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Sealing Ability of Four Root End Filling Materials: A Glucose Penetration Leakage Study

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ABSTRACT

Background: The aim of this study was to determine the sealing ability of four root end filling materials- Intermediate Restorative Material (IRM), Mineral Trioxide Aggregate, Geristore and Retroplast using a glucose leakage model.

Material and Method: 100 extracted teeth were used for this study. The teeth were divided into 6 groups – 4 experimental groups of 20 teeth each and 2 control groups of 10 teeth each. In the positive control, no root end filling was done and in the negative control, the teeth were completely coated with nail varnish. All the teeth were instrumented, their apices were resected. 3mm deep root end preparations were prepared with retrotips. The root end cavities of the experimental groups were filled with the retrograde filling materials. The materials were manipulated according to the manufacturers' instructions. Each tooth was mounted in a glucose leakage device as described by Xu and coworkers.[6] The amount of glucose was determined by a UV-VIS recording spectrophotometer at 500-nm wavelength. The results were analyzed using One way ANOVA followed by Tukey-HSD procedure and Student's paired t-test.

Results: The results showed that Mineral Trioxide Aggregate showed the least leakage compared to other three experimental groups.

Conclusion: According to the results of this study, MTA showed the least leakage at both 7th and 14th days and hence can be considered as the material of choice for root end filling.

Keywords: Glucose penetration, Intermediate Restorative Material, Retroplast, Geristore, Mineral Trioxide Aggregate.

INTRODUCTION

Preservation of natural teeth is one of the ultimate goals of modern dentistry. In the case of periradicular pathosis, potential pathogens are usually eliminated by non-surgical root canal treatment with subsequent obturation and coronal restoration. If conventional endodontic retreatment fails, endodontic surgery may become the last resort for salvaging the affected tooth[1].

One of the several treatment options in endodontic surgery is periradicular surgery, which includes three critical steps to eliminate persistent endodontic pathosis: 1) surgical debridement of pathological periradicular tissue, 2) root end

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resection (apicectomy), and 3) retrograde root canal obturation (root end filling).

Significant advances in the use of magnification and illumination in recent years have benefitted treatment protocols in apical surgery. By combining magnification using a surgical operating microscope and ultrasonic technology, apical preparation can be visualized and executed with a high level of precision and confidence that was previously unattainable[2].

It has been suggested that the ideal retrograde filling material should be nontoxic, non-carcinogenic, and biocompatible and should prevent leakage of microorganisms to the apical tissues. The materials should possess certain requirements like easy manipulation, moisture stability in the environment and radiopacity[3].

Various methods have been used to assess the sealing ability of root canal filling. Leakage is detected using methods such as dye penetration, radioisotope penetration, bacterial leakage, electrochemical technique, fluid filtration and capillary flow porometry[4].

Recently, a new model was introduced that measures the leakage of glucose molecules by Xu and coworkers[6]. The glucose leakage test allows a long term, quantitative determination of the cumulative amount of microleakage, which has been suggested to be a more sensitive test than the fluid filtration method[5].

The purpose of this study was to compare the sealing ability of four root end filling materials – Intermediate restorative material (IRM), Mineral trioxide aggregate (MTA), Resin modified Glass Ionomer cement (RMGIC) and Retrograde Composite following root end resection and preparation using a diamond coated ultrasonic retrotip under surgical operating microscope with a glucose leakage model.

MATERIALS AND METHODS

Sample Preparation

100 single rooted human teeth with mature apices were used. The roots were cleaned of attached tissues and calculus, washed, debrided with 5.25% sodium hypochlorite and were then stored in deionized water and 2% sodium azide until use. Roots were optically inspected for the presence of cracks or resorption. Radiographs were taken to determine the canal anatomy in different angles. Teeth with root fractures, root caries, evidence of periapical resorptive processes or multiple canals were excluded from the study. The specimens were fixed securely to a jig to facilitate handling and cavity preparation and the specimens were kept moist throughout.

Root Canal Preparation

Straight line access was obtained using size # 4 round diamond abrasive. Working length was determined by inserting #10 K-file in the canal until the file tip became visible at the apical foramen and then subtracting 1mm from the tooth length. The canal was then cleaned and shaped by using the step-back method and #50 K-file was chosen as the master apical file. The canals were irrigated with 5.25% NaOCl (3mL) and saline (3mL) during the instrumentation. The canals were dried with paper points and obturated with guttapercha using lateral condensation technique without a sealer. This gutta-percha was used only as a stop for placement of root end fillings. The guttapercha was later removed after retrograde filling placement to ensure that the leakage was a function of the apical filling material alone.

Root End Preparation

The apical 3mm was resected at 90^{o} to the long axis of the tooth by using a tungsten carbide fissure bur with water. A 3mm deep root end preparation was prepared under a surgical operating microscope (8X) with Satelac P14 diamond coated retrotips (3mm length, power setting at 5) in a feather like back and forth motion. A periodontal probe served as the measuring device for preparation depth. The cavities were washed with deionized water for 5sec and then dried with paper points.

Experimental Groups: The teeth were randomly divided into 6 groups – 4 experimental groups of 20 teeth each and 2 control groups of 10 teeth each. The root end cavities were filled with the retrograde filling materials. The materials were manipulated according to the manufacturers' instructions.

Group 1- Intermediate restorative material (IRM)

Group 2- Mineral trioxide aggregate (MTA)

Table 1: mean, standard deviation and test of significance of mean values between 7th and 14th day for the study groups

Group	7th Day Subgroup A Mean ± S.D	14th Day Subgroup B Mean ± S.D	p-value*
IRM Group I	1.73 ± 0.12	4.21 ± 0.36	< 0.0001 (Sig)
MTA Group II	1.66 ± 0.45	0.98 ± 0.08	< 0.001 (Sig)
GRE Group III	1.38 ± 0.27	2.58 ± 0.40	< 0.0001 (Sig)
RET Group IV	2.08 ± 0.87	3.02 ± 0.51	< 0.008 (Sig)
Positive control Group V	7.99±0.38	9.04±0.45	< 0.004 (Sig)

S.D – Standard deviation
IRM – Intermediate restorative material
MTA – Mineral trioxide aggregate
GRE – Geristore
RET - Retroplast
*Student's independent t-test was used to calculate the p-value.

Table 2: Comparison of mean values among different study groups at 7th day (Subgroup A)

Group	Mean ± S.D	p-value	Significant Groups at 5% Level #
IRM Group I A	1.73 ± 0.12	<0.0001(Sig)	RET Vs GRE. Positive Control Vs IRM, MTA, GRE, RET.
MTA Group II A	1.66 ± 0.45		
GRE Group III A	1.38 ± 0.27		
RET Group IV A	2.08 ± 0.87		
Positive Control Group V A	7.99±0.38		

Table 3: Comparison of mean values among different study groups at 14th day (Subgroup B)

Group	Mean ± S.D	p-Value	Significant Groups at 5% Level #
IRM Group I B	4.21 ± 0.36	< 0.0001 (Sig)	IRM vs MTA, GRE, RET RET vs MTA GRE vs MTA Positive Control Vs IRM, MTA, GRE, RET
MTA Group II B	0.98 ± 0.08		
GRE Group III B	2.58 ± 0.40		
RET Group IV B	3.02 ± 0.51		
Positive Control Group V B	9.04±0.45		

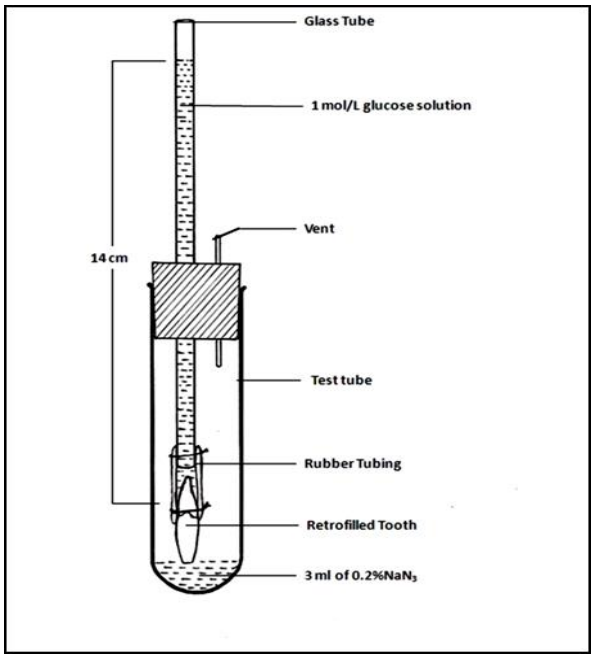

Fig 1: Diagramatic representation of Glucose leakage model.

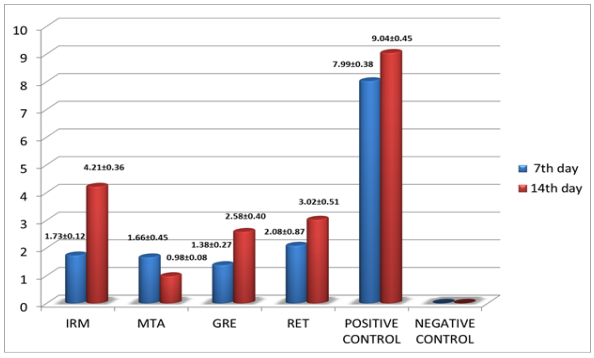

Fig 2: Mean, Standard Deviation and Test of Significance of mean values between 7th day and 14th day for different study groups.

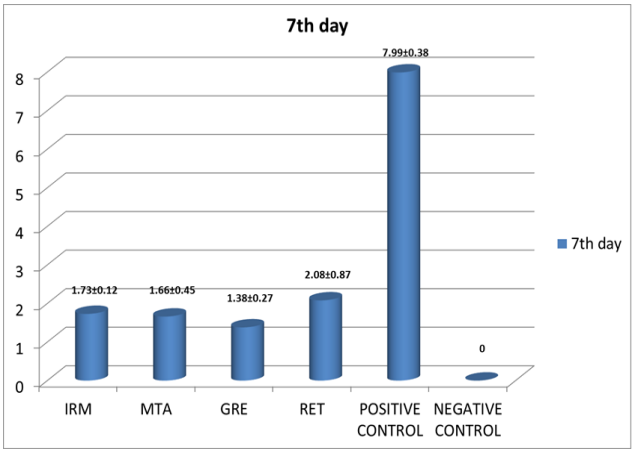

Fig 3: Comparison of Mean values among different study groups at 7th day.

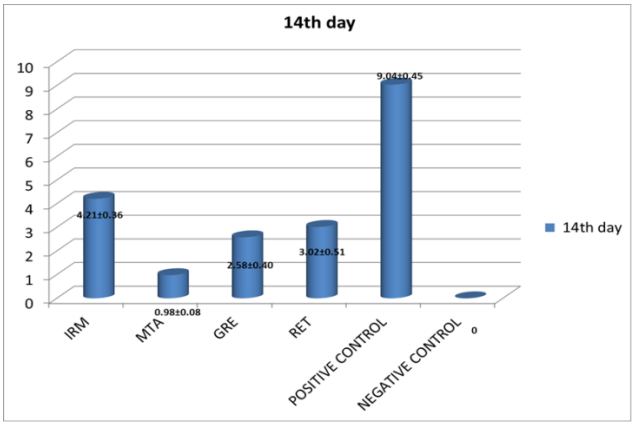

Fig 4: Comparison of Mean values among different study groups at 14th day.

Group 3- Resin modified Glass Ionomer cement (Geristore)

Group 4- Retrograde Composite (Retroplast)

Control Groups:

Group 5- Positive control. Teeth with no root end filling.

Group 6- Negative control. The teeth were completely coated with nail varnish.

All the groups were further subdivided into two subgroups, A & B based on time intervals of 7 days and 14 days.

Quantification of microleakage

Each root was mounted in a leakage device that has been described by Xu and coworkers.[6] Coronal part of the root was attached to the end of a rubber tube. A glass tube 25 cm long was connected to the cap of the rubber tube. The assembly was placed in a sterile 20mL glass test tube with a rubber stop. Leakage at all connections was eliminated by use of cyanoacrylate glue and sticky wax. Glucose solution (1mol/L, pH 7.0), containing 0.2% NaN_3, was injected into the glass tube until the top of the solution was 14 cm higher than the top of the root, which created a hydrostatic pressure of 1.5kPa. Glucose that leaked through the root end filling material was collected in the glass test tube containing 3mL of 0.2% NaN_3. The assembly was then placed in an incubator at 100% RH and 37°c throughout the observation period (Figure 1).

Leakage was quantified as the amount of glucose that reached the apical reservoir in the glass test tube after 7 and 14 days. The amount of glucose was determined by a UV- VIS recording spectrophotometer at 500- nm wavelength. The results were evaluated using One way ANOVA followed by Tukey- HSD procedure, for comparison of mean values among the different groups. Student's paired t-test was used for comparison of mean values between the two time intervals within each study group.

RESULTS

Mean and standard deviation were estimated from the samples for each study group. In the present study, $p< 0.05$ was considered as the level of significance (Table 1, 2 and 3), (Figures 2, 3 and 4).

DISCUSSION

The goal of root canal treatment is the cleaning, shaping and complete obturation of the root canal system, thus preventing the proliferation of microorganisms and their byproducts. When failure occurs, retreatment by an orthograde approach is the treatment of choice. However, when a non surgical attempt proves unsuccessful, surgical endodontic therapy is indicated to obtain an apical seal.

The apical part of the root is often curved, contains accessory canals and ramifications and is difficult to retreat and obdurate through orthograde approach. Removal of a minimum of 3mm of the root apex is necessary, as most canal aberrations and/ or abnormalities are present in this zone[7]. Thus by removing the apical part of the root, the infected root canal space may be eliminated[8]. Hence 3mm root end resection is recommended and this was followed in the study. An ideal root- end preparation is a class I preparation at least 3.0mm into root dentin with walls parallel to and coincident with the anatomic outline of the pulp space.

Due to the limited working space of the surgical window, with conventional techniques of using bulky instruments such as traditional handpieces or even a miniature contra-angle handpiece with a quarter round bur, an ideal preparation was difficult to obtain without an excessive removal of bone and tooth structure and also inadvertent perforation of the lingual walls.[9] Hence specially designed tips for ultrasonic root end preparations that have been introduced were used in this study.

The materials used in this study are some of the other alternatives to amalgam belonging to various classes of retrofilling material - Intermediate restorative material, Mineral Trioxide Aggregate (MTA), Resin modified Glass Ionomer cement (Geristore) and Retrograde Composite (Retroplast).

Apical seal can be evaluated by various methods, generally by measuring microleakage that allows the tracer agent to penetrate the filled canal. Recently, glucose has been proposed as a tracer substance for evaluating endodontic leakage

because of its small molecular size, and hence is a sensitive tracer. The glucose leakage test allows a long term, quantitative determination of the cumulative amount of microleakage, which has been suggested to be a more sensitive test than other methods.[6] Glucose as a marker has clinical relevance because it is an important nutrient for microorganisms and even at its very low concentrations, the biofilm is able to survive.[10] Hence a glucose leakage model device by Xu[4] was used to evaluate the leakage of root end fillings in this study. The glucose concentration was measured using spectrophotometer.

Spectrophotometer is an instrument, which can measure the optical density of a sample at any wavelength. Spectrophotometric method is undoubtedly the most accurate method of determining the concentration of substances in solution. It is regarded as a refined filter photoelectric photometer which permits the use of continuously variable and more nearly monochromatic bands of light.

The results of this study show that on the 7th day Group IV (Retroplast) showed the highest leakage (2.08 ±0.87) compared to the other experimental groups. Retroplast does not bond to the dentin. Hence, it is used in combination with Gluma, a dentin bonding agent. The reasons may be due to leakage of the material from the canal through dentinal tubules[11]. Another reason for the leakage may be due to poorly bonded resin composites. This is possibly due to the technique sensitivity of composite since isolation of the retro cavity is very difficult[12]. Compared to the traditional preparation which was followed in this study a slightly concave resection of the root would have minimized the formation of contraction gaps during polymerization of the resin composite[13].

On the 14th day, Group I (IRM) showed the highest leakage (4.21±0.36) than Retroplast (3.02± 0.51). The reason for the leakage in IRM can be attributed to the hydrolysis and disintegration of zinc eugenolate as the day's advance, when the cement comes in contact with moisture. In this process, eugenol continues to be released from zinc eugenolate until all zinc eugenolate is converted to zinc hydroxide[7]. The results of this study are in accordance with studies done by Hong Ming Tang[14] where he compared the sealing ability of root end filling materials using fluid filtration technique and concluded that IRM showed more leakage compared to MTA. Another study done by Siqueira[15] showed that leakage was observed in IRM and concluded that IRM does not have a good sealing ability against bacteria.

Compared to Group I (IRM) and Group IV (Retroplast), Group III (Geristore) showed less leakage on 7th (1.38±0.27) and 14th day (2.58±0.40). Geristore, a resin modification of GIC, was designed to produce favorable physical properties similar to those of resin composites and resin cements while retaining basic features of conventional GIC. Geristore undergoes an acid base reaction causing an adhesion to the dentin primarily by chemical interaction and to a lesser extent by micromechanical retention. However the reason for its significant leakage within the retrograde cavity must have been due to the polymerization shrinkage caused by the resin component leading to gap formation on one side of the wall, which has been confirmed by study done by Chong B S[16]. Bill D[17] evaluated the sealing ability of Geristore by comparing with IRM using fluid filtration model. He concluded that Geristore was superior to IRM in their ability to reduce apical leakage.

Compared to the other groups, Group II (MTA) showed the least leakage on 7th (1.66±0.45) and 14th (0.98±0.08) day respectively. The reason may be because of the expansion pattern of MTA.[18] Between the subgroups, MTA showed significantly less leakage on the 14th day (0.98±0.08) compared to the 7th day (1.66±0.45). This could be due to the fact that MTA gradually dissolves in the presence of synthetic tissue fluids (pH 7.4) in root canal and hydroxyapatite crystals nucleate and grow, filling the microscopic spaces between MTA and dentinal walls. Initially the seal is mechanical. Over time, a diffusion controlled reaction between the apatite layer and dentin leads to their chemical bonding and creates a seal at the MTA- dentin surface.[19]

According to the results of this study, it can be concluded that MTA showed the least leakage at both 7th and 14th days and hence it can be considered as the material of choice for root end filling.

CONCLUSION

Under the limitations of this current study, it is concluded that:

1) Retroplast showed the highest leakage on the 7th day and IRM showed the highest leakage on the 14th day when compared to the other experimental groups.

2) MTA showed less leakage on both 7th and 14th day when compared to the other experimental groups. Leakage on the 14th day was less compared to the leakage on 7th day.

According to the results of this study, MTA showed the least leakage at both 7th and 14th days.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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