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Original Research

Comparative Evaluation of the Sealing Ability of Various Retrofilling Materials Using Stereomicroscope: An *In Vitro* Study

H Madhu[1], Baby James[2], S Ashok[1], Saud M Orfali[3], M H N Dalati[4], Saleh Al-Klayb[5]

Contributors:
[1]Reader, Department of Conservative Dentistry and Endodontics, Amritha School of Dental Sciences, Kochi, Kerala, India; [2]Professor, Department of conservative dentistry and Endodontics, Pushpagiri College of Dental Sciences, Thiruvalla, Kerala, India; [3]Consultant Endodontist, King Saud Medical City and Associate Clinical Professor, Riyadh Dental College, Riyadh, Saudi Arabia; [4]Consultant Orthodontist and Restorative Dentist, Springs Dental Care, New Road Side, Horsforth, Leeds, LS18 4QD, UK; [5]Post Graduate Resident, Department of Pediatric Dentistry, Riyadh Colleges of Dentistry and Pharmacy, Riyadh, Saudi Arabia.

Correspondence:
Dr. Madhu H. Department of Conservative Dentistry and Endodontics, Amritha School of Dental Sciences, Kochi - 682 024, Kerala, India. Phone: +91-9995296770. Email: hariharanmadhu@gmail.com

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Abstract:

Aim: To study the sealing ability of Ketac silver, Ketac molar, Super-EBA, and intermediate restorative material (IRM) when used as retrograde filling materials using a dye penetration technique.

Materials and Methods: A total of 80 freshly extracted, single rooted, permanent maxillary central, and lateral incisors were selected for the study. The cleaning and shaping of the root canals were done and then obturated with gutta-percha using AH plus as root canal sealer. Apical root resection was performed. All the roots involved in this study were randomly divided into 4 groups (20 each) and retrofilled using Ketac silver (Group I), Ketac molar (Group II), Super-EBA (Group III), and IRM (Group IV). The roots were then sectioned buccolingually and were evaluated by a stereomicroscope for dye penetration at restorative-tooth interface to record the microleakage status of each group. The data were tabulated and statistically analyzed using analyses of variance test and *post-hoc* test of Scheffe.

Results: There was statistically significant difference in the mean dye penetration values between Group III (Super-EBA) when compared to Groups IV and I (IRM and Ketac Silver). Although Group III (Super-EBA) was better than Group II (Ketac Molar), there was no significant difference statistically between the groups.

Conclusion: Super-EBA and Ketac Molar has the superior sealing ability when compared to Ketac silver and IRM. Although Super-EBA demonstrated a better apical sealing ability compared to Ketac Molar, the difference between the materials was not statistically significant.

Key Words: Dye penetration, retrograde filling materials, sealing ability

Introduction

The objectives of modern endodontic therapy are to clean and shape the root canal system removing all organic material and sealing the root canal with a three-dimensional filling. Pulpal and periradicular pathosis develop more frequently due to bacterial contamination of the pulp and periradicular tissues. The removal of irritant factors like bacteria and adequate obturation of the root canal system after thorough cleaning and shaping results in the resolution of periradicular lesions.[1] Although the degree of success following root canal therapy has been reported to be as high as 98.7%, the majority of the failure in the case of conventional root canal therapy is due to inadequate apical seal.[2] The surgical approach is indicated when healing is not achieved after non-surgical endodontic therapy, or when re-treatment is not possible or has failed.[1] The procedure routinely consists of the exposure and resection of the involved root apex, followed by the insertion of a root-end filling material.[1,3]

The root-end filling material should improve the sealing of the existing root canal filling or provide an apical seal to an otherwise unobturated root canal, thus preventing the movement of bacteria and bacterial products from the root canal system to periapical tissues.[3,4] These retrofilling materials should be biocompatible, non-toxic, non-carcinogenic, easy to use, and should not be sensitive to moisture.[5]

Many materials have been investigated in an attempt to achieve the most effective seal when used as a retrograde root filling. These include amalgam gutta-percha and silver cones, gold foil, composite resins, cavit, zinc oxide eugenol cements, glass ionomer cement, dentin bonding agents, titanium screws and others.[6]

A novel material, mineral trioxide aggregate (MTA) was reported to seal off all of the communication between the root canal system and external surface of the tooth.[7] MTA has various advantages such as biocompatibility, excellent sealing ability, radio-opacity and the ability to set in moist environments, but it also possesses disadvantages like long setting time, difficulty in manipulating the material and high cost. This has led to researchers searching for other suitable materials.[8]

Although amalgam was the most popular retrofilling material, microleakage has been demonstrated between the amalgam and the prepared root canal.[9] Studies have concluded that zinc oxide eugenol cement is better than amalgam.[10] The original zinc oxide eugenol cements were weak, had a long setting time and high water solubility.[11] They were cytotoxic due to the presence of eugenol.[10] Because of these disadvantages, newer modifications of ZOE compounds, such as intermediate restorative material (IRM) and Super EBA were developed.

IRM is zinc oxide eugenol cement reinforced by addition of 20% polymethacrylate by weight to the powder.[12] The main virtues of this cement are its plasticity and slow setting time in the absence of moisture and good sealing potential. However, it has the disadvantage of being decomposed by water through a continuous loss of eugenol. On the other hand, eugenol in IRM formulation has affinity for polymethacrylate, which limits its release.[13]

Super-EBA is zinc oxide eugenol cement which is modified by the partial substitution of eugenol liquid with ortho-ethoxybenzoic acid and the addition of fused quartz and alumina to the powder. This modification is done to alter the setting time and increase the strength of the mixture.[10,11] Super-EBA has high compressive strength, high tensile strength, neutral pH, and low solubility compared to other zinc oxide formulations. Even in moist conditions Super-EBA adheres to tooth structure.[9] IRM must be placed in the root-end preparation in one segment because it does not self-adhere well and cannot be added in small increments. On the other hand, Super-EBA can be placed in the root-end preparation and condensed in increments because it is self-adhesive. The main disadvantage of using Super-EBA is that it is difficult to mix and it is very technique sensitive.[14]

Various investigations compared the sealing ability of Super-EBA and IRM and concluded that Super-EBA has got a better sealing ability than IRM.[15,16] Other studies, however, show that the difference is not statistically significant.[17-19]

It has been proved that Super-EBA and IRM have excellent biocompatibility.[10,20,21] Super-EBA and IRM when compared with glass ionomer cement, amalgam, and composite resin are superior with the lowest number of inflammatory cells present.[20] Super-EBA and IRM have been shown to cause repair of periapical tissues which indicate that these two materials have good biocompatibility and favorable sealing ability.[2,10,20,21] But, in a study, it was shown that IRM is more cytotoxic than Super-EBA.[2] However, no study has shown regeneration of periradicular tissues and formation of cementum over these materials when used as root end filling materials.

Glass ionomer cements have been reported to have several advantages for using as a restorative material, such as adhesiveness to tooth structure, fluoride release, and antimicrobial activity. Because of these properties, glass ionomer cements have also been recommended for use as retrofilling material. However, a major disadvantage of glass ionomer cement is the sensitivity of the material to both hydration and dehydration. Various types of glass ionomer such as conventional glass ionomer cement, metal modified glass ionomer cement, light cured glass ionomer cements, and compomers have been tried as root-end filling materials.[11]

In the late 1980's, a new restorative material was developed by combining glass ionomer cement with silver by high-temperature sintering. Strong bonding of the metal-glass composite results in the formation of cermet or ceramic metal, where the metal becomes the part of the glass powder.[22] High-temperature sintering of silver into the glass ionomer has improved its physical properties and added radiopacity to the mixture. Moreover, the setting time of silver glass ionomer cement is shorter, which makes moisture contamination less likely.[23] Though the material is considered to have less microleakage when compared to amalgam[24,25] the results are controversial.

Various investigations done concluded that conventional glass ionomer cements have a better sealing ability than IRM and metal modified glass ionomer cements.[18,26-28] However, Super-EBA is considered to be a better root-end filling material when compared to Glass ionomer cements.[18] Studies conducted by many investigators confirmed that glass ionomer cements are biocompatible to the periapical tissues when used as a retrofilling material.[28-30] Studies carried out using metal modified glass ionomer cements as a retrograde filling material confirmed that the sealing ability of metal modified glass ionomer cement was inferior to Super-EBA, IRM, and conventional glass ionomer cement.[18,27,31,32] The silver-reinforced glass ionomer cements may cause tissue irritation due to release of silver ions and their corrosion products.[33]

Mineral trioxide aggregate (MTA), which contains tricalcium silicate, tricalcium aluminate, tricalcium oxide, silicate oxide and other mineral oxides, provides superior seal when compared with amalgam, Super-EBA, when used as a root-end filling material.[7] Although various materials have been tried, Super-EBA, glass ionomer cements, silver glass ionomer cement, IRM, and MTA when used as retrofilling materials have shown better sealing efficiency when compared to amalgam, which was one of the most commonly used retrofilling material.[7,9,11,13]

Materials and Methods

A total of 80 freshly extracted human permanent maxillary central and lateral incisors were collected from the Department of Oral and Maxillofacial Surgery. All the extracted teeth were then scaled using ultrasonic scaler to remove the debris and calculus and rinsed with 5.25% Sodium hypochlorite to remove organic tissue. The cleaned teeth were stored in distilled water.

Inclusion criteria

i. Single rooted maxillary permanent central and lateral incisors
ii. Teeth with complete root formation
iii. Teeth without anatomic variations
iv. Teeth with patent canals.

Exclusion criteria

i. Teeth with open apices
ii. Teeth with calcified canals
iii. Multirooted teeth
iv. Teeth with variation in the radicular anatomy.

The clinical crowns were removed with a carbide bur using a slow-speed straight handpiece. The working length of the teeth was determined by subtracting 0.5 mm from the length at which the file appears out of the apical foramen. The cleaning and shaping of the canal were done using a conventional step-back technique under 5.25% NaOCl irrigation. The apex was enlarged until no 50 K file. The canals were obturated with gutta-percha (no 50) using lateral condensation technique using AH plus (DENTSPLY) as root canal sealer.

3 mm of the coronal portion of the gutta-percha was removed using heated instrument (hand plugger) and was filled with glass ionomer cement (FUJI IX). The following obturation, the roots were stored at room temperature and 100% humidity for 1 week. Apical root resection was performed on all roots by removing 3 mm of each root apex using #701 fissure bur and then the root surface were beveled at approximately 45-degrees to the long axis of the tooth. A single surface (Class I) cavity was prepared in each root with bur at slow-speed to a depth of 3 mm using #35 inverted cone bur, measured from the labial margin of the cavity.

All the preparations were retrofilled according to manufacturer's instructions. Then, all the roots involved in the study were randomly divided into 4 groups comprising 20 each:

Group I: This group was retrofilled with Ketac Silver (Ketac Silver Applicap 3M ESPE).
Group II: This group was retrofilled with Ketac Molar (3M ESPE) using a plastic instrument.
Group III: This group was retrofilled with Super-EBA (Super-EBA regular set, Harry J Bosworth Co, Skokie, IL).
Group IV: This group was retrofilled with IRM (Caulk, DENSTPLY).

The entire surfaces of the specimens were coated with nail varnish except the 2 mm of the apical end. All the roots were then immersed in 2% methylene blue dye solution for 72 h, after which the roots are rinsed under tap water and dried. The roots were then sectioned buccolingually using a tapered fissure bur in a slow-speed handpiece. Finally, the sectioned roots were evaluated by a stereomicroscope for dye penetration at restorative-tooth interface under ×12 magnification to record the microleakage status of each group. Statistical analysis was done based on the values obtained and used to assess the sealing ability of the four root-end filling materials used in this study.

Results

The results were tabulated and appropriately analyzed by statistical analysis techniques. Test one-way analyses of variance were applied to find out significant difference between the study groups. To find out mean value of which of the two groups is significantly different *post-hoc* test of Scheffe was used.

Comparison of two variances was estimated for two groups respectively using F test. In case, F value is not significant it indicates that there is no significant difference between the groups. In all above test *P* value < 0.05 was taken to be statistically significant. Data analysis was performed using Statistical Package for Social Science package. The results were averaged (mean + standard deviation) for each retrofilling material and were presented in tables and figures.

The apical dye penetration values in millimeters of each group of retrofilling materials (20 samples) are given in Table 1. The mean of the apical dye penetration values of each group was calculated.

In Group I (Ketac silver), the mean dye leakage value was approximately 2.09 mm (Table 2).

In Group II (Ketac Molar), the mean dye leakage value was approximately 1.89 mm. In Group III (Super-EBA), the mean dye leakage value was approximately 1.88 mm. In Group IV (IRM), the mean dye leakage value was approximately 2 mm.

Table 1: Die p enetration values.

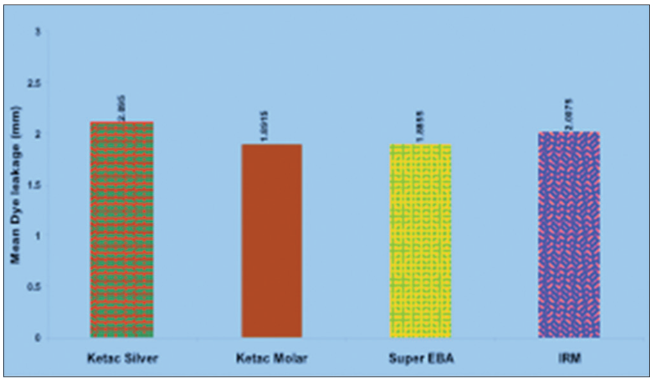
Teeth (*n*=20)	Dye leakage (mm)			
	Ketac silver (Group I)	Ketac molar (Group II)	Super-EBA (Group III)	IRM (Group IV)
1	2.12	1.85	1.95	1.95
2	2.10	1.95	1.98	1.85
3	2.20	1. 78	1.85	1.98
4	2.15	1.90	1.80	2.10
5	2.04	1.80	1.95	2.12
6	2.15	1.88	1.90	2.05
7	2.10	1.92	1.85	1.95
8	2.12	1.85	2.00	1.98
9	1.95	1.90	1.98	2.10
10	1. 98	1.84	1.80	2.08
11	2.08	2.00	1.83	2.05
12	2.10	2.04	1.87	1.98
13	2.14	1.86	1.92	1.85
14	2.22	1.94	2.00	2.10
15	2.18	1.92	1. 95	2.12
16	2.08	1.88	1.98	2.05
17	1.92	1.76	1.80	2.10
18	2.12	1.74	1.75	1.98
19	2.14	2.02	1.70	1.86
20	1.95	2.00	1.85	1.90

IRM: Intermediate restorative material

Comparing the groups with respect to the sealing ability, Group II (Ketac Molar) and Group III (Super-EBA) showed better sealing ability when compared to Group I (Ketac Silver) and Group IV (IRM). Though Group III (Super-EBA) showed a slightly better result when compared to Group II (Ketac Molar) as represented in Table 2, there was no statistically significant difference between these groups (Tables 3 and 4) (Graph 1). When Group I (Ketac Silver) and Group IV (IRM) were compared for the apical dye penetration, there was no significant difference between the leakage values of these groups (Table 4). But Group IV (IRM) showed a slightly better result compared to Group I (Ketac Silver) (Table 4 and Graph 1).

Discussion

Pulpal and periradicular pathoses develop more frequently as a consequence of the bacterial contamination of these tissues. The removal of these irritant factors and the adequate sealing



Graph 1: Comparison of mean dye leakage (mm).

Table 2: Comparison of mean values of dye leakage (mm).

Group	*n*	Mean	SD	Minimum	Maximum
Ketac silver	20	2.0935	0.0813	1.95	2.22
Ketac molar	20	1.8915	0.0852	1.74	2.04
Super-EBA	20	1.8855	0.0885	1.70	2.00
IRM	20	2.0075	0.0926	1.85	2.12

SD: Standard deviation

Table 3: Results of ANOVA test.

Group	Sum of squares	df	Mean square	*F*	Significant
Between groups	0.599	3	0.200	26.391	0.001
Within groups	0.575	76	0.0075		
Total	1.174	79	0.0075		

Table 4: *Post hoc* test scheffe result.

Comparision	*n*	Group		
		1	2	3
Super-EBA	20	1.8855		
Ketac molar	20	1.8915		
IRM	20		2.0075	
Ketac silver	20			2.0935
Significant		0.997	1.00	1.00

IRM: Intermediate restorative material

of the canal system should be achieved through its complete cleaning, shaping and obturation, resulting in the resolution of periradicular lesions. When healing is not achieved after non-surgical endodontic therapy, and when retreatment is not possible or has failed, the surgical approach is indicated. The procedure routinely consists of the exposure and resection of the involved tooth apex, the preparation of a Class I cavity and insertion of a root-end filling material.[1]

Endodontic surgery includes three critical steps to eliminate endodontic pathogens. These steps include surgical debridement of pathological periradicular tissue, root-end resection (apicoectomy) and retrograde root canal obturation (root-end filling).

Root-end resection is one of the essential components of endodontic surgery. According to a study the rationale for periradicular curettage as a terminal procedure to protect root length and to ensure the presence of cementum is highly questionable, especially if the source of periradicular irritant is still within the root canal system.[3] It has been stated that periradicular curettage without root-end resection and root-end filling should never be considered a terminal treatment in periradicular surgery unless it is associated with concurrent orthograde root canal treatment.[16] In this study, the apicoectomies were performed at a 45° linguo-buccal bevel as done by various investigators in their studies.[2,10,30] This procedure decreases the crown-root ratio and also increases the apical leakage, due to the permeability of the dentinal tubules that are more exposed by the bevel angle.[5,6] In a study, it was stated that there was a significant increase in apical leakage as the amount of bevel increased.[31] However, a beveled resected root is necessary for good visibility and accessibility when conventional burs in a handpiece are used for the Class I cavity preparation.[1]

Root-end resection can be best accomplished by the use of a No.701 or No. 702 tapered fissure bur or a No.6 or No.8 round bur in a low-speed straight Handpiece.[16] Although various types of burs have been recommended for root-end resections, there is no evidence to support an advantage of one type of bur over another with regard to tissue-healing response.[31] However, clinical practice has favored a smooth, flat, resected root surface.[16] Hence, in the present study, a No 701 tapered fissure bur was used for the root resection.

The purpose of a root-end preparation in periradicular surgery is to create a cavity apically to receive a root-end filling. Scanning electron microscopy studies have shown that the act of root-end resection disturbs the gutta-percha seal.[19] The preparation of a retrocavity and the placement of a root-end filling are therefore recommended whenever root-end resection has been performed.[16] Root-end preparations should accept root-end filling materials that predictably seal off the root canal system from the periradicular tissues. In the present study, a Class I root-end cavity preparation of depth 3 mm was prepared on the resected root apex. This was concurrent with the studies done by various investigators.[10,30]

The purpose of a root-end filling is to establish a hermetic seal between the root canal space and the periapical tissues. A suitable root-end filling material should be non-toxic, non-carcinogenic, biocompatible with the host tissues, insoluble in tissue fluids, dimensionally stable, unaffected by moisture during setting, possess good handling characteristics, radiopaque and should prevent leakage of bacteria and their by-products into the periradicular tissues.[2]

Various materials have been tested for evaluating the microleakage of retrofilling materials. These methods include dye penetration technique, radioisotope penetration technique, bacterial penetration technique, fluid filtration technique, endotoxin technique, electrochemical test, etc.[1,3,4,10,34] In this study, the most frequently used dye penetration method using 2% methylene blue is employed to assess the sealing ability of root-end filling materials.[1,7,10] Although this method has got limitations like size of dye particles which are smaller than the size of bacteria, it could provide an estimation of the sealing ability under extreme circumstances.[1]

In this study, the sealing ability of two zinc oxide based root-end filling materials (IRM and Super-EBA) and two glass ionomer based root-end filling materials were compared using dye penetration studies. As far as the sealing ability of the materials was concerned, none of the groups showed complete ability to resist apical dye leakage when used as a retrofilling material. All the materials showed apical dye penetration to an extent (Tables 1, 2 and 4, Graph 1).

Among the retrofilling materials compared in this study Group III (Super-EBA) showed minimum amount of apical dye leakage (Tables 2 and 4, Graph 1). These results are concurrent with earlier studies.[2,20,29] Group III (Super-EBA) showed better sealing ability when used as retrograde filling material compared to Group I (Ketac silver) (Tables 2 and 4, Graph 1). This was concomitant with a study in which it was confirmed that the sealing ability of metal modified glass ionomer cement was inferior to Super-EBA.[11] Many studies done by various researchers have shown that the difference in apical leakage between EBA cement and IRM when used as retrofilling material was not significant.[2,9,27,29] In this study, when comparing Group III (Super-EBA) with Group IV (IRM), it was found that Group IV (IRM) has a significantly inferior sealing ability than Group III (Super-EBA) (Tables 2 and 4, Graph 1). This result was concomitant with the findings of studies done by various investigators who concluded that Group III (Super-EBA) has got a better sealing ability than Group IV (IRM).[4,24,35,36]

Even though Group III (Super-EBA) showed lesser apical dye penetration than Group II (Ketac Molar) which is similar to a study done,[29] the difference between the sealing ability of Group III and Group II was not very significant (*P* value > 0.05) (Table 4 and Graph 1).

Group I (Ketac silver) showed maximum amount of dye penetration suggestive of inferior sealing ability compared to other groups (Table 2 and 4, Graph 1). These results were similar to the earlier studies conducted by various investigators. In their studies, they concluded that Ketac Silver demonstrated an inferior sealing ability when compared to many retrofilling materials.[2,10,28] The inferior sealing ability may be due to the release of silver ions and their corrosion products. In the present study, it was found that Group II (Ketac molar) demonstrated a significantly superior sealing ability when compared to Group I (Ketac silver) as a root-end filling material. This was in confirmation with the results of various studies in which it was shown that conventional glass ionomer cements have a significantly better sealing ability than metal modified glass ionomer cements.[23,29,35,36] When comparing Group II (Ketac Molar) with Group IV (IRM), Group II demonstrated significantly better sealing ability as a retrofilling material (Tables 2 and 4, Graph 1). This was in concurrence with the studies performed by many researchers who concluded that conventional glass ionomer cements (Group II) have a significantly superior sealing ability compared to IRM (Group IV).[23,36]

Though Group I (Ketac silver) and Group IV (IRM) showed inferior sealing ability, Group IV had a better sealing ability than Group I when used as a retrofilling material. This was shown in the results where the mean apical dye penetration value of Group IV is less than that of Group I (Tables 2 and 4, Graph 1).

However, the difference in the apical dye penetration values between Group I and Group IV was not significant (*P* value > 0.05). This was well-documented by many investigators in their studies.[27,29]

Thus, in the present study, all the retrofilling materials showed apical dye penetration. When comparing all the four groups, it was found that Group III (Super-EBA) showed least apical dye penetration followed by Group II (Ketac Molar), Group IV (IRM) and Group I (Ketac Silver) (Table 2 and Graph 1). Although Group III (Super-EBA) demonstrated lesser apical dye penetration when compared to Group II (Ketac Molar), there was no significant difference between the groups (Table 4 and Graph 1). The maximum apical dye penetration was observed in Group I (Ketac silver). However, there was no significant difference between Group I (Ketac silver) and Group IV (IRM).

Conclusion

Although all the retrofilling materials showed apical dye penetration to an extent, Super-EBA showed the least apical microleakage followed by Ketac Molar, IRM, and Ketac Silver. Although Super-EBA demonstrated lesser apical dye penetration when compared to Ketac molar, there was no significant difference between these retrofilling materials. The formation of a hermetic seal at the root apex using retrofilling materials still remains unfulfilled, and hence further research for an ideal retrofilling material is needed.

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