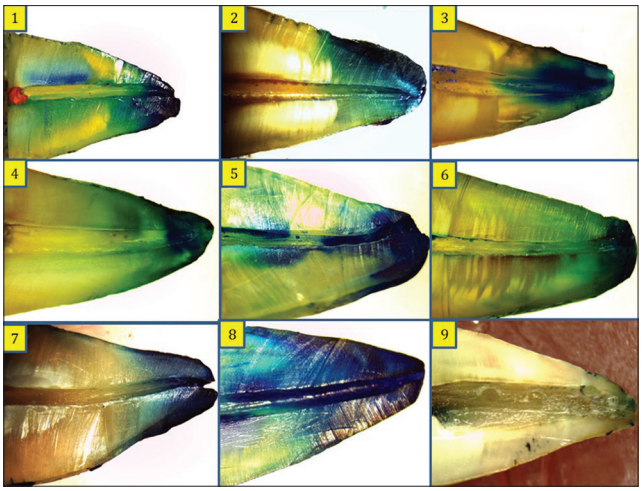

Figure 2: Apical dye leakage of all Groups: 1: Group 1 (GP/AH Plus), 2: Group 2 (GP/MTA Fillapex), 3: Group 3 (GP/EndoSequence BC), 4: Group 4 (CPoint/AH Plus), 5: Group 5 (CPoint/MTA Fillapex), 6: Group 6 (CPoint/EndoSequence BC), 7: Group 7 (Lateral condensation technique), 8: Positive control group, 9: Negative control group

root canals were irrigated with 3% NaOCl followed by 17% EDTA solution to remove the remaining organic tissues and smear layer, which may improve sealer penetration inside the dentinal tubules and enhance its sealing ability.[14]

In this study, methylene blue dye penetration method was selected to assess apical microleakage because it is inexpensive and easy to manipulate. In addition, it has a high degree of staining capability and a molecular weight lower than that of bacterial toxins.[11] In spite of these advantages, the *in vitro* penetration of dyes into root canals should not directly compared with the *in vivo* leakage of irritants in or out of the root canal system. Instead, dye penetration should be considered an indicator of the potential for leakage because a filling material that does not allow penetration of small molecules, such as dyes, has the ability to prevent leakage of larger molecules, such as bacteria and their byproducts.[15]

The maintenance of the apical patency of root canals after finishing instrumentation is important to avoid the blocking of the apical foramen with dentinal plug that could influence the results of dye leakage penetration. In the current study, the dye penetration was linearly measured from the apical end of root canal filling material toward its maximum coronal extent and not from the anatomical root end, to assess the actual dye leakage alongside the obturation materials.

The findings of the present study indicated that all obturation systems did not totally prevent the apical dye leakage. The positive control group showed the highest level of dye penetration, indicating that sealing ability of single-cone gutta-percha is deteriorated when used without a root canal sealer. On the other hand, the negative

control group did not show any apical leakage, and this confirms the sealing quality of nail varnish and indicates that leakage occurred only through the apical foramen.

The lowest leakage mean value was observed in Group 6 (CPoint + EndoSequence BC). These findings may be attributed to the lateral expansion of CPoint while absorbing residual moisture from the instrumented root canal space or the naturally present moisture in the dentinal tubules.[9] It was found that CPoint has an approximately 14% lateral expansion after 20 min of moisture exposure.[9] The better sealing ability of this single-cone obturation system may also be due to the slow setting time of bioceramic sealer, which provides more time for the expansion of the CPoints and pushing the sealer toward the radicular dentinal walls. The high flowability of the bioceramic sealer and the hydraulic pressure resulting from the insertion of a greater taper CPoint into the root canal of similar taper could create intimate contact between biocermic sealer and radicular dentin, especially at the apical portion. This allows the formation of an interfacial hydroxyapatite layer that creates a chemical bond between the bioceramic sealer and dentin.[7]

In the present study, the apical leakage mean values of all experimental groups showed statistically similar results except for single-cone CPoint/MTA Fillapex and single-cone ProTaper/EndoSequence BC groups that showed the highest significant mean values of leakage. These results are in agreement with that of Zhang *et al.* who found that the sealing ability of the bioceramic sealer was equivalent to that of AH Plus when used with single-cone or continuous wave gutta-percha obturation techniques.[16] Parvez *et al.*, in spite of differences in the root canal filling materials and methodology, showed similar results that indicated that the sealing ability of single-cone obturation technique was similar to that of lateral condensation technique.[17] The good apical sealing ability of AH Plus may be explained by its good adhesiveness, which is likely caused by its ability to penetrate into microirregularities on dentinal wall, its setting expansion after being inserted in the root canal, and its ability to form a covalent bond with amino groups of exposed radicular dentin collagen.[18]

In contrast to the present results, Hegde and Arora found that the apical sealing ability of single-cone CPoint sealed with a bioceramic sealer was better than that of laterally condensed gutta-percha sealed with an epoxy resin sealer.[19] Moreover, El-Sayed *et al.* concluded that single-cone ProPoint, which is similar to CPoint, sealed with the bioceramic sealer had better coronoapical sealing ability than single-cone ProPoint sealed with epoxy resin sealer. The cause of this disagreement may be due to the differences in the method of leakage assessment.[20]

The use of MTA Fillapex with single-cone gutta-percha produced statistically similar results to that of lateral condensation technique, single-cone gutta-percha/AH Plus, CPoint/AH Plus, and CPoint/EndoSequence BC obturation systems. This may be explained by the volumetric expansion of MTA especially if it is not exposed to any pressure during setting period.[21] However, Sönmez z *et al*. found that MTA Fillapex sealer had inferior sealing ability when compared with resin-based sealer because of the presence of salicylate resin component.[5]

The changing of dentin surface energy because of using EDTA solution can significantly reduce its wetting ability and thus reduce the adhesion of hydrophilic root canal sealer especially when used with a core material that has dimensional stability such as gutta-percha.[22] This could explain the high leakage mean value observed in the canals obturated with single-cone ProTaper gutta-percha/EndoSequence BC.

The high leakage mean value of single-cone CPoint/MTA Fillapex may be explained by the pressure created by the continuous lateral expansion of CPoint during setting of MTA Fillapex that affects negatively the hydration process of its mineral oxide compounds.[23] Further studies are required to study the effect of lateral condensation technique on the sealing ability of MTA Fillapex and EndoSequence BC root canal sealers

CONCLUSIONS

Within the limitations of the current study, the following conclusions can be drawn:

1. The apical leakage cannot be prevented by any of the current experimental obturation systems
2. The matched-taper single-cone CPoint with EndoSequence BC sealer showed the lowest value of apical leakage but without statistically significant difference when compared with single-cone gutta-percha/AH Plus, gutta-percha/MTA Fillapex, and cold lateral condensation technique. Therefore, EndoSequence BC and AH Plus may be the suitable sealers when single-cone CPoint obturation is used, while AH Plus and MTA Fillapex are suitable when single-cone gutta-percha obturation is used
3. Single-cone gutta-percha/EndoSequence BC and CPoint/MTA Fillapex showed the highest values of apical leakage. Therefore, the using of EndoSequence BC with single-cone gutta-percha and MTA Fillapex with single-cone CPoint may be not recommended
4. Single-cone obturation technique using matched taper CPoint or gutta-percha may be an alternative to lateral condensation technique if the proper root canal sealer is selected
5. CPoint may be an alternative to the gutta-percha, and further studies must be conducted to evaluate its retrievability, solubility, and biocompatibility.

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Conflicts of interest
There are no conflicts of interest.

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