Comparative Evaluation of Three Different Materials as Barriers to Coronal Microleakage in Root Filled Teeth : An in Vitro Study

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Abstract

Thirty four freshly extracted single canal teeth were cleaned, shaped, and obturated with gutta percha and Zinc Oxide Eugenol sealer. After removing 4 mm of coronal gutta percha from thirty teeth, they were randomely divided into three groups of ten teeth each. 4mm of either Mineral Trioxide Aggregate or Glass ionomer or bonding agent and flowable composite was placed in the chamber over gutta percha. A positive control group of two teeth received no barrier. A negative control of two teeth was covered on the coronal aspect with sticky wax. Teeth were thermocycled for 500 times($5^0$and 55^0). All teeth were covered with two coats of nail varnish except the access openings. All teeth were immersed in Indian ink for 48 hours and then sectioned longitudinally and then the amount of dye penetration was measured under a stereomicroscope at 30X magnification to the nearest 0.5 mm. The mean penetration was for each group was compared using ANOVA and Multiple comparisons were carried out within the different groups. Results showed that glass ionomer group leaked significantly more than MTA and flowable composite. There was no significant difference between MTA and flowable composite. Positive control sections exhibited maximum leakage whereas negative controls had none. It was concluded from this study that the placement of intracoronal barrier potentially reduces the avenue for microleakage as compared to a barrier-less root canal. Mineral trioxide aggregate and flowable composite with dentin bonding agent when placed coronally in 4mm thickness over gutta percha, seals the canal content significantly better than glass ionomer cement. The gray or white MTA and flowable composites can be advantageous in case of retreatment or post preparation as its removal would be much easier. Mineral trioxide aggregate and flowable composite with dentin bonding agent may be preferred over glass ionomer as a coronal barrier placed immediately following root canal treatment to prevent reinfection of the canal system.

Keywords: Coronal seal, coronal leakage, dye leakage, Glass ionomer, Mineral Trioxide Aggregate, Flowable composite, Dentin bonding agents, Root canal therapy.

Introduction

The goal of endodontic therapy is the removal of necrotic debris, microbes, and their byproducts, and obturation of the canal space to prevent recontamination. Root canal treatment failures have been attributed to many causative factors. These include inadequate cleaning and shaping, over instrumentation, inadequate obturation[1], procedural errors, fractures and apical leakage.

Endodontic obturation is often thought of in terms of an effective apical seal[2]. A commonly suggested cause of failure of root canal therapy is apical percolation or microleakage due to an inadequate apical seal. This allows periapical fluids, proteins and bacteria access to the root canal. Through this interchange an inflammatory response is initiated, often resulting in radiographic and clinical, signs of failure of root canal therapy[3].

Many investigators have compared materials and techniques in an attempt to identify a means of attaining an impermeable seal at the root canal terminus. The desired results are yet to be achieved.

The question then arises that if apical microleakage is a cause of endodontic failure, what role might coronal microleakage play in the prognosis of root canal treatment. Delay in placement of permanent restoration, fracture of the coronal restoration and/or tooth, inadequate thickness of the temporary restoration, and preparation of the post space with inadequate remaining apical filling are potential means of coronal recontamination of obturated root canals[4,5].

Temporary restoration is routinely used before the placement of final restoration. cavit requires a minimum thickness of 3.5mm and has been shown to be effective against bacterial contamination for up to 3 weeks[6]. In teeth that are severely broken down, this thickness may not be possible increasing the likelihood of loss of temporary seal. Contamination of the entire root canal system was shown to occur in unrestored teeth exposed to saliva in as little as 3 days.[3]

Khayat et al determined saliva contamination through the apical foramen can occur within 4 days in non restricted teeth.[4] Bacterial models have been used to confirm contamination of 50% of filled canals within 19 to 42 days with staphylococcus epidermidis or p. Vulgaris, respectively.

The degree to which different temporary materials are capable of maintaining a good coronal seal is questionable. It has been suggested that temporary restorations be replaced after three months.[7] Webber et al reported that the sealing ability of temporary restorations decreased over time. Leaking restoration are encountered clinically leaving the access to the canals open to the oral cavity, thus the potential exists for oral fluid and bacterial contamination of the root canal space due to dissolution of the coronal seal.

In addition recurrent caries and restoration with inadequate margins may result in coronal microleakage. The technical quality of the coronal restoration was concluded to be significantly more important than the technical quality of the endodontic treatment for periapical health based on the radiographic evaluation of more than 1000 endodontically treated and restored teeth[9].

One approach to improving the coronal seal has been to place an additional layer of restorative material or a double seal directly over the orifices of the root canal. Double seal is achieved by removing 3-5 mm of gutta percha from the canal orifice and placing a additional layer of restorative material. Hommez et al found that teeth restored with a intracoronal barrier had significantly less failure rate than teeth without a barrier[9]. When used in addition to an endodontic temporary an intracoronal barrier provides a supplemental layer to protect the obturated canal.

Studies have found that, using a coronal barrier of Cavit, super EBA or IRM, decreased leakage significantly as compared to using a barrier of gutta percha and sealer only but do not completely prevent microleakage in long term studies[10].

An ideal intracoronal barrier should have the following charecterstics as proposed by Wolcott et al. They should (a)be easily placed (b) bonds to tooth structure (c)seal against microleakage (d) be distinguishable from tooth structure (e) not interfere with the final restoration[11].

A variety of permanent restorative materials have been used in a attempt to produce a coronal barrier with varying results and lack of agreement between the studies.

Many restorative materials however are tooth colored, increasing the possibility of perforation during restoration or re entry into the canals. Non tooth colored barriers may decrease the risk of iatrogenic mishaps. Fuji VII is a glass ionomer cement which is pink in colour and clearly distinguishable from the adjacent dentin. Triage, which is similar to Fuji VII was judged to be the most visible through the access preparation[11].

Mineral trioxide aggregate (MTA) has been developed by the Loma Linda University to seal communication between the root canal and the external surfaces. The sealing ability of MTA has been shown in bacterial and dye leakage studies to be superior to that of amalgam and to be equal to or superior than super-EBA. Cytotoxicity of MTA was investigated and was found to be less than super EBA and IRM[12].

Most recently, the use of dentin bonding agents has been advocated to help provide a better intracoronal seal. A 2 to 3 mm barrier of flowable composite used with dentin bonding agents was shown to provide a significantly better seal than IRM. This transparent material allowed visualization of gutta percha after placement, facilitating re-entry into the tooth[13, 14, and 15].

However there are not many studies which have evaluated the effectiveness of these materials (i.e. MTA, glass ionomer and flowable composites) as intracoronal barrier material over gutta percha.

So the purpose of the present in-vitro study is to compare the microleakage of three restorative materials when placed over canal orifices as an additional intracoronal barrier.

Methodology

The present in-vitro study was carried out in the Department of Conservative Dentistry and Endodontics, M.S.Ramaiah Dental College and Hospital, Bangalore.

Thirty four freshly extracted human permanent single canal teeth stored in normal saline were used for the study. All teeth were assessed radiographically and teeth with more than one canal, teeth with evidence of fractures, caries and teeth having root length shorter than 15 mm were excluded from the study. All the teeth were ultrasonically cleaned to remove calculus and surface debris. They were stored in saline at room temperature.

All teeth were decoronated with a straight fissure bur to a standardized length of 15 mm. pulp tissue was removed using barbed broaches. working length was determined visually placing #15 file at the apex and subtracting 1mm. gates glidden burs #2,3,4 were used for coronal preparation of the samples. canals were cleaned and shaped using k-files to a master apical file size of #40 in a step back preparation and irrigated with sodium hypochlorite(2.5%).final irrigation was done with EDTA(17%) followed by sodium hypoclorite. canals were dried using absorbent paper points and patency was reconfirmed using #15 file.

Teeth were obturated with gutta percha and zinc oxide sealer using lateral condensation. In thirty teeth excess gutta percha was removed using a heated pugger and coronal gutta percha was vertically condensed leaving 4 mm of canal space. The level of gutta percha reduction was verified radiographically. Teeth were placed into a humidor at 37^0 C for one week to allow the sealer to set.

Teeth were randomly distributed into the following groups:-

Group I- Fuji VII glass ionomer, 10 teeth. Glass ionomer was mixed according to manufacturer's instructions. 4 mm of the material was placed into the canal using a small plastic instrument and then condensed using endodontic pluggers.

Group II- Mineral trioxide aggregate, 10 teeth. mineral trioxide aggregate was mixed according to the manufacturer's instructions. 4 mm of material was placed in the canal using a spoon excavator and a small plastic instrument, and then condensed using endodontic pluggers.

Group III- Flowable composite, 10 teeth. Bonding agent was applied using a microbrush. It was then cured for 20 seconds using a light curing unit. Flowable composite is syringed into the 4 mm space in 2 increments cured to a depth of 2mm at a time.

Group IV - Positive control, 2 teeth. Here no material was placed over the gutta percha.

Group V - Negative control, 2 teeth. The entire access opening was covered with 2 coats of nail varnish.

Evaluation of Microleakage

All teeth were thermocycled for 500 cycles between 5^0+/-2^0 and 55^0+/-2^0 C with a dwell time of 30 seconds in each bath and 10 seconds interval between the baths at ambient air. All root surfaces of both experimental groups and positive controls were covered with 2 layers of nail varnish leaving only the access openings uncovered. Teeth in the negative control group were covered completely with sticky wax.

All teeth were fixed to microslides using sticky wax and then immersed in India ink for 48 hours. All teeth were sectioned faciolingually using a diamond disk in a slow speed handpiece. The maximum amount of coronal dye penetration was measured under a stereomicroscope at 30X magnification to the nearest 0.5 mm.

Statistical Analysis

The mean penetration was for each group was compared using ANOVA and Multiple comparisons were carried out within the different groups.

Results

Table 1: Distribution of leakage scores between the groups in mm

Specimens	Group I	Group II	Group III
1	3.9	0	0
2	3.6	0	0.75
3	3.2	0	1.5
4	3.5	0.2	0.2
5	3.8	0.4	1.9
6	3	0.1	0
7	2.9	0	0
8	2.6	0	0
9	3.6	0	1.2

The mean leakage scores in the positive control group was 6.5mm and in the negative control group was 0 mm.

Table 2: Mean Dye Penetration Scores In All Groups

Group	N	Mean	Std. Deviation	Minimum	Maximum
Group 1	9	3.34	0.44	2.60	3.90
Group 2	9	0.08	0.14	0.00	0.40
Group 3	9	0.62	0.75	0.00	1.90

Table 3 : Anova

Leakage	Sum of Squares	DF	Mean Squares	F	Signi-ficance
Between Groups	55.207	2	27.603	106.890	.000
Within Groups	6.198	24	0.258		
Total	61.405	26			

Fig 1: Frequency of Microleakage Scores in Different Groups

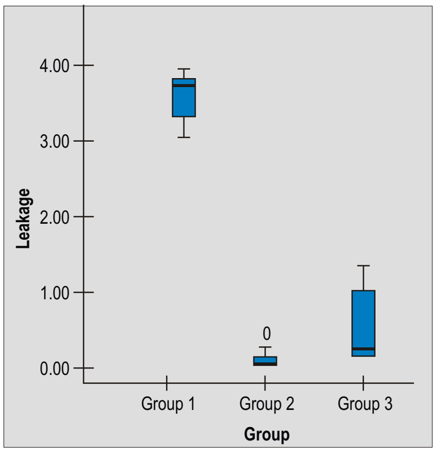
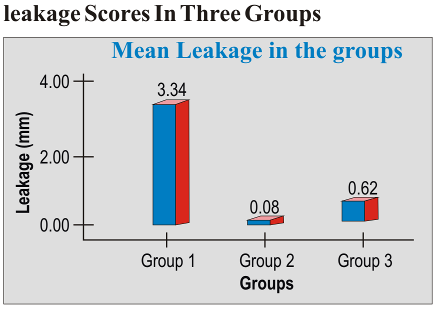


Table 4: Multiple Comparisons between the Three Groups

Multiple Comparisons Dependent Variable : Leakage Tukey HSD						
(I) Group	(J) Group	Mean Difference (I-J)	STD. Error	Sig.	95% Confidence	
					Lower Bound	Upper Bound
Group 1	Group 2 Group 3	3.26667* 2.72778*	.23956 .23956	.000 .000	2.6684 2.1295	3.8649 3.3260
Group 2	Group 1 Group 3	-3.26667* -0.53889	.23956 .23956	.000 .083	-3.8649 -1.1371	-2.6684 .0593
Group 3	Group 1 Group 2	-2.72778* 0.53889	.23956 .23956	.000 .083	-3.3260 -0.0593	-2.1295 1.1371

* The mean difference is significant at the .05 level.

Fig 2: Comparison of Mean of Micro-leakage Scores In Three Groups



Method of Statistical Analysis

Following the microleakage and statistical analysis of the values obtained, the following observations were made:the positive control group showed complete leakage and the negative control group showed no leakage. Mean leakage value of group I (Fuji VII) was 3.34 mm, with the maximum and minimum leakage values being 3.90 mm and 2.60 mm respectively. dye penetration in the Group II (MTA) was hardly discernible with a maximum and minimum penetration of 0.40mm and 0 mm, respectively with a mean leakage value of 0.08 mm. Group III (flowable composite and dentin bonding agent) showed a mean leakage of 0.64 mm with a maximum and minimum dye penetration values of 1.90 mm and 0 mm, respectively. amongst the three groups, Group I specimens showed maximum leakage and Group II specimen showed least leakage. hence Group 1 has a higher leakage score compared to Group 2 and this difference in leakage is statistically significant (P<0.001). Group 1 also has a higher leakage score compared to Group 3 and this difference is also statistically significant (P<0.001). Whereas between Group 3 and Group 2, the difference in leakage is not statistically significant (P>0.05).

Discussion

The rationale of endodontic therapy is to primarily free the root canal of any viable bacteria and to achieve a 3 dimensional obturation of the entire root canal. It has been said that a good apical seal is imperative for a successful root canal treatment. However many endodontic treatments have failed after a successful obturation. The reason being an apical reaction caused by seepage of irritants from the oral cavity through the loss of coronal seal.

Thus root fillings have to be regarded as an additional barrier for microorganisms to overcome, and they cannot be considered as a hermetic seal. A restoration that provides a good coronal seal has been shown to be as important as a apical seal. Ray and Trope reported that the quality of coronal restoration was as important as the quality of the root canal obturation for the successful treatment of root canal.

Many materials have been suggested as a temporary restoration. These materials include Cavit, IRM, Super EBA, and TERM, to name a few. Many studies were done to determine the integrity of these materials after subjecting to mechanical and thermal stresses on a long term basis and it was concluded that Cavit, IRM, TERM, and GIC restorations demonstrated maximum microleakage. They also concluded that these materials disintegrated resulting in its rapid deterioration of the restoration surface. Thermal stress and low compressive strength also contributes to this deterioration.[20,22].

All these studies indicated that these temporary materials are only interim materials by design and therefore have a finite useful life[27]. Realizing this, several investigators studied other permanent materials as access filling materials and their ability to control microleakage. Studies showed that these access filling materials however are impractical for the endodontist to place because (i) removal of these permanent materials can be difficult; potentially increasing the risk of perforation in case of retreatment (ii) the referring dentist may desire an alternate material as part of the overall treatment plan.

To address this, Beckham et al, studied three different materials which could be placed in the orifice of root canals removing around 3-5 mm of gutta percha from the canal orifice. This he referred to as the intra-orifice barriers also referred as intracoronal barriers or double coronal seal over which the restoring dentist could place a final restoration.

The ideal intra orifice barrier has not yet been identified or perhaps not even developed. Wolcott et al proposed the following criteria for the intracoronal barrier; (a) easily placed by the specialist, (b) bonds to tooth structure (retentiveness), (c) effectively seals against microleakage, (d) easily distinguishable from natural tooth structure and (e) does not interfere with the final restoration of the access preparation.[11]

Flowable composite with dentin bonding agents were used in this study. Dentin bonding agents are widely used in restorative dentistry to improve bond of materials to teeth and to prevent microleakage under restorations. In endodontics these agents have been evaluated in root canal obturations, for perforation repairs and as root end barriers. The sealing ability of dentin bonding agents was demonstrated by Barthet etal[30], White et al[25] who said that dentin bonding agents and resin displayed a total sealing of the coronal aspect and they concluded that dentin bonding agents have the potential to enhance the seal by reducing coronal microleakage.

Filled composites are more difficult to remove if retreatment of the root canal is required because they are harder and stiffer than unfilled resins. Hence we used flowable composite which is more transparent than filled resins in an attempt to permit visualization of the gutta percha in the underlying canal.

Conflicting results exist concerning the effect of eugenol of a root canal sealer on the sealing ability of dentin bonding agents. Studies done to this effect concluded that the use of a eugenol- containing sealer had no effect on the sealing ability of composites. The use of chloroform, alcohol or 37% phosphoric acid to clean the pulp chamber is deemed sufficient in neutralizing the effects of eugenol

Fuji VII was used in this study. Fuji VII is a pink colored non resin command set light curing cement. One of the criteria proposed for an ideal intra orifice barrier was visibility through the access opening. As it was felt that the pink color of this glass ionomer would enhance its visibility during removal, this material was used in our study. A study concluded that teeth with thermocycled Triage intracoronal barriers leaked significantly less than teeth with no barriers.[44]

In our study a relatively new material, MTA was examined as a intracoronal barrier. MTA or mineral trioxide aggregate was developed by the Loma Linda University in the 1990's as a root end filling material. It received acceptance by the US FDA and became commercially available as ProRoot MTA in white and grey forms. MTA consists of 50-75% (Wt) calcium oxide and 15-25% silicon dioxide. When these raw materials are blended they produce tricalcium silicate, dicalcium silicate, tricalcium aluminate and tetracalcium aluminoferrite. On addition of water the cement hydrates to form silicate hydrate gel.[42] Two forms of MTA are available on the market, gray and white MTA. The difference between them has been reported to be in the concentrations of aluminium, magnesium and iron compounds.

The results of this study showed that MTA and flowable composite with dentin bonding agent had a mean leakage value of 0.08 mm and 0.64 mm respectively. Fuji VII had a mean leakage value of 3.34 mm. Hence it was concluded from the present study that Group I (Fuji VII) had a higher leakage score compared to Group 2 (MTA) and this difference in leakage is statistically significant ($P<0.001$). Group 1(Fuji VII) also has a higher leakage score compared to Group 3 (Flowable composite with DBA) and this difference is also statistically significant ($P<0.001$). Even though the leakage is higher in Group 3(Flowable composite with DBA) compared to Group 2 (MTA), the difference in leakage is not statistically significant ($P>0.05$).

This study showed that MTA was better than glass ionomer and flowable composite. The biological response to MTA has been likened to that of calcium hydroxide and it was postulated that the mechanism of action were similar. It has been postulated that MTA released calcium ions and promoted an alkaline pH.[29,45]

The physiochemical basis for the biological properties of MTA has been attributed to the production of hydroxyapatite when the calcium ions released by the MTA comes in contact with the tissue fluid. [33] MTA absorbs water during hydration of the powder. Therefore the material expands during solidifying which must have played a role in its superior adaptation to dentin.[41]

A recent study by Dauodi and Saunders, comparing MTA and resin modified glass ionomer in repairing furcal perforations, found that MTA leaked significantly less than glass ionomer.[32] Barrieshi-Nusair and Hammad in their study tried to determine the effectiveness of mineral trioxide aggregate and glass ionomer when placed coronally as double-sealing materials over gutta percha showed that the glass ionomer group leaked significantly more than the mineral trioxide aggregate group. [4]

The only disadvantage associated with MTA is the long setting time and moisture required to enhance setting which prevents immediate placement of acoronal restoration immediately after placement of MTA.[38]

In our study flowable composite with dentin bonding agent showed better results. Resin composite restorative materials and adhesive systems are sensitive to thermocycling as thermal fluctuations increases the potential for leakage around dental restorations because of the difference in co-efficient of thermal expansion between the tooth and the material being tested. Contrary to these results, flowable composites with dentin bonding agents showed better results than Fuji VII in our study. This might be attributed to the acid etching procedure which might significantly contribute to the improvement of the sealing ability of composites.[19,30]

Fuji VII showed maximum leakage under these testing conditions The disappointing results showed by glass ionomer is due to the shrinkage of the material that occurred after upon setting resulting in a potential avenue for microleakage. The dentin was etched with polyacrylic acid before the application of glass ionomer cement but its application showed no improvement in the seal and also did not show any increase in the bond strength between the glass ionomer cement and dentin. On the contrary a study done to evaluate the bacterial leakage with MTA and RMGIC said that both the materials were equally effective and provided a acceptable seal for up to 90 days. This they attributed to the water sorption property of RMGIC's resulting in setting expansion and consequently a better bond.[39] A study done by Maloney et al.[44]and Mavec et al[37] also showed similar results.

A 4-mm thickness of restoration was selected for this study to comply with the recommendations of Webber et al. They concluded that 3.5 mm was the minimum thickness of Cavit necessary to prevent leakage and would be relatively easy to remove if retreatment deemed necessary as well as it would not compromise the retention of the final restoration.

The ease of removal of these intraorifice filling materials for post room was also taken into consideration in selecting these intraorifice barriers for this study. An ultrasonic tip or long shanked, slow speed round bur can be used to remove the filling materials from the dentinal walls of the root canal.

Many variables such as molecular size, pH, polarity, capillary action, and relative co-efficient of thermal expansion, may influence microleakage as indicated by dyes or radioactive labeled elements[18].

A passive penetration of dye leakage model was used in our study. The technique is uncomplicated and does not require sophisticated material or equipments that might affect the teeth. Some investigators questioned the usefulness of passive dye, and suggested using vacuum pressure prior to subjecting the samples to the dye[21]. It was felt that immersion in water during the thermocycling process would negate the effect of a vacuum on entrapped air during the subsequent dye submersion Other investigators however found no difference between amount of leakage whether vacuum is applied prior to dye immersion or not.[23,24] Moreover, studies showed that teeth placed under vacuum had artifacts caused by vacuuming raising questions as to its value and also that presence of voids did not correspond to the teeth which demonstrated the greatest leakage values.[8] Magura et al evaluated the coronal leakage in obturated root canals using fresh human saliva and found that salivary leakage was slower than dye penetration.[7]

India ink was used in this study. The pH of India ink is neutral and therefore does not require buffering. India ink has been shown to consist of a range of particle sizes, some small enough to permeate dentinal tubules. It has been reported that it appears to produce leakage patterns similar to those of bacteria and it has therefore been suggested to be a clinically relevant tracer able to represent microbiota.[36]

Thermal cycling procedures seemed to affect the sealing ability of certain types of temporary endodontic materials.[35] When the effects of temperature cycling on temporary restoratives and gutta percha have been assayed by dye penetration studies, most of the materials allowed microleakage including Cavit, IRM and gutta percha.[17]

A study done by Marosky et al showed that in general the microleakage increased as the material was subjected to thermo-cycling.[16] Hence thermal cycling was incorporated into the study protocol with the range of temperature variation between 55+/-2 and 5+/-2^{0}C representing the extremes found in an oral environment.500 cycles were incorporated with a dwell time of 30 seconds in each bath and a changing time of 10 seconds to better correlate thermocycle testing with in vivo conditions hence preventing the tooth from stabilizing at the extreme temperature.

To conclude, the placement of intracoronal barrier potentially reduces the avenue for microleakage as compared to a barrier-less root canal. Mineral trioxide aggregate and flowable composite with dentin bonding agent when placed coronally in 4mm thickness over gutta percha seals the canal content significantly better than glass ionomer cement. The gray or white MTA and flowable composites can be advantageous in case of retreatment or post preparation as its removal would be much easier. Mineral trioxide aggregate and flowable composite with dentin bonding agent may be preferred over glass ionomer as a coronal barrier placed immediately following root canal treatment to prevent reinfection of the canal system. .

For over a decade, research has been presented that emphasizes the important role coronal microleakage plays in endodontics. However a standard regimen incorporating some form of coronal barrier after obturation is nonexistent. The placement of a barrier to prevent coronal microleakage may be one simple, additional step that may improve the success rate of endodontic treatment.

It should be noted that these results are based on in-vitro data. Comparison of the results from different studies is critical, since there are no accepted standards for experimental parameters. In addition, there is lack of correlation between in vitro and in vivo studies, since in vivo studies present some conditions that could hardly be reproduced in vitro. Although we tried to simulate the oral conditions, further in-vivo studies should be conducted to evaluate the clinical performance of these materials in oral cavity, and the fact that it is a short term study necessitates evaluation of the performance of these materials on a long term basis and future research.

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