Coronal Leakage Inhibition in Endodontically Treated Teeth Using Resin-coating Technique

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The purpose of this study was to evaluate coronal leakage inhibition using a resin-coating technique after endodontic treatment. Thirty-six human incisors were cut at the cemento-enamel junction, and endodontic obturations were performed. The specimens were randomly divided into three groups according to post space preparation (10 mm depth), resin coating, and temporization. For the resin coating, the dentin surface was coated with either a combination of Clearfil SE Bond and Protect Liner F (SE/PLF) or RZII (RZ). Then, the specimens were stored in 37°C distilled water for 24 hours and placed in 1% methylene blue solution for 48 hours. After which, the specimens were sectioned faciolingually along the root canal and the length of dye penetration was measured from the cemento-enamel junction. Three-way ANOVA revealed that the dye penetration scores were influenced by post space preparation, resin coating, and temporization. Resin coating with RZ significantly reduced the dye penetration score and SE/PLF completely eliminated dye penetration.

Key words: Resin coating, Coronal leakage, Endodontically-treated teeth

INTRODUCTION

Recent advances in adhesive technology have made direct placement of composite resin restorations a commonplace treatment procedure in clinical dentistry. Direct composite restorations are the preferred treatment over indirect composite restorations because they require minimal intervention and cavity preparation¹⁾. Dentin adhesives can be applied not only to vital teeth but also to non-vital teeth. It has been extensively reported that recent dentin adhesive systems can bond to root canal dentin^{2,3)} and pulpal floor dentin^{4,5)} as well as to coronal dentin. However, the chemical irrigants and medicaments used during root canal treatment are the clinical factors that influence bonding to dentin in direct and indirect restorations^{6,7)}.

Endodontic obturation can provide an effective apical seal. However, the apical seal can be adversely affected once the coronal restoration is lost or becomes defective. Significant coronal dye penetration has been shown to occur following dissolution of the sealer by artificial saliva^{8,9)}. Dissolution of the sealer allows access of periapical fluids, proteins, and bacteria to the root canal. Fractured teeth and leaking/lost temporary restorations are often encountered clinically, which can leave the root canal filling open

to the oral cavity. Therefore, the quality of the coronal seal is equally important for the ultimate success of any root canal obturation since endodontic sealers do not bond well to dentin.

In the case of indirect restorations, resin cement has become widely accepted for luting tooth-colored restorations. However, the dentin bonding ability of resin cements is lower than that of resin adhesives. Therefore, new methods are urgently needed to improve the dentin bonding ability of contemporary resin cements to obtain optimum indirect restorations.

A resin-coating technique has recently been developed in which both a hybrid layer and a tight sealing film are produced on the dentin surface¹⁰⁾. In this technique, a resin coating of a dentin adhesive system and a low-viscosity microfilled resin are recommended to be applied to the prepared cavity immediately after tooth preparation and just before taking impression. However, the combination of a dentin bonding system and a low-viscosity microfilled resin creates a thick coating layer on the dentin surface¹¹⁾, which is not appropriate for crown preparations.

Recently, a thin-film coating material has been developed through advancement in single-step bonding technology¹²⁾. It was reported that the thin-film coating material could improve the dentin bonding

performance of the resin cement¹²⁾, as well as prevent marginal leakage beneath full cast crowns¹³⁾.

This technique has the ability to minimize pulpal irritation caused by mechanical and thermal stimuli and bacterial infiltration in vital teeth¹⁰⁾. Nonetheless, the technique can also be applied in the restoration of non-vital teeth. Therefore, the purpose of this study was to evaluate the effect of resin coating on coronal leakage inhibition in endodontically treated teeth. In addition, the influences of post space preparation and temporization on coronal leakage were evaluated.

MATERIALS AND METHODS

Materials used in this study

The materials used in this study are listed in Table 1. For the resin coating, a combination of Clearfil SE Bond and Protect Liner F (Kuraray Medical, Tokyo, Japan) or a single coat of an experimental material, RZII (Sun Medical, Moriyama, Japan), was applied to dentin. Clearfil SE Bond is a two-step self-etching primer system, and Protect Liner F is a microfilled resin. The combination of Clearfil SE Bond and Protect Liner F has been reported to be one of the optimal combinations for resin coating of cavity preparations^{14,15)}. On the other hand, RZII is an experimental single-step bonding material. It creates a thin film (5-6 μm) on the dentin surface, which is appropriate for the resin coating of crown preparations¹²⁾.

Previous studies have demonstrated that a water-setting temporary filling material, Cavit-G (3M ESPE, Seefeld, Germany), is an appropriate temporary filling for the resin-coating technique¹⁶⁾.

Specimen preparation

Specimen preparation is illustrated in Fig. 1. Thirty-six extracted, single-canal, human incisors stored in distilled water within three months of extraction were used. All the teeth were cut at the level of the

cementoenamel junction with a diamond bur (ISO #173016, GC, Tokyo, Japan). Standard endodontic access cavities were made and the root canal contents were removed with #15-#35 K-type files (Zipperer, VDW, Monachium, Niemcy). Patency of the apical foramen was determined using a #35 K-type file. Working length was established 0.5 mm short of the length at which this file exited the foramen, ensuring that the apical preparation was complete to within 1 mm of the apical foramen. The canals were irrigated with 3% sodium hypochlorite and chemomechanically prepared to a #35 master apical file. Then, the canals were dried with paper points followed by apical cleaning. Master gutta-percha cones (GC, Tokyo, Japan) were fitted to within 1 mm of the working length in the 36 teeth. The cones were coated with Sealapex (Kerr, Orange, U.S.A.), placed in the canals, and condensed by cold lateral condensation. Excess gutta-percha was removed with a heated hand instrument at the level of the cementoenamel junction. After obturation, the coronal openings were covered with the temporary filling material, Cavit-G, while the apical foramens were sealed with utility wax. Following this, the specimens were placed in water at 37°C for 24 hours to allow the sealer to set.

Specimens were randomly divided into three groups of twelve according to the following factors: post space preparation, resin coating, and temporization. Post space preparation was carried out in half of the specimens and no preparation was done in the remaining specimens. Post spaces, 10 mm in length, were prepared from the cementoenamel junction using a post preparation bur (Size 25, 0.05 taper, GC, Tokyo, Japan). For each group, the specimens were divided into two subgroups – with or without resin coating. For the resin coating subgroups, the dentin surface was coated with either a combination of Clearfil SE Bond and Protect Liner F (SE/PLF) or one coat of RZII according to the manufacturer's instructions. Light-curing unit used in this study was New Light-VL-II (GC Co., Tokyo, Japan). Each sub-

Table 1 Manufacturers' instructions on the bonding procedures for resin coating, bonding system, and low-viscosity microfilled resin

Material (Batch No.)	Components	Chemical composition	Directions
Clearfil SE Bond (003A)	Primer Bond	MDP, HEMA, photoinitiator, water, functional monomer MDP, HEMA, Bis-GMA, microfiller, water, functional monomer	20 seconds apply, dry 10 seconds light-cure
RZII (010410)	Liquid Sponge	Water, acetone, 4-META, polyfunctional acrylate, monomethacrylate, photoinitiators, stabilizers p-toluenesulfinate, amine	Mix sponge and liquid, apply, dry 10 seconds light-cure
Protect Liner F (0003)		Microfiller (SiO ₂), MF-MMA copolymer, dimethacrylate monomer, catalyst	20 seconds light-cure
Cavit-G (0311)		Zinc oxide, calcium sulfate, zinc sulfate, glycol acetate, polyvinyl acetate, polyvinyl chlorite acetate, triethanolamine	

group was further divided into two groups, where the coronal opening was either covered with or without the temporary filling material, Cavit-G.

Dye penetration test

Entire tooth surfaces were coated with nail varnish, leaving only the coronal openings exposed. The apical parts were sealed with utility wax. The teeth were then placed in 1% methylene blue solution for 48 hours before they were sectioned into two halves faciolingually using a water-cooled diamond saw (Leitz1600, Wetzlar, Germany). Dye penetration measurement was carried out to the nearest 0.01 mm using a stereomicroscope (Olympus Colposcope, Olympus Optical Japan, Tokyo, Japan) at $\times 3$ magnification. Linear dye penetration along the facial and lingual sides of the root canal was measured from the cementoenamel junction for the specimens without post space preparation, while measurement was performed from the surface of the post space

preparation for the specimens with post space preparations¹⁷⁾.

Statistics

Number of specimens in each group was three. Mean dye penetration score achieved by each group were compared using one- and three-way ANOVA and Scheffe's test at a 95% confidence interval except for the SE/PLF group, which demonstrated no dye penetration. The three evaluation factors were post space preparation, resin coating, and temporization.

RESULTS

Results of the dye penetration test are summarized in Table 2 and Fig. 2. Statistical analysis of the results is summarized in Table 3. Three-way ANOVA revealed that coronal leakage was influenced by resin coating ($F=161.311$; $p<0.0001$), post space preparation ($F=10.257$; $p<0.006$), and temporization ($F=$

Fig. 1 Schematic illustration of the specimens' preparation procedures.

Table 2 Mean dye penetration measurements (in mm)

Post space preparation	Temporization	No coating	Coating	
			RZII	SE/PLF
—	—	1.74 $\pm$ 0.50	0.28 $\pm$ 0.26	n. d.
	+	0.92 $\pm$ 0.09	0.11 $\pm$ 0.07	n. d.
+	—	2.17 $\pm$ 0.19	0.26 $\pm$ 0.26	n. d.
	+	1.78 $\pm$ 0.21	0.19 $\pm$ 0.16	n. d.

Fig. 2 Bar charts representing mean dye penetration measurements. Red lines on graph mean they do not have a significant difference.

(a)

(b)

(c)

(d)

Fig. 3 Representative stereoscope photographs of the no coating/post group (a), no coating/no post group (b), SE/PLF coating/no post group (c), and RZII coating/no post group (d).

Table 3 Results of the statistical analysis

	F-value	Significant probability
Resin coating	161.311	<0.0001
Post space preparation	10.257	0.006
Temporization	8.81	0.009
Resin coating *Post space preparation	4.548	0.049
Resin coating *Temporization	7.234	0.016
Post space preparation *Temporization	1.257	0.279

8.810; $p < 0.009$).

Only the SE/PLF group's specimens demonstrated no coronal leakage. All the RZII-coated groups exhibited coronal leakage except for one specimen. In particular, non-coated specimens showed greater dye penetration regardless of temporization and post space preparation.

Representative specimens after the dye penetration test are shown in Fig. 3. For the no coating/post space preparation group (a) and no coating/no post group (b), methylene blue was highly visible between the laterally condensed gutta-percha cones in the dentinal tubules, and between the gutta-percha and canal walls. For the SE/PLF coating group (c), no staining was observed. For the RZII coating group (d), slight dye penetration was observed along the root canal. In addition, the coating material itself was stained — thereby indicating possible dye penetration through the material.

DISCUSSION

Obtaining a hermetic seal is one of the keys to achieving a successful long-term root filling. However, a hermetic seal cannot be obtained if root canal filling materials do not bond to the dentin walls^{18,19}. Several methods have been reported to prevent coronal leakage through obturated root canals in the event that the coronal restoration becomes defective or lost. These include placement of an additional material into the canal orifice after removal of part of the gutta-percha and sealer, sealing the entire chamber floor with a restorative material, or use of a root canal filling method that provides a seal without the addition of other sealing materials²⁰. Ideally, it would be that the root canal obturation alone could prevent coronal leakage, since no extra steps would then be required.

To evaluate dye penetration, methylene blue solution was chosen as a tracer in this study. Previously, several dye solutions, such as nitric acid⁸, pelican ink^{9,20}, india ink²¹, and methylene blue dye solution^{19,22–24}, have been used for the dye penetration test. Although there is no universally accepted solution, 0.2–2.0% methylene blue solutions have been commonly used for dye penetration experiments in leakage studies^{25,26}.

In the present study, higher coronal leakage occurred in the non-coated groups. The post space preparation group demonstrated significantly higher dye penetration than the non-preparation group. It is desirable that during post space preparation, the root canal sealer/gutta-percha and root canal sealer/root dentin interfaces be stabilized without dislodgement or loss of seal. However, post space preparation stimulates a gap between the root and root canal filling material²⁷. Moreover, a post space preparation shortens the distance from the root opening to the apex, thereby increasing the risk of coronal leakage.

Temporization does not provide a sufficient marginal seal. Cavit-G was used as a temporary filling in this study. Previously, the effect of temporary filling materials on bond strength to a resin-coated surface was evaluated after removal of the temporary filling materials¹⁶. Highest bond strengths were obtained when Cavit-G was used as the temporary filling material. Cavit-G reduces mixing inconsistencies commonly encountered during chairside manipulation. However, such a hygroscopic material tends to absorb fluids, which can be demonstrated by dye penetration into the filling material²⁸. Therefore, temporary fillings can delay the progress of dye penetration but not inhibit coronal leakage.

Application of a resin coating to the coronal openings significantly reduced coronal leakage scores. Perfect sealing was demonstrated by a combination of Clearfil SE Bond and Protect Liner F. It was reported that the resin-coating technique could minimize gap formation at the interface of MOD inlay restorations using a combination of a two-step self-etching primer adhesive system and a flowable microfilled resin¹¹. Clearfil SE Bond is a two-step self-etching primer adhesive system, which has demonstrated good dentin bond performance with direct composite restorations¹⁵. An acidic monomer, MDP, in SE primer dissolves the smear layer and demineralizes the underlying dentin, thus resulting in mild surface etching²⁹. With the resin-coating technique, a suitable combination of a dentin bonding system and a low-viscosity microfilled resin can improve adhesion to dentin³⁰. Further, the additional application of a low-viscosity microfilled resin can protect and promote polymerization of the underly-

ing adhesive, hence resulting in increased bond strength³¹⁾.

In this study, the post space was 10 mm long and therefore light may not reach the lower portion of the post space. Consequently, in the RZII coating groups, the lower portion might not have been sufficiently polymerized and hence dye penetration occurred. Since the behavior of these coating materials in a clinical situation was the purpose of this study, the effect of polymerization shrinkage was also studied.

The experimental material, RZII, is a single-step resin coating material. Thickness of a single application of RZII is approximately 5-6 μ m. Therefore, the development of RZII was aimed at resin-coating crown preparations³²⁾. It was reported that the application of RZII to crown preparations significantly reduced microleakage¹³⁾. However, it has been pointed out that the bonding performance of all-in-one adhesive systems to dentin needs to be somewhat improved³³⁾. It was reported that an all-in-one adhesive system acted as a semi-permeable membrane, which could be permeable to water³⁴⁾. Therefore, RZII might have allowed methylene blue dye solution to penetrate through the RZII adhesive, thereby resulting in an increase in the dye penetration score.

Differences in regional bond strength could be attributed to the type of bonding system used, whereby photocure adhesive systems seemed to be effective on root canal dentin³⁵⁾. However, irradiation time influences adhesion to root canal dentin when using photocure adhesive resins, because light irradiation from the orifice of the post cavity to the apical region is limited. Light irradiation for Clearfil SE Bond and RZII was performed according to the manufacturers' recommendations in this study. However, extending the irradiation time for the adhesives might enhance the mechanical properties of the adhesive resins, resulting in better sealing and a reduction in coronal leakage at the apical region.

Ray & Trope investigated the relationship between the quality of coronal restoration and that of root canal obturation on the radiographic periapical status of endodontically treated teeth³⁶⁾. Their results demonstrated that coronal restoration quality was statistically correlated to the presence of periradicular inflammation more than the quality of endodontic treatment. Therefore, the sealing ability of coronal restorations significantly affects the prognosis of endodontic treatment. The current study demonstrated that the resin-coating technique inhibited coronal leakage in endodontically treated teeth.

Until recently, non-vital teeth were usually treated with a crown, core, and/or dowel often leading to the sacrifice of sound tooth structure³⁷⁾. A post space is prepared to gain mechanical retention of the core, meaning further removal of sound tooth substance. In the case of a post and core system, a

greater degree of stress may be concentrated in the root^{38,39)}. These factors may adversely affect the longevity of a non-adhesively restored tooth. If good retention can be obtained using a dentin bonding system, a post may not be necessary, therefore preserving sound tooth structure. From a clinical standpoint, the resin-coating technique has strong possibilities for minimizing coronal leakage and removal of sound tooth structure, resulting in the achievement of minimally invasive restorations for non-vital teeth.

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