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Comparative Evaluation of Sealing Ability and Marginal Adaptation of Furcation Repair Materials: An *in vitro* Study

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Authors' contributions

This work was carried out in collaboration among all authors. Author SYB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors VK and SV managed the analyses of the study. Author MG managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The present study was undertaken for evaluating the sealing ability of furcation repair materials GC Fuji VII, MTA Plus and Biodentine. Diagnosis of iatrogenic perforation requires a combination of symptomatic findings in clinical observations. Perforations can be defined as mechanical or pathological communications between the root canal system and the external tooth surface. Study was conducted in the Department of Conservative Dentistry and Endodontics, Himachal Dental College, Sundernagar, Himachal Pradesh, India. Fifty five sound mandibular molars with non fused and well developed roots were used for the study. The specimens were examined using SEM which is maintained approximately 15Kv and 10-6 Torr under high vacuum condition. Specimen imaging were done by secondary electrons using a secondary electron detector. Scanning Electron Microscope (SEM) pictures, MTA plus shows the minimum marginal gap of 2.17 micrometers, followed by Biodentine 5.55 micrometers and GC FUJI VII 8.00 micrometers. The most important factors determining the success of a perforation repair procedure are the location of the perforation; time elapsed between the occurrence of the perforation and repair, the ability of the

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material to seal the perforation and the biocompatibility of the repair material. In our study, MTA Plus showed minimum leakage compared to GC FUJI VII and Biodentine. The minimum microleakage as observed in MTA Plus group might be attributed to its superior marginal sealing ability resulting from its hydrophilic properties and formations of an inter facial layer. Biodentine also provides a good seal almost similar to that of MTA Plus when used as a furcation repair material. GC Fuji VII showed significantly more leakage and gap formation than Biodentine and MTA Plus.

Keywords: Marginal adaptation; endodontics; biodentine; scanning electron microscope; conservative dentistry.

1. INTRODUCTION

Maintaining the integrity of the natural dentition is essential for full function and natural esthetics. The reason many tooth do not respond to root canal treatment is because of procedural errors that prevent the control and prevention of intra-canal endodontic infections. Perforations may be induced by iatrogenic causes, resorptive process or caries. Perforations can be defined as mechanical or pathological communications between the root canal system and the external tooth surface. Diagnosis of iatrogenic perforation requires a combination of symptomatic findings in clinical observations. Identifications of root perforations is possible through diagnostic aids that include direct observation of bleeding assessment using a paper point, two or more radiographs taken at various angles for comparison and use of apex locators [1-3].

However management of a perforation still remains a challenge in endodontics as there is no ideal means to repair a perforation defect. Ideally, an effective repair material should provide an adequate seal with less setting time, be biocompatible, non – toxic, non-carcinogenic, relatively inexpensive, bacteriostatic, easy to procure, simple to handle and possess the ability to induce osteogenesis and cementogenesis [4].

GC Fuji VII, a new generation of Glass Ionomer Cement has intended use as a furcation repair material because of its advantage of very high fluoride release, easy application due to the low viscosity and can be used when saliva control is not possible. Mineral Trioxide Aggregate (MTA) contains tricalcium silicate, tricalcium aluminate, tricalcium oxide, silicate oxide, bismuth oxide, calcium sulphate and other mineral oxides forming hydrophilic powder which sets in the presence of water or moisture. MTA Plus, which is the recent modification of MTA, has finer particle size that improves it's handling and placement characteristics. MTA Plus kit has an optional gel as the mixing vehicle to improve washout resistance [5,6]. Another material with excellent biocompatibility has been emerging in recent years is Biodentine™. Septodont developed a new technological platform called Active Biosilicate Technology™. This consists of controlling every step of the material formulation beginning with the purity of the raw materials. However, sealing of the perforation is very important and necessary because a cascade of complications may arise as sequelae to a perforation which includes chronic inflammation, damage to the periodontal attachment, proliferation of the epithelial tissue, and continuous osseous break down with eventual loss of teeth [7,8]. Hence; under the light of above mentioned data, the present study was undertaken for evaluating the sealing ability of furcation repair materials GC Fuji VII, MTA Plus and Biodentine.

2. MATERIALS AND METHODS

The present study was conducted in the Department of Conservative Dentistry and Endodontics, Himachal Dental College, Sundernagar, Himachal Pradesh. The aim of the study was to comparatively evaluate the sealing ability and marginal adaptation of furcation repair materials namely; GC Fuji VII, MTA Plus and Biodentine.

Fifty five sound mandibular molars with non fused and well developed roots were used for the study. Any tooth with severe anatomical variations, open apex, extreme curvature or crown and root fracture was excluded. The surfaces of all the fifty five mandibular molars were hand scaled to remove all adhering debris. They were then disinfected by overnight immersion in 2.5% sodium hypochlorite. These teeth were then rinsed and stored in moist atmosphere during the study period at room temperature.

2.1 Inclusion Criteria

1. Teeth with multiple root canals.
2. Teeth without visible root caries.
3. Teeth with fully formed root apex.
4. Teeth with normal anatomical roots.
5. Teeth without crown and root fractures.

2.2 Exclusion Criteria

1. Teeth with anatomical variations.
2. Teeth with open apex.
3. Teeth with extreme curvatures of roots.
4. Teeth with crown and root fractures.

The study was done using three repair materials namely GC Fuji VII, MTA Plus and Biodentine to seal the furcation perforations in the pulpal floor of the extracted mandibular molars following endodontic access cavity with proper sealing of the canal orifices with sticky wax.The samples were then covered completely including the cavity walls and pulpal floor with two successive layers of nail varnish followed by a perforation in the pulpal floor using BR-41(Ball Round Type, DIA-BURS MANI, INC.) under a water cooled, high speed, airotor handpiece. For every five preparations, a new bur was used. Following this they were grouped according to type of furcation perforation repair materials used.

Group 1 (n=10)

Ten perforation defects were repaired with GC Fuji VII (GC Corpration, Tokyo, Japan.)

Group 2: (n=10)

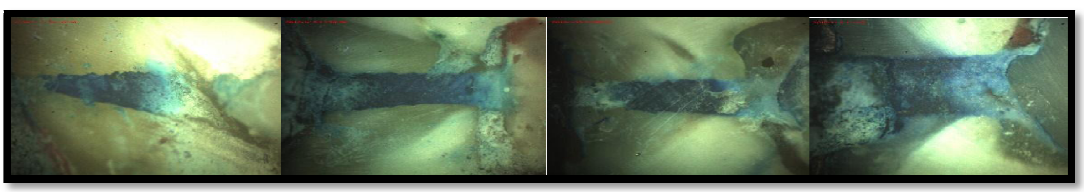
Ten perforation defects were repaired with MTA Plus. MTA Plus (PREVEST DENPRO LIMITED Unit)

Group 3: (n=10)

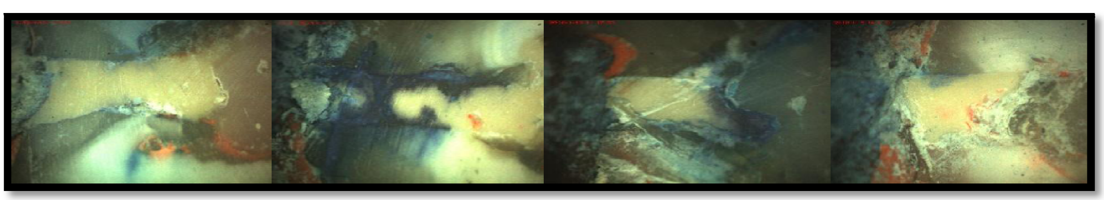
Ten perforation defects were repaired with Biodentine.

Group 4: (n=10)

Ten perforation defects were not repaired and this served as a positive control. A moist cotton was placed in between the roots at the perforation area during the repair of perforation with all three above mentioned sealants in order to simulate the oral tissues.



Microleakage of samples of GC Fuji VII (Group 1) seen under stereomicroscope



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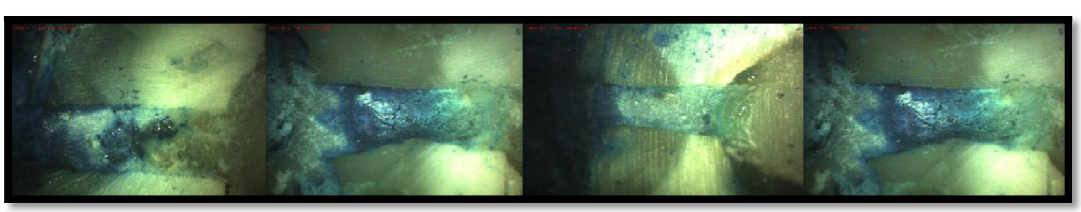
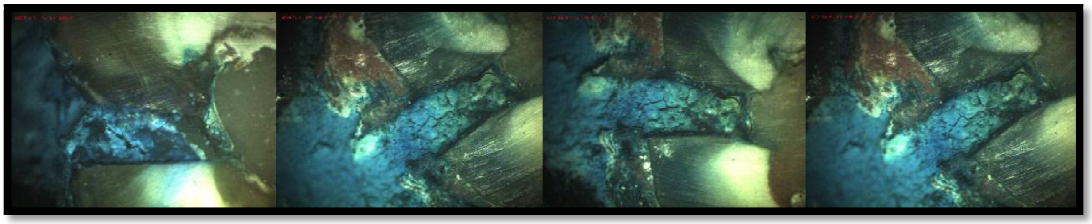
Microleakage of samples of MTA Plus (Group 2) seen under stereomicroscope



Microleakage of samples of Biodentine (Group 3) seen under stereomicroscope



Microleakage of samples of Control (Group 4) seen under Stereomicroscope

2.2.1 Dye penetration

After the restoration of perforation with three different repair materials, the pulp chamber and the access preparation of all teeth were filled with composite and all the teeth were coated with two successive applications of nail enamel except for 1-2mm around furcation area. Each layer of nail enamel was allowed to dry before the next layer was applied. The coated teeth were then immersed in 2% methylene blue dye for 48 hours at normal room temperature. Then, the sample were removed out of the dye and thoroughly washed under running water for 40 minutes to remove all residues of methylene blue dye. The teeth were cleaned with a sterile number 15 BP blade to remove any excess of nail polish and dye on the external surface of the teeth. They were air dried and sectioned under copious amount of water spray with a diamond disk (DOUBLE SIDED DIAMOND DISC 0.17, SHAPE 355, SIZE 190, GRIT 1, THICKNESS 0.17) attached to a slow speed motor handpiece in a buccolingual direction through the centre of the tooth to separate the two roots(mesial and distal) into two equal halves in order to evaluate the dye penetration at the furcation area under Stereomicroscope at 30X magnification **(**Nikon smz 1500 zoom stereomicroscope**)**. The depth of dye penetration for each sample were measured in millimetres.

2.2.2 Evaluation of marginal adaptation

For evaluation of marginal adaptation of these furcation repair materials (GC Fuji VII, MTA Plus, Biodentine); additional 15 specimens were prepared. They were divided into three subgroups depending on the type of repair material used.

GROUP 1: (n=5)

Five perforation defects were repaired with GC Fuji VII. **GC** Fuji VII. (GC Corpration, Tokyo, Japan)

GROUP 2: (n=5)

Five perforation defects were repaired with MTA Plus. MTA Plus. (PREVEST DENPRO LIMITED Unit)

GROUP 3: (n=5)

Five perforation defects were repaired with Biodentine. Biodentine (Septodont; St Maur Des Fosses, Val-de-Marne, France) was mixed according to the manufacturer's instructions.

The specimens were examined using SEM which is maintained approximately 15Kv and 10^{-6} Torr under high vacuum condition. Specimen imaging were done by secondary electrons using a secondary electron detector. The surface of each specimen were viewed and photographically recorded with a charged couple device (CCD) at 1000X magnification. After the restoration of perforation with three different repair materials, the pulp chamber and the access preparation of all teeth were filled with composite. A carborundum disc was used to cut the samples longitudinally into two halves. The sections were sputtered with gold in an ion sputtering device and these specimens were used to study the marginal adaptation of the restorative material with the dentin. The sections were placed in wet guaze at 100% humidity for 12 hours prior to SEM (SCANNING ELECTRON MICROSCOPE) viewing. The maximum and minimum gap between the repair material and the tooth structure was measured using SEM. All the results were recorded in Microsoft excel sheet and were analysed by SPSS software.

3. RESULTS

Table 2 shows that the mean value of Control group is highest followed by GC Fuji VII, Biodentine and then MTA Plus. The "P"value is 0.03 and this shows that results are statistically significant. So, in terms of microleakage:

CONTROL > GC FUJI VII > BIODENTINE > MTA PLUS

3.1 GC Fuji VII

GC Fuji VII had higher values of dye leakage as compared to MTA plus (p=.296) and Biodentine (p=.968) and less than control group (p=.635), however the results are statistically not significant.

3.2 MTA Plus

MTA Plus had lesser values of dye leakage as compared to GC Fuji VII (p=.296), Biodentine (p=.549) and Control group (p=.025), however the results are statistically significant when compared to Control group and statistically not significant when compared to GC Fuji VII and Biodentine.

3.3 Biodentine

Biodentine had higher values of dye leakage as compared to MTA Plus (p=.549) and less dye leakage when compared to GC Fuji VII (p=.968) and Control group (p=.365), however the results are statistically not significant.

3.4 Control

Control had higher values of dye leakage as compared to GC Fuji VII (p=.635), MTA Plus (p=.025) and Biodentine (p=.365); however the results are statistically significant when compared to MTA Plus and statistically not significant when compared to GC Fuji VII and

Table 1. Descriptive statistics of all of the studied groups

Group	N	Mean	Std. Deviation
GC FUJI VII	10	2.23	0.994
MTA PLUS	10	1.77	0.949
BIODENTINE	10	2.21	0.412
CONTROL	10	2.92	0.404

Table 2. Intergroup comparison of mean of all of the groups by Kruskal Wallis test

Group	N	Mean Rank	P value
GC FUJI VII	10	22.55	
MTA PLUS	10	13.55	0.03*
BIODENTINE	10	17.75	
CONTROL	10	28.15	

**statistically significant*

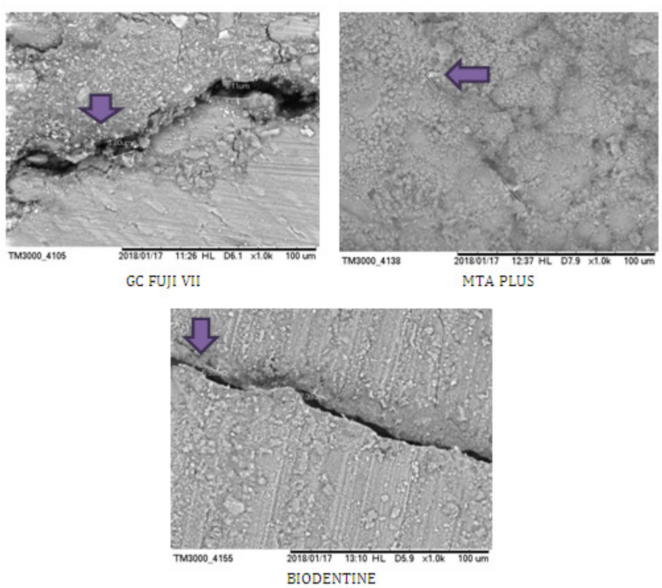


Fig. 1. Sem pictures showing marginal adaptation among groups (minimum gap)

Table 3. Multiple comparison of mean of different groups by Tukey's test

(I) gp	(J) gp	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
GC FUJI VII	MTA PLUS	.596	.333	.296**	-.30	1.49
	CONTROL	-.398	.333	.635**	-1.30	.50
	BIODENTINE	.152	.333	.968**	-.75	1.05
MTA PLUS	GC FUJI VII	-.596	.333	.296**	-1.49	.30
	CONTROL	-.994*	.333	.025*	-1.89	-.10
	BIODENTINE	-.444	.333	.549**	-1.34	.45
BIODENTINE	GC FUJI VII	-.152	.333	.968**	-1.05	.75
	MTAPLUS	.444	.333	.549**	-.45	1.34
	CONTROL	-.550	.333	.365**	-1.45	.35
CONTROL	GC FUJI VII	.398	.333	.635**	-.50	1.30
	MTA PLUS	.994*	.333	.025*	.10	1.89
	BIODENTINE	.550	.333	.365**	-.35	1.45

**statistically significant* ***statistically non-significant*

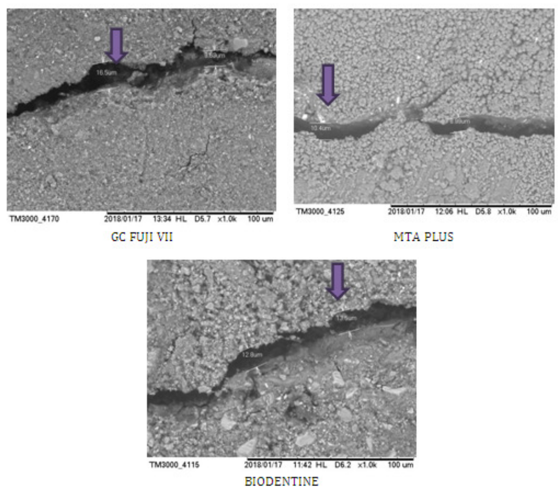


Fig. 2. Sem pictures showing marginal adaptation among groups (maximum gap)

Biodentine. Hence, Table 3 shows that MTA Plus has the least dye penetration than biodentine and GC Fuji VII and Control group showed the maximum dye penetration.

From the above Scanning Electron Microscope (SEM) pictures, MTA plus shows the minimum marginal gap of 2.17 micrometers, followed by Biodentine 5.55 micrometers and GC FUJI VII 8.00 micrometers. Thus MTA Plus shows the best marginal adaptation between the repair material and the tooth structure as compared to Biodentine and GC Fuji VII.

From the above Scanning Electron Microscope (SEM) pictures, GC FUJI VII shows the maximum marginal gap of 16.5 micrometers, followed by Biodentine 13.5 micrometers and MTA Plus 10.4 micrometers.

4. DISCUSSION

The most important factors determining the success of a perforation repair procedure are the location of the perforation; time elapsed between the occurrence of the perforation and repair, the ability of the material to seal the perforation and the biocompatibility of the repair material. The prognosis of endodontically treated teeth becomes worse when root perforation occur because of the damage to the periodontal attachment apparatus. Sealing the perforation is therefore of paramount importance for healing to occur. Moisture, bleeding, unconventional accessibility and a bottomless cavity, however make repair of the perforation difficult which will eventually have a great impact on the prognosis of the perforated teeth. However management of a perforation still remains a challenge in endodontics as there is no ideal means to repair a perforation defect. Perforation repair can be achieved intracoronally or by external surgical approach in which usually the former precedes the latter. The important factor in both approaches is however in achieving a good seal between the tooth and the periodontium [7-10]. Hence; under the light of above mentioned data, the present study was undertaken for evaluating the sealing ability of furcation repair materials GC Fuji VII, MTA Plus and Biodentine.

The result of the present study demonstrated that MTA Plus had the least dye penetration followed by Biodentine and GC Fuji VII Also, the result obtained was significant. In this study the Control group showed the maximum dye penetration since no material was used to repair the defect. These results were different from a previous study done by Kumar Y et al. [10] and Khandelwal et al. [11] in which least leakage was observed with Biodentine than MTA. The difference in the results of two studies could be due to a fact that in our study methylene blue dye was used for evaluation while Rhodamine dye was used in their study. Another study done by Nikoloudaki et al. [12] compared MTA and Biodentine in perforation repaired. They observed the least amount of dye penetration in MTA group followed by Biodentine. The result of their study was in accordance with our study.

In our study, MTA Plus showed minimum leakage compared to GC FUJI VII and Biodentine. The minimum microleakage as observed in MTA Plus group might be attributed to its superior marginal sealing ability resulting from its hydrophilic properties and formations of an inter facial layer (passivating trisulfate layer over hydrating crystals of MTA Plus) between the material and dentin [12]. The interfacial layer reduces the risk of marginal percolation and gives promising long-term clinical success. Kubo et al. [13] found that the further hydration of MTA Plus powder by moisture can result in an increase in compressive strength and decrease leakage. Sarkar et al. [14] demonstrated that MTA Plus has the ability to precipitate hydroxyapatite crystals in the presence of fluid which may be relevant in minimizing leakage thereafter.

Better sealing ability of MTA Plus may also be due to the different consistency of the tested materials. After mixing, MTA Plus has a paste like consistency which enables the material to flow laterally when a minimal resistance is met from the periodontal tissues. Biodentine after mixing in the vibrator machine has a thicker consistency, resulting in handling and condensation problems. Thus, the higher percentage of microleakage can be attributed to the delivery method, which does not allow precise and controlled placement of the putty sealing material in the perforation cavity [11-14].

In the present study, MTA Plus showed comparatively better marginal adaptation than Biodentine and GC Fuji VII. This could be attributed to a prolonged maturation process because of the formation of passivating trisulfate layer over hydrating crystals of MTA [2]. The main advantage of MTA Plus over MTA is shorter setting time, which is around 80-100 min. A possible explanation could be that the main part of MTA was mineral oxide, which for setting it had to react with water. It was hydrophilic and the moisture in the surrounding tissues activated the chemical reactions. Therefore moisture was importance when using MTA. Mixing the powder with water turns the cement into a colloidal gel which sets in four hours. The characteristics of the mixture depended on the size of the particles, the ratio of powder to gel, heat and presence of water. The literature shows that, MTA was also a type of Portland cement with smaller particles of limestone as filler [15].

According to the study done by Parirokh et al, the reparative dentin under MTA was consistently thicker and more uniform compared with Calcium Hydroxide [16].

The least amount of marginal adaptation and maximum microleakage was seen with respect to Glass Ionomer Cement. Though GIC has showed good dentinal wall adherence, it is technique sensitive. Freshly mixed GIC shows difficulty in handling and is also sensitive to moisture. GIC may exhibit shrinkage upon setting with more voids. This could be the probable reason for increased mean gap size and increased mean microleakage in GIC [14]. Attempts to pack the material apically could probably result in overextension. It appears that the gross overextension of the chemically cured materials adversely affected the leakage. Biocompatibility studies have shown the evidence of initial cytotoxicity with freshly mixed samples of GIC, with decreasing toxicity as setting occurs. It was reported to cause inflammation when placed in contact with bone [17,18].

Therefore, considering the methodology used in the current *in vitro* study, it may be said that MTA Plus presents optimum sealing ability followed by Biodentine and GC Fuji VII. Also the least gap formation between the repair material and the tooth surface were found in MTA Plus followed by Biodentine and GC Fuji VII. However, an in vivo study would be able to provide a better performance as an efficient furcal repair material in long term clinical situations.

5. CONCLUSION

Within the limitations of this in-vitro study, it can be concluded that: MTA Plus is the best of the three materials used for furcation repair. It showed the least amount of microleakage and least gap formation between the repair material and the tooth surface followed by other repair materials namely Biodentine and GC Fuji VII. Biodentine also provides a good seal almost similar to that of MTA Plus when used as a furcation repair material. GC Fuji VII showed significantly more leakage and gap formation than Biodentine and MTA Plus.

CONSENT

It is not applicable.

ETHICAL APPROVAL

As per international standard or university standard written ethical approval has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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