Evaluation of the Effect of Flowable Composite, Vitremer and Biodentine as intraorifice Barriers on the Fracture Resistance and Coronal Microleakage of Roots Obturated with Gutta Percha – an in Vitro Study

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ABSTRACT

Introduction: Studies show that even in cases where root canal filling is done under good microbial control, re-contamination of the root canal system can still occur within days after obturation in teeth without adequate coronal seal. The objective of this in vitro study was to evaluate the effect of flowable composite, Vitremer and Biodentine as intraorifice barriers on the fracture resistance and coronal microleakage of roots obturated with gutta percha.

Material and Methods: Crowns of 90 extracted human mandibular premolar teeth were sectioned off to obtain 14mm long root specimens. After endodontic therapy, all samples were then randomly divided into following two main experimental groups: Group 1: fracture resistance test [n=40] Group 2: dye penetration test for coronal microleakage [n=50]. In both experimental groups, the specimens were further sub grouped with respect to the intra orifice barrier material placed after removal of 3mm of the coronal portion of the root fillings: 1) Flowable composite, 2) Vitremer and 3) Biodentine. The specimens in the fracture resistance group were loaded vertically using a universal testing machine at 1mm/min crosshead speed until the fracture occurred. The specimens in the dye penetration group were immersed in Indian ink for 5 days following which they were decalcified, dehydrated and cleared. Microleakage into the canals was measured in millimeters using a stereomicroscope. The results were evaluated statistically using one way ANOVA for multiple comparisons followed by post hoc Tukey test for pairwise comparison.

Results: The use of Flowable composite, Vitremer and Biodentine as an intra orifice barrier significantly increased the fracture resistance and decreased the coronal microleakge of the root canal treated teeth.

Conclusion: Within the limitations of this study it can be concluded that the use of Flowable composite, Vitremer and Biodentine as an intra orifice barrier after root canal treatment significantly improves the fracture resistance and decreases the coronal microleakge after endodontic therapy.

Keywords: Intra Orifice Barrier, Fracture Resistance, Coronal Leakage, Vitremer, Biodentine, Flowable Composite

INTRODUCTION

Endodontic therapy aims to eliminate infections in the root canal system and to prevent re infections from apical and coronal directions.[1] The most commonly encountered problem influencing the long term success of endodontic treatment is microleakage. In endodontics, microleakge refers to movement of fluid and microorganisms along the interface of the dentinal walls and the root filling materials or through the voids within the root filling material.[2] A number of studies have indicated that leakage whether from coronal or apical direction adversely affects the success of root canal treatment.[3,4] In recent times, it has been suggested that apical leakage may not be the most important factor leading to failure of endodontic treatment but that microbial infection through coronal leakage is far more likely to be major determinant of clinical success or failure.[4]

Guttapercha combined with the sealer is the most commonly used root canal filling material, they have weak sealing ability when exposed to a conventional oral environment. [5,6]

In an attempt to minimize this coronal microleakage, Roghanizad and Jones advocated the placement of intraorifice barriers into the root canals by replacing a part of the coronal *guttapercha* immediately after obturation which can act as a second line of defence for the obturated teeth without permanent restoration.[7]

Studies have shown that the root canal filling materials (*Guttapercha* or Resilon along with sealer) have low interfacial strength to radicular dentin which is not enough to reinforce the root structure so as to prevent vertical root fracture.[8] But these intra orifice barriers with higher modulus of elasticity than these root canal filling materials can additionally reinforce the residual tooth structure, thereby preventing vertical root fracture to an extent.[9]

Vertical root fracture is a common complication of root canal treatment that can occur before, during or after root canal obturation. Studies have shown that 11 – 13% of extracted

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teeth with endodontic treatment are associated with vertical root fracture, making it the second most frequent reason for the extraction of endodontically treated teeth.[10]

Several materials have been used as intraorifice barrier such as Cavit, resin based temporary restorative material, amalgam with varnish, glass ionomer cement and composite resins, out of which the most commonly used barriers however are composites and glass ionomers.[7]

These restorative materials should fulfil the primary objective of an intraorificebarrier, that is to provide a permanent, leak proof coronal seal.[7] Different studies have reported conflicting results regarding the sealing ability of different materials and attempts are being made to introduce new materials with the aim of long term seal because according to the type of material and its exposure in the oral cavity over time, all these conventional materials leak to a certain extent, thus resulting in a compromised coronal seal.

Biodentine is a newly introduced calcium silicate based material in the market, which micromechanically bonds to the tooth surface without surface preparation. It has improved physico-chemical properties when compared to other calcium silicate based materials, with advantages like short setting time and high mechanical strength which makes it clinically easier to handle and compatible for restorative clinical cases of dentine replacement. It is used for perforation repair, retrograde surgical filling, external/internal resorption. But studies are scarce in terms of its role as an intraorifice barrier.[11]

The objective of this study was to evaluate the effect of a flowable composite,Vitremer and Biodentine as intraorifice barriers on the fracture resistance and coronal microleakage of roots obturated with guttapercha.

MATERIAL AND METHODS

The study was conducted on 90 extracted single rooted mature human mandibular premolar teeth with single canal.

The following were the selection criteria for the samples of the study:

Inclusion criteria

1. Teeth indicated for extraction due to orthodontic reason belonging to the age group 17 to 35 years.
2. Teeth devoid of any developmental defects.

Exclusion criteria

1. Dental caries.
2. Any previous restorative or endodontic treatment
3. Fractured teeth.
4. Teeth with abrasion, erosion.

The teeth were stored for 2 days in sodium hypochlorite (NaOCl), at room temperature, to remove any organic debris. Subsequently, they were scaled with ultrasonic instruments, washed with distilled water, and immersed in 10% formalin solution for further use.

Teeth were then reduced to a standardized root length of 14mm from the coronal aspect. The mesio- distal and bucco-lingual dimensions were measured with a caliper. Roots with ±10% difference from those values were discarded.

Specimen preparation

Canal length was determined by using a #10K file and working length was determined by subtracting 1mm from the canal length. Root canals were then be instrumented with Protaper rotary files in conjunction with 2ml of 5.25% sodium hypochlorite (NaOCl) between each file size. Root canals were enlarged till size F4 (Tip size 40/0.06) upto the working length and final irrigation was done with 5ml 17% EDTA and 5ml of 2.5% NaOCl. Following this, canals were flushed with 10ml distilled water to avoid prolonged effect of EDTA and NaOCl and dried with paper points.

All the samples were obturated with Guttapercha points and AH plus sealer. Obturation was done with continuous wave thermoplastic method using a commercially available device [Elements ObturationUnit™(SybronEndo)]. With the aid of a heated instrument coronal 3mm of root filling was removed for all the samples except for the control groups and was confirmed by using RVG.

All samples were randomly divided into following two main experimental groups:

Group 1: fracture resistance test [n=40]

Group 2: dye penetration test for coronal microleakage [n=50].

In fracture resistance test group, samples were further divided into four subgroups according to the intraorifice barrier placed with 10 specimens in each subgroup.

GROUP 1: Fracture resistance test

- Subgroup A: Flowable composite (Esthet X Flow) in conjunction with self-etching dentin bonding agent.
- Subgroup B: Vitremer (Placement of Vitremer after application of Vitremer primer according to manufacturer's instructions).
- Subgroup C: BIODENTINE.
- Subgroup D: No barrier (CONTROL).

In dye penetration test group samples were divided into five subgroups with 10 samples in each subgroup.

GROUP 2: Dye penetration test

- Subgroup 1: Flowable composite in conjunction with self-etching dentin bonding agent.
- Subgroup 2: Vitremer (Placement of Vitremer after application of Vitremer primer according to manufacturing instructions)
- Subgroup 3: BIODENTINE
- Subgroup 4: Control. (no barrier is placed and orifice is exposed to dye)
- Subgroup 5: Control (orifice completely sealed with three layers of nail polish)

After the placement of intraorifice barrier the specimen were stored at 37^0C and 100% humidity for 1 week to allow the material to set completely.

Fracture test

The apical root ends were embedded along their long axis in self curing acrylic blocks leaving 9mm of each root exposed. The specimens were then mounted on a universal testing machine. A custom stainless steel loading fixture with a 2mm spherical tip was centred over the canal opening. A compressive force was applied at a cross head of crosshead speed of 1mm/min until the fracture occurred. The forces necessary to fracture each root was recorded in Newton. (Fig: 1)

Dye penetration test

All of the experimental teeth and Subgroup 4 control group received three layers of nail polish leaving only the area of the canal orifice exposed. All the surfaces of the Subgroup 5 control were completely sealed with three layers of nail polish. For each specimen, root apex was blocked by sticky wax.

The teeth were immersed in India ink for 5days. Following the exposure to dye, the teeth were then be rinsed in tap water and nail polish was completely removed with a scalpel. Then the teeth were decalcified in 5% hydrochloric acid [HCl] for 3days with constant stirring followed by running water wash. The teeth was dehydrated for 3hours each of 50%, 75% and 95% ethyl alcohol and cleared by immersion into methyl salicylate. Leakage was observed by using a 10X stereomicroscope and measured to greatest penetration from the coronal extent of orifice material. (Fig. 2)

Statistical analysis

The descriptive statistics, including mean, standard deviation and standard error of mean, minimum and maximum values were calculated for each group tested. One way analysis of variance (ANOVA) was used to analyze the data for significant differences. The Bonferronis adjustment test was used for inter group comparison. The significance of all statistical tests was predetermined at P<. 05.

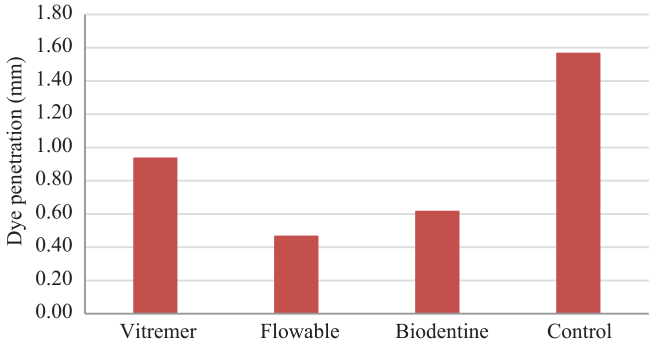
RESULTS

A negative control subgroup in the dye penetration group was not taken into consideration for statistical analysis since all the values in that subgroup were zero.

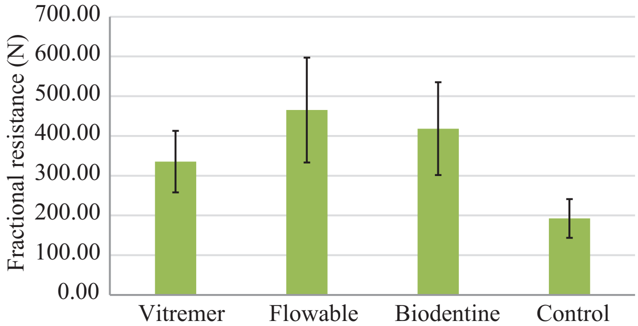
The graphical representation in Graph 1 and 2 shows the mean fracture resistance in Newton and dye penetration in mm for each subgroup respectively. The corresponding group numerical averages, standard deviations and significant differences after using one way ANOVA and a Bonferronis adjustment are shown in Table1-6.

The results indicated that

Lowest mean dye penetration value was recorded for Flowable composite subgroup (0.47±016 mm) followed by Biodentine subgroup (0.62±0.36 mm) and Vitremer subgroup (0.94±0.28 mm). The positive control group with no intra orifice barrier showed the maximum leakage. The



Graph-1- Mean dye penetration



Graph-2- Mean fractional resistance

Figure-1: Post fracture view of the

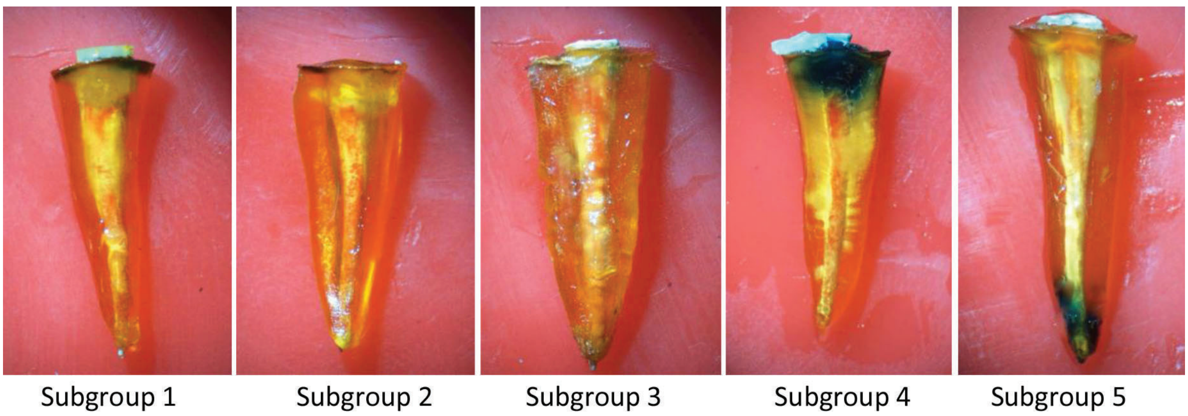


Figure-2: Dye penetration from the coronal area

Sub-group	Mean	Standard Deviaton	SE of Mean	95% CI for Mean		Min	Max
				Lower Bound	Upper Bound		
Vitremer	0.94	0.28	0.09	0.74	1.14	0.30	1.30
Flowable	0.47	0.16	0.05	0.36	0.58	0.20	0.70
Biodentine	0.62	0.36	0.11	0.37	0.87	0.20	1.50
Control	1.57	0.61	0.19	1.14	2.00	0.60	2.80

Table-1: Showing mean dye penetration values recorded among the sub-groups

Source of Variation	Df	Sum of Squares (SS)	Mean SS	F	P-Value
Between Groups	3	7.138	2.379	16.034	<0.001*
Within Groups	36	5.342	0.148	-	-
Total	39	12.480	-	-	-

* denotes significant difference

Table-2: Description of ANOVA

(I) Group	(J) Group	Mean 0 Difference (I-J)	SE of Mean diff	P-Value	95% CI	
					Lower Bound	Upper Bound
Vitremer	Flowable	0.470	0.172	0.059	-0.011	0.951
	Biodentine	0.320	0.172	0.429	-0.161	0.801
	Control	-0.630	0.172	0.005*	-1.111	-0.149
Flowable	Biodentine	-0.150	0.172	1.000	-0.631	0.331
	Control	-1.100	0.172	<0.001*	-1.581	-0.619
Biodentine	Control	-0.950	0.172	<0.001*	-1.431	-0.469

Table-3: Dye penetration between the subgroups

	Mean	Standard Deviation	SE of Mean	95% CI for Mean		Min	Max
				Lower Bound	Upper Bound		
Vitremer	335.55	77.37	24.47	280.21	390.90	241.14	456.70
Flowable	465.27	131.98	41.74	370.85	559.68	329.11	776.30
Biodentine	418.36	116.80	36.93	334.81	501.91	308.90	629.00
Control	192.45	48.67	15.39	157.63	227.27	123.66	258.80

Table-4: Mean fractional resistance values recorded among the subgroups

Source of Variation	Df	Sum of Squares (SS)	Mean SS	F	P-Value
Between Groups	3	429570.474	143190.158	14.531	<0.001*
Within Groups	36	354737.008	9853.806	-	-
Total	39	784307.482	-	-	-

* denotes significant difference

Table-5: Description of ANOVA

(I) Group	(J) Group	Mean Difference (I-J)	SE of Mean diff	P-Value	95% CI	
					Lower Bound	Upper Bound
Vitremer	Flowable	-129.712	44.393	0.036*	-253.657	-5.767
	Biodentine	-82.805	44.393	0.422	-206.750	41.140
	Control	143.107	44.393	0.016*	19.162	267.052
Flowable	Biodentine	46.907	44.393	1.000	-77.038	170.852
	Control	272.819	44.393	<0.001*	148.874	396.764
Biodentine	Control	225.912	44.393	<0.001*	101.967	349.857

Table-6: Fractional resistance between the subgroups

differences in dye penetration values among the groups were found to be statistically significant. (P<0.001)

Similarly, Flowable composite subgroup showed the highest mean fracture resistance (465±131.98 N) followed by Biodentine subgroup (418±36 N) and Vitremer subgroup (335.55±77.37 N).The control group with no intra orifice barrier had the lowest fracture resistance. The differences in the mean fractional resistance among the groups were found to be statistically significant. (P<0.001)

Multiple comparisons using Bonferronis test were also done to find out which pair of groups there exist a significant difference.

The results were:

- The mean dye penetration in Vitremer subgroup, Flowable composite subgroup and Biodentine subgroup was found to be statistically different from positive control group.
- The differences in the mean dye penetration among the experimental groups were not found to be statistically significant.
- The mean fracture resistance in Vitremer subgroup was found to be statistically different from Flowable composite subgroup (P<0.05) and control subgroup (P<0.05)
- The mean fracture resistance in Flowable composite subgroup and Biodentine subgroup was found to be statistically different from control subgroup (P<0.001).
- The difference in mean fracture resistance between Flowable and Biodentine subgroup was not found to be statistically significant.

DISCUSSION

The conventional root canal filling materials such as gutta percha and sealer provides minimal resistance to bacterial leakage.[7] Therefore the coronal portion of the root canal must be sealed adequately to minimize the endodontic treatment failure rate.[5,6] Various researchers have supported the effectiveness of intra orifice barriers in preventing coronal microleakage, however, there is no consensus as to the protocol or material used as the coronal barrier after root canal treatment.

In the present study, care was taken to select the teeth with similar dimensions and roots with ±10% difference from those values were discarded.[9] Obturation was done with gutta percha as the core material with a non eugenol based sealer. A non eugenol based sealer was selected in this experimental design to circumvent the potentially detrimental influence the eugenol containing sealers have on adhesion between root dentin and composite resin.[12,13]

After the endodontic procedure, 3 mm of intra canal gutta percha was removed coronally and was replaced with one the following restorative material: flowable composite, vitremer and Biodentine. This was in accordance with the recommendations of Roghanizad and Jones, who suggested that 3 mm thickness of material coronally is adequate to provide a good seal and also it is easy to remove should re treatment be necessary.[7] The specimens were then subjected to dye penetration test and fracture resistance test.

Microleakage is a phenomenon that involves diffusion, thus the knowledge of the dynamic relation between the dental structure and the restorative material is of prime importance. In this study microleakage was assessed using passive dye penetration and clearing technique.

In vitro methodologies are used to estimate sealing quality; generally by measuring microleakage that allows a tracer agent to penetrate the filled canal.[14]

In this study, clearing technique was used to view the dye penetration. This technique was first recommended by Okmura in 1927, in which teeth become transparent after a process of demineralization, dehydration and immersion in methyl salicylate, thus providing a three dimensional view of internal anatomy of root canals without the loss dental substance and making it easier to view the leakage area.[15,16]

Indian ink was used as the tracer in this study as it allows adequate visualization after decalcification and clearing of the specimens.[15,17] Indian ink is a neutral suspension of carbon particles, most of which have a diameter smaller than or equal to 3µm. Owing to range of particle sizes within the ink suspension penetration is made possible into the cracks where microleakage may occur.

In the present study, all the samples in the positive control group, where the gutta percha was not replaced by 3 mm of restorative material, presented with extensive dye penetration when compared to other groups. This can be considered as an indicator of the potential for leakage and in accordance with the studies conducted by Torabinjad et al and Magura et al who showed that gutta percha and sealer do not provide an adequate barrier to coronal leakage.[6,18]

As expected, all the samples in the negative control group showed no microleakage.

Collectively, the calculated leakage scores for flowable composite, biodentine and Vitremer were found to be a mean of: 0.47 mm, 0.62mm and 0.84 mm respectively. Flowable composite showed the least coronal leakage whereas Vitremer (resin modified glass ionomer cement) showed the greatest coronal leakage.

In general, flowable composites have a reduced filler load and/or an increase in diluent monomers.[19] The resulting material is one that flows more easily than traditional composites, making restoration of small preparations easy, especially with improved delivery systems such as syringes. However, these characteristics also lead to less favorable mechanical properties, increased wear and polymerization shrinkage.[20]

Previous microleakage studies have shown that flowable composite can effectively seal the margins in enamel, dentin and cementum.[19,20] Good coronal seal demonstrated by flowable composite in this study is in consistent with the findings of Jiang et al who reported that flowable composite have better adaptation to the cavity walls when compared with hybrid composite.[1] Moreover, flowable composites have the ability to form a layered structure of minimum thickness to improve or eliminate air inclusion or entrapment.[19] However, a study done by Sauaia et al reported poor coronal seal by flowable composite.[12] This discrepancy may be attributed to differences in sealer used. While Sauaia et al used eugenol containing sealer, Jiang et al and the present study used non eugenol containing sealer. Eugenol is claimed to interfere with the polymerization of composite resins and to affect shear bond strengths of dentine-bonded composite restorations.[13]

Resin modified glass ionomer cements are a class of hybrid materials created by modifying GICs with the addition of the monomer component typically 2-hydroxyethyl methacrylate (HEMA) and an associated initiator system. RMGICs are said to overcome the problems of low mechanical strength and moisture sensitivity associated with GICs while retaining their advantages. In addition to ionic bonding, RMGICs adhere to dentine by micro-mechanical retention.[21]

Vitremer demonstrated greatest leakage among the three tested materials. This was consistent with the findings of Attin et al, Zaia et al and Sauaia et al. Authors of these studies have reported that the results may be explained by polymerization contraction.[12,22,23]

In the present study, Biodentine showed a good coronal seal, which was comparable to that of flowable composite. Biodentine is composed of a highly purified tricalcium silicate powder that contains small proportions of dicalcium silicate, calcium carbonate, and a radiopaquer. It is dispensed in a fixed powder: liquid proportion, providing a shorter setting time of 12 min.[18] The authors additionally expressed the nanostructure and small size of the forming gel of the calcium silicate cement as one of the factors that influenced the sealability as this texture allowed the material to better spread onto the surface of the dentine. Slight expansion was also noted in these materials which contributed to their better adaptation.[11, 24]

It has been an empirical clinical observation that teeth are more prone to fracture as increasing amounts of tooth structure are lost due to endodontic therapy, prior pathology and/or restorative procedures. There is evidence that these teeth have reduced levels of proprioception, which could impair normal protective reflexes which ultimately leads to fracture.[25]

The use of restorative materials with high elastic moduli can provide stiffness against the forces that generate root fractures.[9] Therefore, in the second part of the present study these tested materials, in addition to coronal microleakage were evaluated for their role in reinforcing the root structure. In the present study, forty specimens were subjected to fracture resistance test. The apical root ends were embedded along their long axis in self curing acrylic blocks, leaving 9 mm of each root exposed.

The testing technique used in this study was linear compressive loading (static) applied at a crosshead speed of 1mm/min. This is the most widely used technique for checking fracture resistance of endodontically treated teeth in a common universal testing machine. Because of its efficiency (less time consuming and low costs) static loading becomes the frequently applied technique that simulates the clinical load conditions in a simplistic way.[9,26]

The results of the present study indicate that the endodontically treated tooth roots with intra orifice barriers are more resistance to fracturing loads compared with those without one, and this reinforcing effect is material dependant. The placement of intra orifice barriers significantly increased the fracture resistance of obturated roots, with flowable composite and biodentine subgroups showing highest fracture resistance followed by Vitremer subgroup.

As expected, gutta percha along with the sealer as control, were not able to increase the fracture resistance. The present result confirms the findings of the previous studies done by Ribeiro et al and Gesi et al who reported that the core materials (gutta-percha or Resilon) combined with the tested endodontic sealers were not able to increase the root fracture resistance.[27,28]

For a material to reinforce the tooth structure the elastic properties of a material should approximate those of the tooth structure, so that lesser amount of tensile stresses will form at the tooth restoration interface and marginal degradation which occurs due the mechanical change in the shape of the restoration will get minimized. The stresses created from occlusal loads will get distributed more evenly along the tooth restoration interface and the whole tooth restoration system will act as a single unit, which will improve fracture strength.

Methodologically, limitations of this study were that static loading testing was used to evaluate fracture resistance and dye penetration may not always reflect the clinical scenarios. Therefore, further laboratory research is suggested, using dynamic loading combined with thermocycling with different restorative materials coupled with clinical trials to validate the results of this in vitro study.[26]

The use of an intra orifice barrier may prevent short term microleakage. It does not preclude the placement of a permanent restoration in remaining tooth structure and the importance of full coverage restorations in limiting vertical root fractures should not be overlooked.

CONCLUSION

Though none of the restorative material used as an intra orifice barrier prevented the microleakage completely, subgroups restored with flowable composite, Biodentine and Vitremer showed significantly less microleakage when compared to the positive control group.

The difference in the coronal microleakage between the experimental subgroups was not found to be statistically significant.

Also, the use of intra orifice barriers significantly improved the fracture resistance of the endodontically treated teeth with flowable composite showing the highest mean fracture load among the tested materials followed by Biodentine and Vitremer.

Considering the fact that dye penetration and static loading fracture test may not always reflect the clinical situation, the direct exploration of the results to clinical situation can only be undertaken after further in vitro and in vivo studies.

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