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ORIGINAL ARTICLE

Immediate endodontic access cavity sealing: fundamentals of a new restorative technique

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Abstract Endodontic access cavity sealing is conventionally performed after endodontic irrigation, referred to as delayed endodontic sealing (DES). Evidence shows that endodontic irrigation with NaOCl decreases dentinal bond quality and could cause coronal leakage. Access cavity sealing before endodontic irrigation is a new restorative approach, referred to as immediate endodontic sealing (IES). The primary aim of this in vitro study was to investigate whether IES improved internal adaptation. The secondary aim was to investigate the influence of the viscosity of the composite used to seal the dentine, on the internal adaptation in both IES and DES groups. Third molars ($n = 40$) with fully developed apices were used. The teeth were prepared into standard Class II MO cavities, and divided in 4 groups according to the approach, and composite viscosity was used for sealing. Group 1: IES + low viscosity composite; group 2: IES + high viscosity composite; group 3: DES + low viscosity composite; and group 4: DES + high viscosity composite. Samples were then sectioned axially for observation using scanning electron microscopy. Outcome was evaluated by determining the internal adaptation of the samples, which was judged based on the percentage of a continuous margin at the tooth–composite interface. The results were analyzed using a two-way analysis of variance and Mann–Whitney test. IES groups exhibited significantly greater internal adaptation ($p = 0.000$) as compared with DES groups. Composite viscosity did not significantly affect internal adaptation in either IES or DES groups ($p > 0.005$).

Keywords Endodontic treatment · Endodontic irrigation · Immediate dentin sealing · Sodium hypochlorite · Coronal leakage

Introduction

A primary goal of endodontic treatment is to ensure adequate disinfection of the pulp chamber and infected root canal [1]. The choice of irrigant is crucial in achieving this goal [2]. Sodium hypochlorite (NaOCl) is currently the most widely used irrigant in endodontic practice [3]. Studies of the effect of NaOCl on dentin permeability and dentin adhesion indicate that dentinal bond quality may increase or decrease depending on the testing methodology, the composition of the adhesive, and the concentration and application time of the NaOCl [4]. It is generally agreed upon, however, that high concentrations and long exposure to NaOCl diminish dentinal bond quality due to the proteolyzing and deproteinizing effects of NaOCl, which damage the collagen layer of the dentin [5]. Endodontic irrigation with NaOCl exposes the dentin to high concentrations of NaOCl.

Although many studies have demonstrated increased microleakage and diminished bond strength as consequences of endodontic irrigation with NaOCl, NaOCl is likely to remain the primary chemical irrigant in endodontics, due mainly to its high bactericidal activity and ability to dissolve vital and necrotic tissues, and organic matter [4, 6, 7]. Although alternate irrigants have been studied, none has demonstrated a risk/benefit ratio profile as favorable as that of NaOCl [8, 9].

Rather than using an alternate irrigant [10] or a combination of irrigants [11] with less favorable properties, this study focused on reducing the negative effects of NaOCl while still benefiting from its inherent disinfecting

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properties. A modified version of the immediate dentin sealing (IDS) technique was applied within the context of endodontic treatment. IDS is a widely documented method used in indirect restoration [12, 13]. IDS technique seals freshly cut dentin, which reduces microleakage [14, 15] and dentin sensitivity [12], protects the pulp chamber complex [7], allows for a stress-free dentin bond development [16] and leads to better adaptation of the subsequent indirect restoration [17]. The new restorative technique described in this study was referred to as immediate endodontic sealing (IES), in contrast to the conventional approach, in which irrigation is performed before cavity sealing, referred to as delayed endodontic sealing (DES) [18]. High-viscosity composite is usually preferred for sealing because it presents lower polymerization shrinkage than low-viscosity composite. However, in cases of narrow and deep cavities such as endodontic access cavities, clinical application of low-viscosity composite is easier.

The aim of this in vitro study was to compare the effectiveness of sealing with IES and DES and the influence of composite viscosity on the internal adaptation at the tooth–resin composite interface (total internal adaptation). Internal adaptation was based on the percentage of continuous margin at the interface. It was hypothesized that internal adaptation would be enhanced by IES combined with a composite having high viscosity to protect against the damaging effects of NaOCl. The effectiveness of sealing with IES and DES was also evaluated at the three regions of the tooth–resin composite interface: enamel, coronal and cervical dentin regions (regional internal adaptation). The null hypothesis was that IES and DES did not show significantly different internal adaptations.

Methods and materials

Forty recently extracted human mandibular molars due to orthodontic or surgical purposes, of nearly identical size were selected for the study. Inclusion criteria, which were completely developed root apices and two or more canals (type II–III), were verified by radiographic examination. A single examiner measured mesio-distal and bucco-lingual tooth width by using an orthodontic-style Boley gauge in order to have relatively homogenous samples. The teeth selected were at least 6.0 mm wide bucco-lingually and at least 8.0 mm mesio-distally at the enamel–dentine junction. The teeth surfaces were debrided with a hand-scaling instrument, cleaned with a rubber cup and a pumice slurry, and then stored in a 0.1 % thymol solution at 4 °C for 72 h, until the initiation of the experiment. Standardized Class II mesio-occlusal cavities were prepared with proximal margin located 1.0 mm below the cement-enamel junction. All cavities were prepared with the following characteristics: 4 mm wide bucco-lingually, 4 mm deep occlusally, 2 mm proximal box width in the mesio-distal direction, and 3 mm wide at the occlusal isthmus. All walls had approximately 15° of divergence. The cavities were prepared using a diamond bur under water spray cooling (Cerinlay No. 3080.018 FG; Intensiv, Lugano, Switzerland) and finished with fine-grain burs (Cerinlay No. 3025.018 FG; Intensiv). The cavity floors (roofs of the pulp chambers) were then removed with a tungsten carbide bur (Endo Access Bur A 0164, Dentsply-Maillefer, Ballaigues, Switzerland) using a high-speed handpiece and the pulp tissue was carefully removed with a spoon excavator (N°31W, Hu-Friedy, Chicago, USA). The walls of the pulp chambers were then cleaned with a tungsten carbide bur (Endo-Z E0152, Dentsply-Maillefer). Each bur was replaced after three dental preparations.

Catheterism of canals was performed with a K-file (N°10, Dentsply-Maillefer) using a lubricant chelating gel (Glyde File Prep, Dentsply-Maillefer). Working length was measured by introduction of a K-file (N°10, Dentsply-Maillefer) until it appeared at the apex. This measurement was then adjusted at 1 mm shorter than the measured length. Glide path was confirmed by introduction of a larger K-file (N°15, Dentsply-Maillefer) until the apical constriction. A ProTaper Sx instrument (Dentsply-Maillefer) was then used to relocate the canal orifices away from the furcal concavities and uniformly enlarge the canal orifices. The Sx instrument was used only in the coronal third of the canal with a rotational speed of 300 rpm. This procedure ensured a good opening of the canal orifices and adequate access to the middle and apical canal portions. Each canal was irrigated with 5 mL of sterile saline solution for 1 min at each instrument change.

Prepared teeth were then randomly divided in 4 groups ($n = 10$): group 1: IES + low viscosity resin composite; group 2: IES + high viscosity resin composite; group 3: DES + low viscosity resin composite; group 4: DES + high viscosity resin composite.

Groups 1 and 2 The internal walls and floor of pulp chambers were cleaned for 5 s with a sterilized cotton pellet imbibed with 95 % ethanol and air-dried. Canals were then dried with 2 % standardized paper points (N°20, Dentsply-Maillefer). Then ProTaper gutta percha points (F1, Dentsply-Maillefer) were shortened 4 mm from the tip and inserted into the canals to block the canal orifices and protect them from the bonding agent. The cavity access sealing protocol was then applied, followed by the preparation and irrigation protocol and finally the obturation and provisional restoration protocol.

Groups 3 and 4 First, the preparation and irrigation protocol was applied followed by the cavity access sealing protocol. Then the internal walls and floor of the pulp chambers were cleaned for 5 s with a sterilized cotton pellet imbibed with 95 % ethanol and air-dried to remove excess of sealer (AH plus, Dentsply-Maillefer). Finally, the obturation and provisional restoration was applied.

Cavity access sealing protocol

A self-etching system (Clearfil SE Bond, Kuraray, Japan) was used to seal the entire pulp chamber (dentin and enamel). The primer and bonding agents were applied and light-cured according to the manufacturer's recommendations. The floors and the internal walls of the cavities were then covered by a layer of composite of about 0.5 mm thick. In groups 1 and 3, a low-viscosity resin composite was used (Majesty Flow, Kuraray) and in groups 2 and 4 a high-viscosity resin composite was used (Majesty Posterior, Kuraray). A Williams probe was inserted in the middle part of the composite (in parallel and perpendicular position) in order to verify and standardize the composite thickness. The composite was light-cured with a polymerization lamp equipped with a new light-tip (Bluephase 1,200 mW/cm^2, Ivoclar-Vivadent, Schaan, Liechtenstein) according to manufacturer's recommendations. In groups 1 and 2, the ProTaper gutta percha points (ProTaper, Dentsply-Maillefer) protecting the canal orifices were then removed using diamond-tipped tweezers.

Preparation and Irrigation protocol

The root canals were instrumented using nickel titanium rotary instruments according to manufacturer's recommendations (ProTaper, Dentsply-Maillefer), to an apical size of 30/100 (N°F3 ProTaper, Dentsply-Maillefer) using an EDTA-based chelator (Glyde Gel, Dentsply-Maillefer) as a lubricant. Each canal was irrigated with 5 mL of 3 % NaOCl for 1 min at each instrument change. Each canal was then irrigated with 2 mL of 17 % EDTA for 1 min followed by 2 mL of 3 % NaOCl. The canals were then dried with sterile ProTaper paper points (N°F3, Dentsply-Maillefer).

Obturation and provisional restoration protocol

Gutta percha master cones (N°F3, Dentsply-Maillefer) were coated with a sealer (AH plus, Dentsply-Maillefer) and compacted by cold lateral condensation. Excess of gutta percha was removed with a heated plugger end at the level of the cement-enamel junction. The coronal openings were then covered with a temporary filling material (Cavit G, 3M ESPE, Rüschlikon, Switzerland).

Storage and sectioning for SEM

All specimens were stored in the dark in a 0.9 % saline solution at 37 °C for 48 h to allow for the sealer to completely set. The provisional restorations were then removed using an ultrasound instrument (Piezon Master, EMS, Nyon, Switzerland) and each tooth was embedded in a phenolic ring mold with epoxy resin. Samples were then vertically sectioned through the center of the pulp chamber using a low-speed diamond saw (Isomet, Buehler Ltd, Lake Bluff, Illinois, USA) under water-cooling. A second horizontal cut was made 2 mm below the cement-enamel junction. This resulted in two sections for each specimen (mesial and distal sections). The external sides of the sections were then attached to a metal support (used for SEM analysis) with cyanoacrylate glue (Quick fix, 3M ESPE AG). The sections were then polished with aluminum oxide discs (SofLex PopOn, 3M ESPE AG) under copious water spray and cleaned with a brush and fine pumice under a stereomicroscope (12× magnification). From each section, an impression made out of silicon was performed and poured with epoxy resin. The obtained replicas were then attached to a support to be gold coated for observation at the SEM. If artifacts due to impression defects or pouring method were present on the replicas, the replicas were repeated.

The internal adaptation was measured in microns at the tooth–resin interface of both sections (mesial and distal) by computer-assisted quantitative margin analysis and under a scanning electron microscope (SEM XL20, Philips; Eindhoven, the Netherlands). It was measured at 200× magnification. The internal adaptation was expressed in terms of percentage of continuous margins (%Cm). Analysis was performed at the enamel–resin interface, at the coronal dentin–resin interface, and at the cervical dentin–resin interfaces. Measurements for all specimens were blinded.

The statistical analysis was performed using the SPSS software, version 17 (SPSS Inc., Chicago, IL).The total internal adaptation data was normally distributed and subjected to a two-way ANOVA test. The variables were the technique (IES/DES) and the material (high/low viscosity). The regional internal adaptation data was not normally distributed and therefore subjected to a Mann–Whitney test. The variable was the technique. The confidence level was set to 95 %.

Results

Total internal adaptation

Internal adaptation at the entire tooth–resin composite interface in all groups is shown in Fig. 1. The resin composite viscosity had no significant effect on the results ($p = 0.609$). On the other hand, the technique used had a significant effect: IES led to significantly better internal adaptation than DES ($p = 0.000$). The interaction between variables, i.e., technique and resin viscosity, was not significant ($p = 0.462$). These findings indicate that the

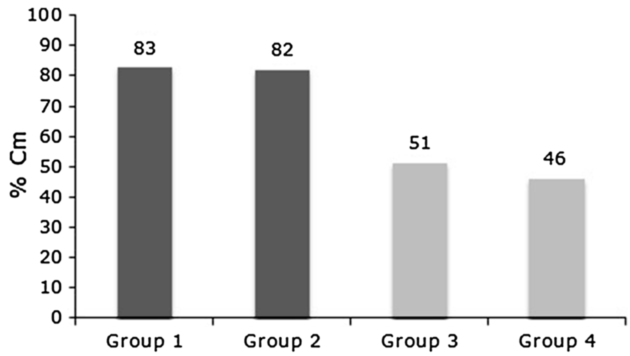

Fig. 1 Mean values of total internal adaptation: percentage of continuous margin (Cm) for immediate endodontic sealing (IES) with low-viscosity composite (group 1); high-viscosity composite (group 2); delayed endodontic sealing (DES) with low-viscosity composite (group 3); high-viscosity composite (group 4)

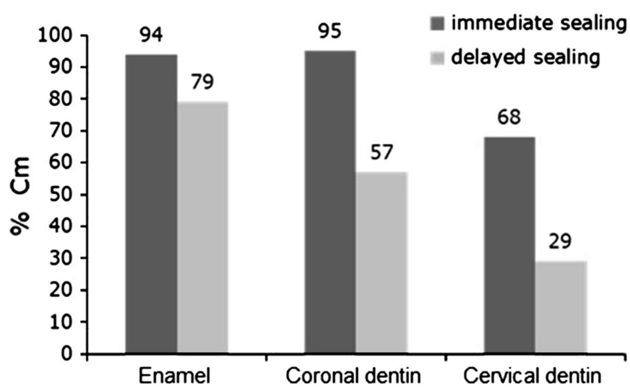

Fig. 2 Mean values of regional internal adaptation: percentage of continuous margin (Cm) measured at the enamel–resin interface, coronal dentine–resin interface and cervical dentine–resin interface for immediate endodontic sealing (IES) and delayed endodontic sealing (DES) groups

internal adaptation results were affected by the technique only.

Regional internal adaptation

Internal adaptation at the three regions of tooth–resin composite interface, i.e. enamel, coronal and cervical dentin regions, was evaluated to compare the restorative techniques (IES/DES). Significant differences were observed in every region of the tooth ($p = 0.00$, 0.00, and 0.003; Fig. 2). IES was advantageous for internal adaptation compared with DES. The lowest internal adaptation scores were observed on the cervical dentin, that is, the dentin closest to the root.

Discussion

A leading cause of endodontic treatment failure is re-infection of the root canal system by coronal leakage [19] during the provisional phase [20, 21] or after placement of the final restoration [22]. Therefore, in vitro tests are fundamental for initial evaluation and screening of the tooth-adhesive bond [23]. The effectiveness of the adhesives for bonding hard tissues can be measured using several methodologies [24]. Measuring bond strength is a commonly used method. The clinical effectiveness of the bond, however, cannot be predicted by this method [25, 26]. A major argument supporting this claim is the wide variation in bond-strength values recorded for one specific adhesive among different research groups. Moreover, because the longevity of restoration is mainly affected by the leakage of oral fluids along the tooth substrate–restorative material interface, evaluation of the capacity of an adhesive to maintain that sealed interface may be more clinically relevant [27, 28]. In the present study, internal adaptation was used as a measure of bond quality based on this rationale. Internal adaptation is assessed as the capacity of an adhesive to maintain a seal based on measurement of the degree of fit of the material to the tooth surface (continuous margin) [26]. There are other advantages in using internal adaptation as a measure of bond quality: (1) the same interfaces can be assessed multiple times because SEM analysis is non destructive, (2) internal adaptation is subject to less technical variation and is easily reproducible, and (3) internal adaptation better predicts the in vivo performance of adhesives [27].

The results indicated that IES led to a significantly better internal adaptation compared with the conventional DES approach. The null hypothesis was therefore rejected. Internal adaptation was evaluated on different parts of the hard tissue: enamel and dentin. IES led to greater internal adaptation at both the enamel–resin interface and the dentin–resin interface (Figs. 3, 4) compared with DES (Figs. 5, 6). IES had a significantly greater impact on the dentin–resin interface than on the enamel–resin interface. This is likely due to differences in structure and composition between dentin and enamel [29]. Enamel is mainly composed by minerals and has not a tubular structure like dentin [30]. The effects of NaOCl are less detrimental to inorganic compounds than they are to organic compounds. NaOCl damages the organic components of the dentin, and hinders the formation of a consistent hybrid layer [5]. Moreover, NaOCl breaks down into sodium chloride and oxygen, which can interfere with resin sealer polymerization, leading to strong inhibition at the resin/dentin interface and lower bond strength [31]. Our findings also indicated that DES led to greater internal adaptation at the coronal dentin–resin interface than at the cervical dentin interface, which might be due in part to the higher permeability of the cervical dentin to NaOCl resulting from its denser and larger tubules [32] and to the greater exposure of the cervical dentin to NaOCl in DES.

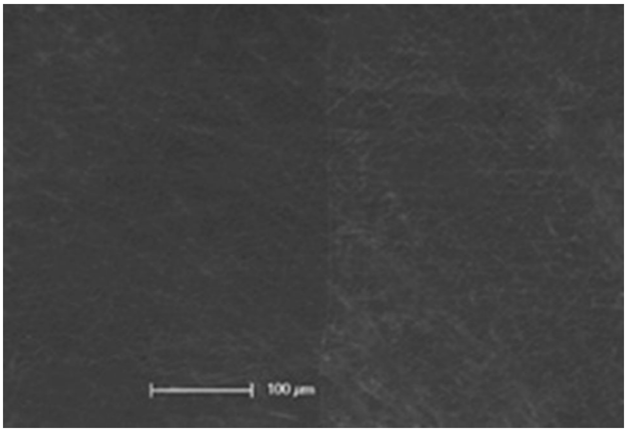

Fig. 3 Representative SEM of IES at the enamel–resin interface: SEM micrograph (200×) of immediate endodontic sealing (IES) showing a continuous margin at the enamel–resin interface

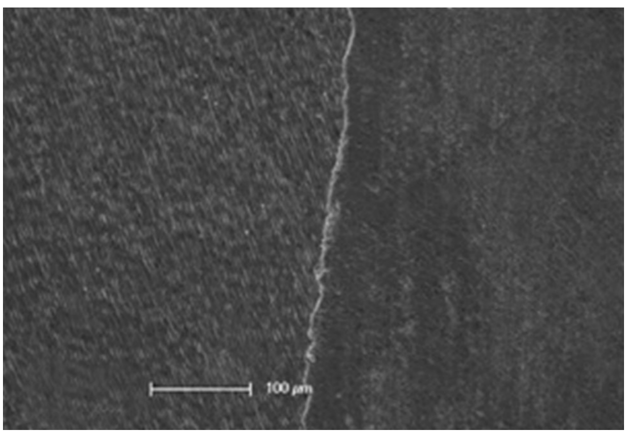

Fig. 4 Representative SEM of IES at the dentin–resin interface: SEM micrograph (200×) of immediate endodontic sealing (IES) showing a continuous margin at the dentin–resin interface

In the present study, two different resin composite types were overlaid on the adhesive to protect it from saliva, which has the capacity of degrading the adhesive [33]. This is especially true with long-term exposure of the adhesive to saliva following an extended provisional phase in a non-compliant patient [34]. Further studies are required to examine the in vivo application of IES. The type of resin used, i.e., the viscosity, did not significantly affect internal adaptation scores.

The choice of the disinfecting agent should be based on its antimicrobial efficacy rather than its "un-altering" capacity or its effect on bonding strength. The findings of the present study suggest that IES protects the dentin from the damaging effects of NaOCl irrigation. In this study, however, interfaces were not subjected to a fatigue test. Further mechanical bond quality assessment should be performed to examine the behavior of these interfaces after long-term function.

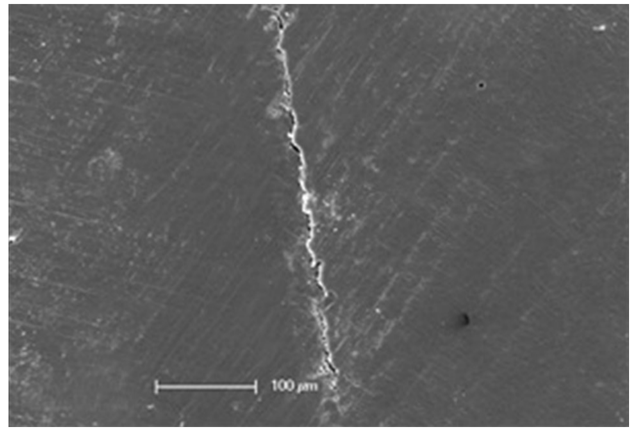

Fig. 5 Representative SEM of DES at the enamel–resin interface: SEM micrograph (200×) of delayed endodontic sealing (DES) showing internal gap at the enamel–resin interface

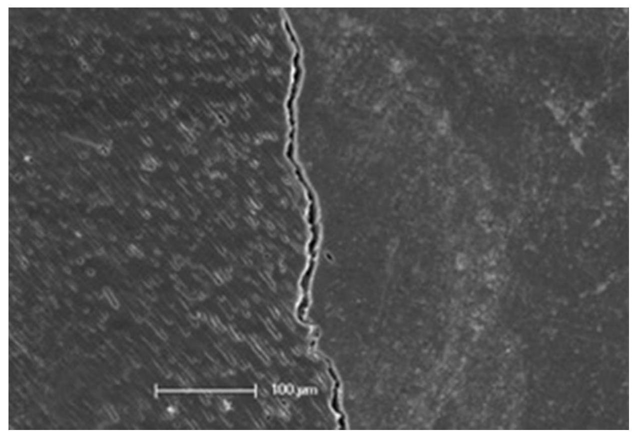

Fig. 6 Representative SEM of DES at the dentin–resin interface: SEM micrograph (200×) of delayed endodontic sealing (DES) showing internal gap at the dentin–resin interface

Conclusion

The findings of this in vitro study indicate that IES led to significantly higher internal adaptation compared with DES, likely due to the protection of the enamel and dentine against the damaging effects of NaOCl. It may be hypothesized that IES could decrease coronal leakage, which is a leading cause of endodontic treatment failure. Additional in vitro studies are warranted to support the results of this study.

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Conflict of interest The authors declare that they have no conflict of interest.

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