Comparative evaluation of sealing ability of glass ionomer-resin continuum as root-end filling materials: An *in vitro* study

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Abstract

Background and Objectives: Root-end filling is a prudent procedure aimed at sealing the root canal to prevent penetration of tissue fluids into the root canals. An ideal root-end filling material should produce a complete apical seal. Therefore, the aim of this study is to compare the leakage behavior of four different root-end filling materials. **Materials and Methods:** Sixty-eight maxillary central incisors were obturated with laterally condensed gutta-percha and AH plus sealer. The roots were resected at the level of 3 mm perpendicular to the long axis of the tooth. Root-end cavities were prepared with straight fissure stainless steel bur. The teeth were then divided into four experimental and two control groups, and cavities restored as per the groupings. The teeth were immersed in methylene blue for 48 h, split longitudinally, and dye penetration was measured. **Results:** A highly significant difference existed in the mean dye penetration of Group I (conventional glass ionomer) and the other groups (resin-modified glass ionomer, polyacid-modified composite, and composite resin). There was no statistically significant difference among the three groups. **Conclusions:** (1) Significant difference was found in the dye penetration values of conventional glass ionomer cement and other groups. (2) No statistically significant difference was found in the dye penetration values of groups II, III, and IV.

Key words: *Dye leakage, glass ionomer-resin continuum, root-end filling, root-end section*

INTRODUCTION

The main aim of endodontic therapy is to seal hermetically both coronal and apical ends to prevent infection by anachoresis and, thus, prevent any communication between intraradicular space and periradicular tissue. The conventional root canal treatment requires the surgical therapy in some situations like calcified canals, iatrogenic perforations, ledge formation, or when teeth restored with post and core crowns are symptomatic after conventional root canal therapy.[1]

Root-end filling following a root-end resection is a very important procedure aimed at sealing the root canal to prevent penetration of tissue fluids into the root canals and leakage of micro-organisms and/or their toxins through apical foramen into the surrounding tissues.

This procedure consists of surgical exposure of the invaded apex, root resection, preparation of cavity at the resected root end, and insertion of root-end filling material in the prepared cavity.[2]

An ideal root-end filling material should produce a complete apical seal, and should be non-toxic, well-tolerated by the periradicular tissues, non-resorbable, dimensionally stable, easy to manipulate, and radiopaque.[3,4] In addition, it should be bacteriostatic or bacteriocidal. Selection of an efficient root-end filling material after root-end resection is major factor in surgical endodontics.

The need for a material that seals the root canal space efficiently has led to the advocation of a wide variety of dental materials for root-end filling, such as amalgam, super EBA, intermediate restorative material, gutta-percha, gold foil, cavit, etc.[1]

Ever since glass ionomer was introduced in dental practice, its applications have continued to grow. These cements reduce microleakage because of their ability to form chemical bond to the tooth structure and have been used as root-end filling materials since 1980s. *In vivo* and *in vitro* studies have shown that they are biocompatible and have good sealing ability.[5]

With the changing scenario, a new generation of hybrid restorative materials has been introduced. These materials contain essential components of (1) resin-modified glass ionomer cements and (2) polyacid-modified composite resins. Resin-modified glass ionomer has shown significantly better results than the conventional glass ionomer cements, since they are easier to handle than their conventional counterparts due to shorter setting time.[6] Polyacid-modified composites also have shown good intraosseous biocompatibility and less microleakage when used as root-end filling material.[7,8]

Therefore, the purpose of this study was to compare the leakage behavior of conventional glass ionomer cement, resin-modified glass ionomer cement, polyacid-modified composite and composite resin as the root-end filling materials.

MATERIALS AND METHODS

Sixty-eight freshly extracted maxillary central incisors were used in this study. The teeth were thoroughly hand scaled, stored in normal saline, and used within 1 month of extraction.

Materials used

- AH plus root canal sealer (Dentsply)
- Sodium hypochlorite 2.5% (Asian)
- Normal saline solution (Claris)
- Gutta-percha (Dentsply Maillefer, Ballaigues switzerland)
- Cavit G (3M ESPE)
- Fuji II (GC Corp., Japan)
- Fuji II LC (GC Corp., Japan)
- Gluma etch 20 (Heraeus Kulzer)
- Gluma comfort bond (Heraeus Kulzer)
- Charisma (Heraeus Kulzer)
- Conditioner 36 (Dentsply)
- Prime and Bond NT (Dentsply)
- Dyract (Dentsply).

Methodology [Figures 1-4]

Root canal preparation and obturation
After gaining access to the pulp chamber, the canals were instrumented using K-files. Working length was determined using a #15 file until it reached the apical foramen, and then subtracting 1 mm from that length. All the teeth were enlarged apically to size 40 K-file and then step back was done to size 70 K-file. The canals were flushed with copious amount of 2.5% sodium hypochlorite. The canals were obturated with laterally condensed gutta-percha and AH plus sealer. The access cavities were sealed with Cavit G. The teeth were stored at 37°C and 100% humidity (incubated) for 7 days. The roots were resected by sectioning the tooth at a level of 3 mm from the apex, perpendicular to the long axis of the tooth using a diamond disk. The root-end cavities were prepared with a #59 plain cut straight fissure stainless steel bur. The cavity preparations were standardized with the cutting blades of #59 bur measuring 1.5 mm in diameter and 3 mm in length. During cavity preparation, the prepared specimens were kept in moist cotton to prevent them from drying [Figure 1].

Root-end cavity restoration
The teeth were then divided into six groups (four experimental, two controls) and the root-end cavities were restored as per the following groupings [Table 1].

Group I (conventional glass ionomer group): The root-end cavities were conditioned with dentin conditioner (10% polyacrylic acid) for 10 s, rinsed with water, and dried. The glass ionomer, Fuji II, was mixed according to manufacturer's instructions. After mixing, the cement was placed and packed in the cavity using plastic filling instrument and mylar strip. Varnish was not applied on the restoration surface as it might
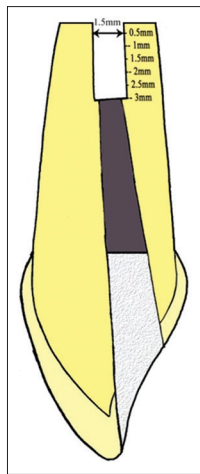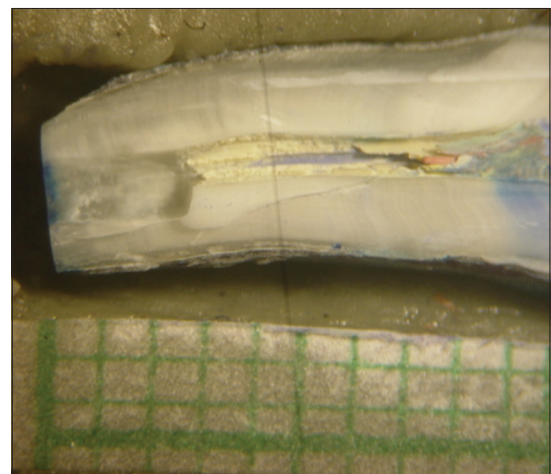
Figure 1: Diagrammatic representation of specimen with root-end cavity
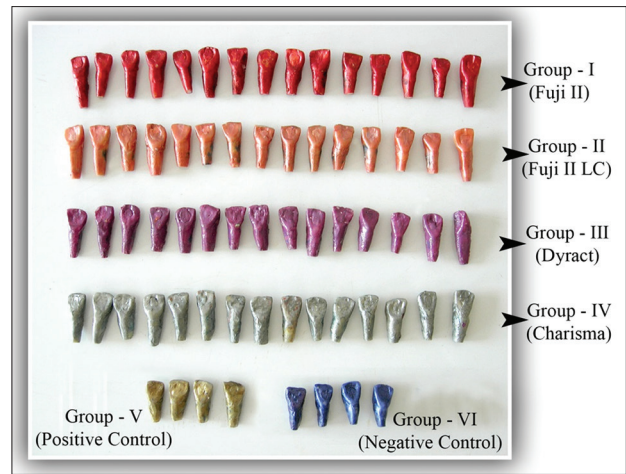
Figure 2: Prepared specimens

Figure 3: Specimen in dye

Figure 4: Specimen after longitudinal section

Table 1: Control and experimental groups

Group I	Root-end cavities filled with Fuji II (*n*=15)	Experimental
Group II	Root-end cavities filled with Fuji II LC (*n*=15)	Experimental
Group III	Root-end cavities filled with Prime and Bond NT and Dyract (*n*=15)	Experimental
Group IV	Root-end cavities filled with Gluma comfort bond and Charisma (*n*=15)	Experimental
Group V	Root-end cavities prepared and not filled (*n*=4)	Control
Group VI	Each root-end cavity filled by one of the materials and varnish applied all over (*n*=4)	Control

penetrate into any space between the restoration and the tooth surface and restrict the penetration of dye. The material was allowed to set for 15 min and excess cement was removed using number 15 B.P. blade. The restorations were allowed to set for 24 h, and were finished and polished using fine diamonds.

Group II (resin-modified glass ionomer group): The root-end cavities were conditioned with dentin conditioner (10% polyacrylic acid) for 10 s, rinsed with water and dried. The resin-modified glass ionomer, Fuji II LC, was mixed according to manufacturer's instructions. After mixing, the cement was placed and packed in the cavity using plastic filling instrument and mylar strip. The material was light-cured for 20 s and excess cement was removed using number 15 B.P. blade. Varnish was not applied on the restoration surface. The specimens were stored dry for 24 h, and restorations were finished and polished using fine diamonds.

Group III (polyacid-modified composite resin group): The root-end cavities were acid-etched with Conditioner 36 gel for 15 s, the cavity was rinsed with water for 20 s and blot dried. The bonding agent, Prime and Bond NT, was applied using an applicator brush and left to air dry for 15 s, followed by light-curing for 20 s. Dyract was placed using a dispensing gun and packed in the cavity in two increments (1.5 mm), and

was light-cured for 40 s after each increment. Any excess material was removed using number 15 B.P. blade. The fillings were finished and polished using finishing diamonds and polishing disks after 24 h.

Group IV (composite resin group): The root-end cavities were acid-etched with Gluma etch for 20 s, the cavity was rinsed with water for 20 s and blot dried. The bonding agent Gluma comfort bond was applied using an applicator brush and left to air dry for 10 s, followed by light-curing for 20 s. Charisma composite was placed and packed in the cavity in two increments (1.5 mm) and was light-cured for 40 s after each increment. Any excess material was removed using number 15 B.P. blade. The fillings were finished and polished using finishing diamonds and polishing disks after 24 h.

Group V (positive control): This group had four specimens. The root canals were obturated and the root-end cavities were prepared, but not filled with any material.

Group VI (negative control): This group had four specimens. The root canals were obturated and the root end cavities were filled with each one of the four materials; nail varnish was applied all over the surface of the specimen [Figure 2].

After restoring, the specimens were stored dry for 24 h and later, these were stored at 37°C and 100% humidity for 24 h. Then, the tooth surfaces in the experimental group were coated with two layers of nail varnish leaving the resected root ends. The teeth in negative control group were completely coated with two layers of varnish [Figure 3]. The teeth were immersed in a 2% methylene blue solution for 48 h. They were rinsed under water for 10 min and left to dry for 24 h. The teeth were then split longitudinally in a labiolingual direction. For this, two grooves were made on the labial and lingual surfaces of the specimen and then by using a sharp hand chisel, the specimens were split into two halves. The half which showed greater dye penetration was selected. Dye penetration was measured using a stereomicroscope (Leica Wild at 30× magnification) to score the extent of microleakage. The grading was done as follows [Figure 4]:
- 0. No leakage
- 1. Up to 0.5 mm
- 2. >0.5–1.0 mm
- 3. >1.0–2.0 mm
- 4. >2.0 mm.

RESULTS

The present *in vitro* study with 68 permanent maxillary central incisors aimed to evaluate the sealing ability of four different materials as root-end filling materials. The sealing ability was evaluated in terms of mean dye penetration.

Mean dye penetration values of conventional glass ionomer were higher than in the other groups (resin-modified glass ionomer, polyacid-modified composite, composite resin) [Table 2].

The increasing order of leakage among the groups was: Composite resin < resin-modified glass ionomer < polyacid-modified composite < conventional glass ionomer. No statistically significant difference was found in the dye penetration values of resin-modified glass ionomer, polyacid-modified composite, and composite resin [Figure 5].

DISCUSSION

Newer root-end filling materials, among other advances, including developments in surgical armamentarium, implementation of microsurgical techniques, and enhanced illumination and magnification, have helped to improve the outcome of periradicular surgery.[9]

In the present study, root canal filling was done using a resinous sealer, AH plus. Eugenol-based sealers usually interfere with the polymerization of resin materials. Investigators have also found that resinous sealer was

Table 2: Comparison of mean dye penetration between experimental groups

Groups	n	Mean (mm)	Std. deviation
Glass ionomer	15	2.8333	0.5233
Resin-modified glass ionomer	15	1.5400	1.1525
Polyacid-modified composite	15	1.8067	0.9794
Composite	15	1.4800	0.8930
Total	60	1.9150	1.0480
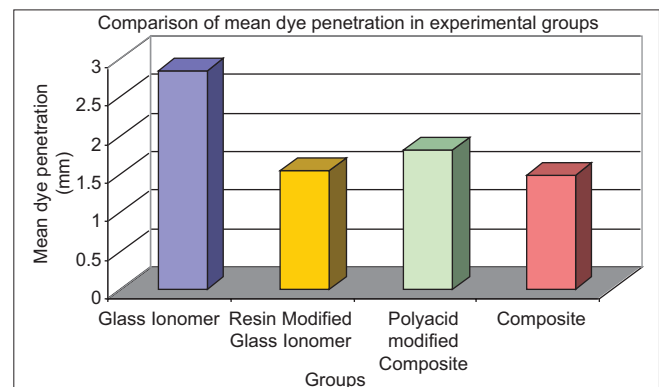
Figure 5: Comparison of mean dye penetration

significantly more effective in preventing bacterial leakage, compared with other root canal sealers. Also, there is less dye penetration with this sealer.[10,11]

Because 98% of apical canal anomalies and 93% of lateral canal system ramifications occur in the apical 3 mm, it is essential that at least 3mm of the root end is removed.[12]

The root-end resection was done perpendicular to the long axis to conserve more root structure and improve the crown/root ratio while meeting the objective of removing the vast majority of apical ramifications.[12] Because of advances in the equipments for periradicular surgeries, i.e. ultrasonic tips and microhead hand pieces, a more perpendicular root-end resection is possible and fewer dentinal tubules are exposed.[13]

The quality of apical seal obtained by root-end filling materials has been assessed by the degrees of dye, radioisotope, or bacterial penetration, electrochemical means, scanning electron microscopy, and fluid filtration technique.[13] Dye penetration technique is the most frequently used method to evaluate the sealing ability of various root-end filling materials. Usage of dyes is simpler, cheaper, safer, easier, and there is no need of special setup compared with other methods like electrochemical method.[13] Also, there are less chances to obtain false leakage other than from apex.

Many different types of dyes such as Eosin, Methylene Blue, Black India Ink, Procion Brilliant Blue and basic fushcin have been used for dye penetration studies. In the present study, methylene blue dye was used because it can serve as an adequate indicator of passage of microorganisms and large sized endotoxins as well as of toxic agents of lower molecular weight. Methylene blue has a lower molecular weight (319.9) which penetrates deeper than other dyes thus ensuring greater sensitivity.[14]

The most commonly used techniques for sectioning are horizontal slices and longitudinal sections.[12] In this study, a longitudinal splitting technique was used to assess the extent of dye penetration. When using a transverse section technique, some tooth structure (equivalent to the thickness of saw blade) is lost during each cut, which could affect the accuracy of results since the loss of tooth structure is in the same direction as the direction of measurement of the dye penetration. However, the disadvantage associated with longitudinal splitting method is that the quality of the root canal filling cannot be assessed since only one plane of root canal filling could be examined.[11]

Amalgam was at one time the most commonly used material. However, this material presents some disadvantages such as the setting expansion, cytotoxity, corrosion, and accumulation of residual mercury in some body tissues.[15] Self-cured glass ionomer cement was introduced as the root-end filling material to overcome the disadvantages of amalgam fillings. In the present study, the results showed as much as twice dye leakage values with glass ionomer cement as compared to the other root-end filling materials. This may be due to the reason that after restoration with glass ionomer, it is recommended that a layer of cavity varnish should be applied on the restoration surface to prevent any loss or gain of water which may cause any dimensional change of the restoration. In this study, no varnish was applied over the restoration surfaces because the varnish might penetrate into any gap between the restoration and the tooth surface, thus restricting the penetration of the dye. However, as varnish was not applied on glass ionomer surface, it might have caused dimensional changes in the material, leading to greater leakage seen in this group. Protracted setting time leading to deficient packing and poor adaptation to the cavity walls, along with difficult manipulation are the other disadvantages associated with conventional glass ionomer cement.[16]

Resin-modified glass ionomer cement (Fuji II LC) is usually tri-cured.[17] The adaptation and sealing ability of other resin-modified glass ionomers used with or without root-end cavity is generally favorable according to the previous studies.[18] It has been documented[19] that water absorption of resin-modified composite resin (174 $\mu g/mm^3$) is higher than that of polyacid-modified composite resin (26 $\mu g/mm^3$). This increase in water sorption of resin-modified glass ionomer would have led to slight expansion and better adaptation to the cavity walls than the conventional glass ionomer or the polyacid-modified composite resin.

Polyacid-modified composite resin (Dyract) contains the essential components of glass ionomer cement, but at levels that are insufficient to produce an acid–base reaction in the dark.[17] It undergoes a weak acid–base reaction by uptake of water. It is essentially light cured. The adhesive used along with Dyract has nanofillers which enhance the material's bonding strength and reduce its contraction when polymerized, thus showing better sealing properties than the conventional glass ionomer.

The adhesive used with Charisma composite did not have any nanofillers, but showed better results than the other groups. This may be because of the properties

of composite such as easy application, little risk of scattering through tissues, and being light-cured makes it suitable for a root-end filling material. Some authors have suggested a slightly concave preparation which will prevent any pooling of the bonding agent and, hence, enhances the sealing ability.[13] In the present study, however, conventional cylindrical cavity was prepared in order to standardize the study. Composite resins are highly technique-sensitive materials and any contamination with moisture can adversely affect the creation of apical seal. But in this *in vitro* study, experimental conditions were dry unlike the clinical situation. This might have led to a better seal and less microleakage seen in this group.

Dye leakage values clearly indicated conventional glass ionomer to be least preferable as a root-end filling material when compared with resin-modified composite, polyacid-modified composite resin, or composite resin. Although polyacid-modified composite resin (Dyract) had higher leakage value than resin-modified glass ionomer (Fuji II LC), which in turn showed greater leakage than composite resin, these values were statistically non-significant. The most important advantage of these three materials is their command set property which makes them easier to manipulate, better condensable with better adaptation with the cavity walls.[20]

CONCLUSION

None of the materials tested was able to provide a perfect seal and dye penetration was seen in all the experimental groups.Mean dye penetration values of conventional glass ionomer was higher than the other groups (resin modified glass ionomer, polyacid modified composite, composite resin). Among the groups increasing order of leakage was composite resin < resin modified glass ionomer < polyacid modified composite < conventional glass ionomer. No stastically significant difference was found in the dye penetration values of resin modified glass ionomer, polyacid modified composite and composite resin.Although light cured materials showed better results in-vitro but because of technique sensitivity of these materials in-vivo, their use as root-end filling materials is questionable.

Conflicts of interest

There are no conflicts of interest.

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