Morphological characteristics of the interface between resin composite and glass-ionomer cement to thin-walled roots: A microscopic investigation

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ABSTRACT: Purpose: To identify how different treatments of the root dentin surface affect the microscopic appearance of the resin composite/glass-ionomer cement-to-dentin interface. Methods: The root canals of 70 extracted human single-rooted teeth were enlarged to reduce dentin wall thicknesses to 0.5 mm. The roots were randomly divided into seven test groups (n=10) according to the canal irrigant used: no irrigant (control), 5% hydrogen peroxide, 5% sodium hypochlorite, a combination of 5% hydrogen peroxide and sodium hypochlorite, 15% ethylenediaminetetraacetic acid (EDTA), 10% lactic acid, or 20% lactic acid. To simulate thin-walled roots, within each group, crowns were sectioned and the entire surface of each root canal space was enlarged with Profile instrument. Half of treated root canals (n=5) were filled with resin composite (PermaFlo) and the other half were filled with glass-ionomer cement (Fuji II LC). A light-transmitting plastic post (Luminex) was used to create space for a fiber-reinforced post and to ensure polymerization of the restorative material. Scanning electron micrographs showed no differences in the morphology of the resin tags at the cervical, middle or apical levels with any of the irrigants or the restorative materials used. Also, no difference in surface topography was found within individual groups. A resin-dentin interdiffusion zone and resin tags developed after application of resin composite with lactic acid solutions and EDTA but not with the glass-ionomer cement. (Am J Dent 2010;23:103-107).

CLINICAL SIGNIFICANCE: The choice of irrigant acid seemed to promote formation of characteristic resin bonding features along the resin/dentin interface. Lactic acid or EDTA irrigant might best prepare intraradicular dentin for resin composite bonding systems.

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Introduction

The strength of an endodontically-treated tooth is directly related to the amount of remaining sound tooth structure. In many clinical situations the root has little remaining wall thickness due to immature development, caries of the canal wall or over-instrumentation. A thin residual root wall can seriously compromise the prognosis for long-term restorative success.

Decisions regarding the selection of materials and restorative techniques for restoring root canals with compromised wall structure are made difficult by the number of options that have been proposed. Moreover, doubts remain about bonding to root dentin. Laboratory studies evaluating the fracture resistance of root filled teeth have shown that resin composites and glass-ionomer cements reinforce remaining tooth structure by bonding to dentin. Several factors may have contributed to the discrepancies in bond strength values, such as morphological differences between coronal and apical root canal dentin, morphological variations, and polymerization contraction of the resin cement. Nevertheless, the efficacy of various agents for cleansing root canals during and after endodontic instrumentation has not been well studied.

For a restorative material to reinforce the tooth, it must bond to dentin. An essential attribute of a good bond is the ability of the restorative material to wet and infiltrate the dentin. Conditioning the tooth surface with an acid prior to bonding removes the smear layer, alters surface energy, and demineralizes the dentin, exposing a fine network of collagen fibrils. Infiltration of this network with resin permits formation of a resin-dentin interdiffusion zone with resin tags and adhesive lateral branches, thus creating micromechanical retention of the resin to the demineralized substrate. In addition, acid conditioning removes surface contaminants before material placement, possibly permitting greater ion exchange and improved bonding between the adhesive cement and the tooth structure. These solutions include proteolytic enzymes, chlorine-releasing agents, chlorhexidine, citric acid, sodium hypochlorite, sulfuric acid, tannic acid, and ethylenediamine-tetraacetic acid (EDTA).

Resin composites may offer one solution, but an alternative class of material, the glass-ionomer cements, may have some potential for fulfilling this role. Glass-ionomer cements have been described as possessing the unique properties of self-adherence to enamel and dentin, release of anticariogenic fluoride into adjacent tooth structure and a low coefficient of thermal expansion similar to dentin. Using resin bonded to dentin prior to the placement of glass-ionomer cement increases its bond strength.

Scanning electron microscopic investigations have been used to evaluate factors such as the bonding mechanism of adhesive cements and post systems which may affect post retention. The efficacy of the bonding system to develop micromechanical retention can be evaluated by observing uniformity and quality of the resin-dentin interdiffusion zone, resin tag adhesive lateral branch formation within the luting material or at the interface between it and the cavity walls and the post. However, there have been few reports on strengthening the remaining root dentin with restorative materials before placing post-retained foundation restorations. Therefore, this study evaluated resin composite and glass-ionomer cement for the replacement of lost dentin tissues in flared root canals. Scanning electron microscopy was used to...
Fig. 1. SEM photomicrograph of control (no irrigant) specimen showing no evidence of dentin tubule penetration or tag formation. A. Resin composite. B. Glass-ionomer cement. Orig. mag. x1000.

Fig. 3. SEM photomicrograph of specimen irrigated with 5% sodium hypochlorite showing no evidence of tag formation by dentin tubule penetration. A. Resin composite. B. Glass-ionomer cement. Orig. mag. x1,000.

Fig. 4. SEM photomicrograph of specimen irrigated with combination of 5% hydrogen peroxide and 5% sodium hypochlorite showing no evidence of dentin tubule penetration. A. Resin composite. B. Glass-ionomer cement. Orig. mag. x1,000.

Fig. 5. SEM photomicrograph of specimen irrigated with 15% EDTA showing complete penetration of resin composite along the widely opened dentin tubules with no evidence of dentin tubule penetration with glass-ionomer cement. A. Resin composite. B. Glass-ionomer cement. Orig. mag. x1,000.

assess variations in surface topography and to assess the physical evidence of bonding. The null hypothesis was that surface modification of root dentin with different regimens would have no influence on tag formation of flowable resin composite and glass-ionomer cement.

Materials and Methods

The study protocol was approved by the Institutional Research Board of King Abdulaziz University, Jeddah, Saudi Arabia. Seventy intact recently extracted human single-rooted teeth were debrided to remove remnants of periodontal ligaments. The teeth were stored in distilled water with 0.1% thymol disinfectant at room temperature and equally divided into seven test groups (n= 10) according to the irrigant used. The irrigants used were: no irrigant (control), 5% hydrogen peroxide (Pharmaplane®), 5% sodium hypochlorite (Sainsbury's bleach®), a 50-50% combination of 5% sodium hypochlorite and 5% hydrogen peroxide, 15% ethylenediaminetetraacetic acid (EDTA enlargement®), 10% lactic acid, and 20% lactic acid.

Crowns of the selected teeth were sectioned perpendicular to the long axis, 2 ± 1 mm coronal to the cemento-enamel junction with a 0.15 mm diamond wafering blade in an Isomet 1000 slow speed saw, to provide root lengths of 13 ± 1 mm. Access to the root canals was gained with diamond rotary cutting instruments. Canals were endodontically instrumented; no fixing solution was used to avoid affecting dentin walls surrounding the root canal spaces. All roots were held by hand during instrumentation, and the plane of greatest curvature was aligned parallel to the plane of file oscillation. An ISO size 15 file (K-flex®) was inserted in the root canal until the tip of the file was just visible at the root apex. The working length was determined by subtracting 1 mm from the total length of the file inside the root canal. A step-back technique was used to enlarge the canals enlarged to an ISO size 50 file (K-flex®). Again, each canal was irrigated with 3 mL of the assigned irrigating solution when there was a file size change and after filing was complete. This was accomplished using a syringe fitted with a 27-gauge needle placed passively in the coronal canal opening. The maximum depth of preparation of the needle tip/file was 1-2 mm from the apical foramen. During irrigations, roots were held vertically, apices down, to ensure apical penetration of irrigant solutions. After the last irrigation, canals were completely dried with paper points. Ketac-Endo Aplicap® root canal sealer was mixed according to manufacturer’s direction and the canals were filled using a lentulo spiral. The apical third of a size 35 master gutta percha cone was coated with the sealer, and then fully seated to the working length. The gutta-percha was then removed from each canal to a point 5 mm from the apex using a Gates-Glidden drill (Lexicon®). To simulate extensive clinical structure damage, the entire surface of each root canal space was further enlarged to reduce dentin wall thicknesses to 0.5 mm using the profile nickel titanium files to a size #40.06 taper (ProFile®). 0.5 mm thickness of dentin was chosen to represent the worse-case clinical situation. Post space lengths of 8 mm were created with residual dentin wall thickness of 0.5 ± 0.2 mm at the cemento-enamel junction. The buccal aspect of each root at points 2.5 and 5.0 mm apical to the coronal sectioned surface was measured for uniformity in thickness among the specimens. Again, each post space was rinsed with 10 mL of the corresponding irrigant for 30 seconds to remove any remaining sealer. Irrigating solutions were removed from the canal with sufficient paper points to completely dry the canal surface.
To standardize the bond to be solely through micromechanical interaction when dentin was etched prior to the application of resin composite or glass-ionomer cement, the root canal spaces were prepared by etching the surface with 32% phosphoric acid for 15 seconds applied with a plastic needle-nose application tip, until excess was seen extruding from canal space. This was followed by rinsing with water for 30 seconds and air drying. OptiBond Solo Plus bonding agent was placed in the root spaces according to manufacturer’s directions. Within each group, half of the enlarged root canal spaces (n = 5) were filled with resin composite (PermaFlo) and the other half were filled with glass-ionomer cement (Fuji II LC). A light-transmitting 1.4 mm diameter plastic post (Luminex) was used to create space for a fiber-reinforced post and to allow the use of light polymerizing restorative materials. Flowable light-polymerizing resin composite (PermaFlo) or light cured reinforced glass-ionomer cement (Fuji II LC) was injected into the canal spaces using a 21 mm needle tip (NaviTip). Then smooth light transilluminating posts (Luminex) were inserted and centered in the root spaces, and the resin was compacted around the posts. The curing light (UltraLume LED 5°) was placed to the end of the smooth light transilluminating post to polymerize the resin composite by transmitting light down the length of the post for 1 minute. Light intensity output was monitored with a curing radiometer to be at least 750 mW/cm². Next, the smooth light trans-illuminating post was removed and light was applied for another 20 seconds.

The prepared specimens were sectioned longitudinally for examination. A notch was prepared on each external root section using a long, cylindrical diamond rotary cutting instrument in a high speed handpiece, with water spray coolant to facilitate freeze fracture. Specimens were fixed in 2.5% glutaraldehyde solution for 24 hours, and then fixed in 0.1 mol/L phosphate buffered in 2.5% glutaraldehyde (pH 7.4) for an additional 24 hours. This process was essential for an accurate examination of dentin morphology without water loss or dimensional changes during preparation for scanning electron microscopy. The moist state of the dentin was maintained with the use of liquid carbon dioxide as a transitional fluid under 1,300 psi pressure (CPD-2°). The specimens were then freeze-fractured using a hammer and chisel placed at the previously prepared notches and mounted on aluminum stubs to evaluate the formation and uniformity of resin-dentin interdiffusion zone and resin tags. Specimens were sputter-coated with gold-palladium alloy (Cressington sputter coater), and observed by a single investigator with a scanning electron microscope (Philips Electron Optics BV) at three sites along the root canal walls (cervical, middle, and apical) for the formation and uniformity of resin-dentin interdiffusion zone and resin tags. The investigator was blinded to the treatment of the specimens.

**Results**

Serial SEM photomicrographs at x1,000 and x3,500 original magnifications were made of the canal walls at three sites. No difference in the microscopic appearance of resin-dentin interdiffusion zone was noticed at different locations within individual groups. SEM analysis of control specimens at x1,000 revealed no tag formation for resin composite (Fig. 1A) or glass-ionomer cement (Fig. 1B) groups. Smear layer obscured the orifices of the dentin tubules in these groups. The dentin surfaces of specimens irrigated with 5% hydrogen peroxide solution did not reveal any evidence of tag formation with resin composite (Fig. 2A) or glass-ionomer cement (Fig. 2B). SEMs of dentin surfaces treated with 5% sodium hypochlorite were also obscured with debris with no evidence of resin composite (Fig. 3A) or glass-ionomer tag formation along the dentin tubules (Fig. 3B). Root canal dentin treated with a combination of 5% sodium hypochlorite and 5% hydrogen peroxide (Fig. 4) appeared similar to those treated with the 5% sodium hypochlorite solution.

With the use of EDTA, complete tag formation for resin composite along the widely opened dentin tubules was evident (Fig. 5A). However, no evidence was observed for glass-ionomer cement (Fig. 5B). Appearance was similar for dentin surfaces treated with 10% or 20% lactic acid (Fig. 6). At higher magnification, the loose collagen fiber network represented the demineralized dentin matrix (Fig. 6C).

**Discussion**

The data supported the null hypothesis that the surface modification of root canal dentin with the different regimens evaluated appeared most conducive to the development of tag formation with flowable resin composite but not for glass-ionomer cement. The increased demand for clinically convenient treatment to restore a severely weakened endodontically treated tooth with a flared root canal has provided clinicians with a plethora of post and core based restorative options. However, abundant choices can present an understandably difficult situation for clinicians trying to select the best materials and techniques for an optimal result.
Research supports the concept that acid treatment of dentin removes the smear layer and hydroxyapatite from the treated dentin, demineralizing the dentin to a certain depth, leaving behind a collagen rich network for interaction with adhesive resins. This process results in the formation of a hybrid, or resin-dentin interdiffusion zone. The diameter of tubule orifices was increased after lactic acid and EDTA treatments due to loss of peritubular dentin, so the area of intertubular dentin decreased. In the SEM observations from a previous study, the etched and deproteinized dentin exhibited this morphology. In resin composite restorations, a dentin bond is produced when the resin monomers infiltrate the dentin tubules and collagen in demineralized dentin, producing a hybrid layer. In the SEM observations of the current study, dentin treatment with an adhesive and resin composite exhibited this same morphology. Resin tags were intimately adapted to the dentin tubules but tags were not observed in glass-ionomer cement group, although the physical aspect of a glass-ionomer bond to dentin, that one would expect to see in a SEM image certifying a possible cement/dentin bond. This can be explained by the different handling characteristics, compositions and properties between resin composite and glass-ionomer. These differences may have an effect on their adhesion to root canal dentin. Another explanation is the placement of dentin adhesive prior to the application of glass-ionomer cements that result in the loss of direct contact between the glass-ionomer cement and the cavity wall. This barrier may affect the ion exchange that normally occurs between a glass-ionomer cement and tooth structure when setting.

Dentin conditioning with lactic acid and the use of resin composite appears to be an efficient method to reconstruct lost dentin tissues. This may have been achieved by the low pH (1.4) of the lactic acid. After etching, the adhesive infiltrates the exposed collagen with hydrophilic monomers, which then copolymerize with the subsequently placed adhesive resin.

Resin tag formation involves penetration of adhesive resin into the dentin tubules. The formation of resin tags and a resin-dentin interdiffusion zone is achievable with available adhesives and resin composites. However, the bond strength is unpredictable and may be influenced by morphological features of the dentin. found increased resin tags in the cervical compared to the middle and apical thirds. However, other SEM observations reported increased resin tags in the apical third of root dentin compared to middle and cervical regions. Results of the current study showed no differences between cervical, middle, and apical levels where a flared root canal prevents bonding agent accumulation in the apical third.

The results obtained from this study are introductory and comparative. A limitation was the use of microscopic investigations that did not permit collection of numeric data or statistical analysis. Moreover, tensile or shear strengths of the bonded interfaces were not evaluated. Future investigations are needed to evaluate the fracture resistance of internally reinforced roots with flared root canals. Also, study is required to investigate the physical properties of the interface between root dentin and restorative materials and to determine the optimal dentin preparation protocol for intraradicular bonding.

References