International Journal of Dentistry and Oral Science (IJDOS)
ISSN: 2377-8075

Effects Of Fiber Insertion And Sonic Energy On Microleakage Of Bulk Fill And Nanohybrid Composites In Deep Class II Cavities: A Stereomicroscopic Study

Research Article

Agrawal Vineet[1]*, Kapoor Sonali[2]

[1] Professor, Department of Conservative Dentistry and Endodontics, M.P. Dental College and Hospital, Vadodara, India.
[2] Professor and HOD, Department of Conservative Dentistry and Endodontics, M.P. Dental College and Hospital, Vadodara, India.

Abstract

Introduction: Composite is material of choice for restoration for cavities in todays era. Fibers and sonic energy are newer technology incorporated into dental composites to reduce polymerization shrinkage and thus microleakage.
Objectives: To evaluate effects of fiber insertion and sonic energy on gingival microleakage in class II composite restorations placed apical to the cementoenamel junction.
Materials and Methods: Standardized class II cavities were prepared on extracted molars and randomly divided into four groups (n = 20 each): Group I, Filtek Z350; Group II, Filtek Z350 + Ribbond; Group III, Filtek Bulk fill; Group IV SonicFill BulkFill composite. All specimens were subjected to a thermocycling regime, immersed in 2% methylene blue dye for 24 h, sectioned longitudinally, and examined under a stereomicroscope to assess dye penetration on a six-point scale. The score data were subjected to statistical analysis, whereby the Kruskal–Wallis analysis of variance was used for multiple group comparisons and the Mann–Whitney test for groupwise comparisons at a significance level of $P \leq 0.05$.
Results: A statistically-significant decrease in microleakage was found when Ribbond fiber and Sonic energy was used: group 2 vs group 1 ($P < 0.001$), group 4 vs group 3 ($P < 0.001$). No significant difference in microleakage scores ($p=0.530>0.01$) in the Filtek Bulk fill composite (group 3) when compared to the nanohybrid composite (group 1) was found. Group 4 (Sonicfill Composite) showed the least mean microleakage score compare to all other groups.
Conclusion: Sonic energy and polyethylene fiber inserts significantly reduces microleakage in class II composite restorations with gingival margins below the cemento-enamel junction.

Keywords: Bulk Fill Composites; Gingival Microleakage; Nanohybrid Composite; Polyethylene Fiber; Sonicfill Bulk Fill Composite.

Introduction

Since their introduction in 1960's, light cure composites have undergone improvement in all areas and have become the material of choice as a direct posterior restorative material in clinical dentistry. Use of composite resins in the occlusal and occluso-proximal cavities of posterior teeth has been supported by various evidences [1]. However polymerization shrinkage of 2.6-7.1% continues to be major disadvantage associated with composite resins leading to development of stress in restoration, gap formation and microleakage [2].

Microleakage is of a great concern as it leads to recurrent caries, postoperative sensitivity, enamel fracture, marginal staining, and eventual failure of restorations. In deep class II cavities where, gingival margins of cavity are placed apical to cementoenamel junction, microleakage is commonly seen as dentin and cementum are less favorable substrates for bonding owing to their higher organic content. Also, increased depth at proximal box, makes adaptation as well as curing of composite more difficult at gingival seat area [3].

In order to decrease microleakage, various techniques are proposed such as slowing down the composite polymerization rate [4] using an incremental placement technique [5] or low modulus intermediate layer, [6] and reducing the C factor (the ratio of bonded to unbonded restoration surfaces) [7]. In recent few years, studies showed placement of polyethylene fibers in class II com-

***Corresponding Author**:
Dr. Vineet Agrawal,
Professor, Department of Conservative Dentistry and Endodontics, M.P. Dental College and Hospital, Vadodara, India.
Tel: +918511580198
E-mail: vineetdent@yahoo.co.in

Received: April 08, 2021
Accepted: September 20, 2021
Published: September 21, 2021

Citation: Agrawal Vineet, Kapoor Sonali. Effects Of Fiber Insertion And Sonic Energy On Microleakage Of Bulk Fill And Nanohybrid Composites In Deep Class II Cavities: A Stereomicroscopic Study. *Int J Dentistry Oral Sci.* 2021;8(9):4431-4436. doi: http://dx.doi.org/10.19070/2377-8075-21000903

posite restorations has led to decrease in microleakage scores[3, 8]. Placement of fiber, resist the pulling of composite from margins due to its higher strength, reduces the amount of resin matrix and also modifies the interfacial stresses, ultimately helping in reducing shrinkage [2, 8].

Incremental placement technique is commonly employed in clinical practice to minimize shrinkage stress and ensure adequate depth of cure [9]. But in large posterior class II restorations, this technique becomes time consuming, risk of contamination of layers increases and also voids can be entrapped in between layers [10]. One of the major advancements that took place in resin based composite technology is the introduction of bulk fill resin composites which made the procedure more user friendly and simplified with the shorten application time.

Bulk fill resin composites can be placed up to 4-mm in thickness, because of its increased depth of cure, which results from its higher translucency. Also, they show low polymerization shrinkage due to addition of stress-relieving monomers, more reactive photoinitiators, and prepolymerized particles [11, 12].

A novel sonic energy driven bulk-fill resin composite system, SonicFill™ System (Kerr Corp, USA), has been introduced which can be bulk filled up to 5 mm in depth as indicated by the manufacturer [13]. SonicFill™ incorporates a highly-filled proprietary resin with special rheological modifiers which react to sonic energy (applied through a specially designed hand piece), causing the viscosity to drop (up to 87%), making the composite more flowable. This flowable composite enables quick placement and precise adaptation to the cavity walls. After dissipation of sonic energy, the composite returns to a more viscous, non-slumping state that is suitable for sculpting and carving. It has dual benefits of flowable composite for placement, and the benefits of traditional incrementally placed composites for sculpting anatomy and durability [13, 14].

Objectives

There are not many studies done comparing both, the effect of fiber insertion and sonic energy, on microleakage of composite restorations. Hence, objective of the present study, was to compare nanohybrid composite, bulk-fill composite, sonic energy driven bulk fill composite and the effect of polyethylene fiber inserts on gingival microleakage in deep class II composite restorations. The null hypothesis of study is no difference in microleakage score in composites tested, and no effect of sonic energy and polyethylene fiber inserts on microleakage.

Material and Methods

Sample size calculation was done using the formula n=2*(Z1+Z2)^2*SD^2/d^2 (Z1=2.64, Z2=0.842, SD=0.8 and d=1) at 95% confidence and 80% power and minimum required sample size was 16 per group (total 64). Hence, 80 teeth (20 in each group), more than minimum sample size was taken in our study. 80 extracted intact mandibular first and second molars with no crack, decay, fracture, abrasion, previous restorations, or structural deformities, were selected, cleaned with a periodontal scaler (Satelec; Gustave Eiffel BP, Merignac Cedex, France), and stored in 0.5% chloramine T solution for 1 month.

All the teeth were embedded in poly (vinyl) siloxane impression material such that it was 2 mm below the cementoenamel junction. 80 standardized mesio-occlusal/disto-occlusal class II cavities were prepared using round bur no. 4 and no. 245 straight fissure diamond burs (Mani, Utsunomiya, Tochigi, Japan) in a high-speed air-turbine hand piece (NSK, Tochigi-Ken, Japan) with copious

Table 1. Materials used in the present study, manufacturer information, and brand names.

Material	Brand Name	Manufacturer	Chemical Content
Bonding Agent	Adper single bond plus	3M ESPE, St Paul, USA	• BisGMA • HEMA • Dimethacrylates • Silica nanofiller • Copolymer (polyacrylic-polyitaconic acids) • Ethanol • Water • Camphorquinone
Resin Composite	Filtek Z350	3M ESPE, St Paul, USA	Organic Matrix · BisGMA · BisEMA · UDMA · TEGDMA Inorganic matrix • Non-agglomerated nanoparticles of silica 20nm in size • Non-agglomerates formed of zirconia/silica particles ranging from 0.6 to 1.4 µm in size
	Filtek BulkFill Posterior restorative	3M ESPE, St Paul, USA	Organic Matrix • AUDMA • UDMA • 1, 12-dodecane-DMA Inorganic Matrix • Non-agglomerated/non-aggregated 20 nm silica filler • Non-agglomerated/ non-aggregated 4 to 11 nm zirconia filler • Aggregated zirconia/silica cluster filler (comprised of 20 nm silica and 4 to 11 nm zirconia particles) • Ytterbium trifluoride filler consisting of agglomerate 100 nm particles
	SonicFillTM 3	Kerr Corporation, CA, USA	Organic Matrix · BisGMA · TEGDMA · EBPDMA Inorganic Matrix · SiO2 · Glass · Oxides
Fiber Insert	Ribbond	Ribbond, Inc, WA, USA	· Polyethylene Fiber

water irrigation (burs were replaced after every five preparations) to the following dimensions (±0.3 mm): 2 mm occlusal isthmus depth; 5 mm facio-lingual proximal box width occlusally and 5.5 mm gingivally; 2.5 mm pulpal-proximal box depth occlusally and 1.5 mm gingivally; and 6–8 mm proximal box height, but always terminating 1 mm below the cementoenamel junction. The dimensions were verified with the help of a UNC-15 periodontal probe (Hu- Friedy, Chicago, IL, USA).

After cavity preparations, teeth were randomly divided by simple random sampling into four groups (n = 20 in each group) (Table 1):

Group I (n = 20): Filtek Z350 (nanohybrid; 3M ESPE, St Paul, MN, USA)
Group II (n = 20): Filtek Z350 + polyethylene fiber (Ribbond, Seattle, WA, USA),
Group III (n = 20): Filtek Bulk fill (Bulk fill Posterior restorative; 3M ESPE, St Paul, MN, USA)
Group IV (n = 20): SonicFill Bulk Fill composite (Kerr corp., Orange, CA, USA).

A universal Tofflemire retainer (API, Schweinfurt, Germany) with a matrix band (Hahnenkratt, Benzstrasse, Germany) was placed around each prepared tooth and supported externally by applying a low-fusing compound (DPI, Mumbai, India).

Group 1

After the application of etching gel (Dentsply Caulk GmbH, Konstanz, Germany) for 15 s, the cavity was blot dried, leaving a moist surface. Adper single bond Plus (3M ESPE, St Paul, MN, USA), was applied twice to thoroughly wet all the cavity surfaces for 20 sec. The cavity was gently air dried for 5 s to evaporate the solvent carrier, followed by light curing for 10 sec using an Elipar S10 LED curing unit (3M ESPE, St. Paul, MN, USA). Filtek Z 350 was dispensed directly into the prepared cavity in 2-mm increments by the oblique layering method. First increment was placed at a 45° angle to the facio-gingivo proximal line angle and cured for 40 sec. Second increment was placed and packed at the linguo-proximal box, and final incremeng in the occlusal portion of the box and the isthmus and cured for 40 sec. After removal of the band, the composite was cured from all the sides again for 40 sec.

Group 2

Acid etching and bonding was similarly carried out per group 1. However, before restoration with Filtek Z 350, 1 mm-thick Filtek Z350 was first placed on the gingival floor. One Ribbond fiber insert, approximately 1 mm less than the bucco-lingual dimension of the proximal box, was cut, impregnated with Ribbond wetting resin and condensed into the bed of the 1-mm composite resin and light cured for 40 s. Filtek Z350 was then dispensed into the remainder of the prepared cavity in 2- mm increments using the oblique layering technique as per group 1.

Group 3

Acid etching and bonding was similarly carried out per group 1. Filtek Bulk fill was dispensed directly into the prepared cavity in 4-mm increments. Starting in the proximal box, the first 4mm increment was placed horizontally in proximal and occlusal area. Light curing was done for 20 sec occlusally. Then the remainder of cavity was filled with another horizontal increment of Filtek Bulk fill and cured similarly as the first increment for 20 sec. After removal of matrix band, composite was cured for 10sec from buccal and 10 sec from lingual side.

Group 4

Acid etching and bonding was similarly carried out per group 1. Sonic Bulk fill was dispensed from the Sonic fill handpiece directly into the prepared cavity in 4-mm increments. Starting in the proximal box, the first 4mm increment was dispensed in proximal and occlusal area. Light curing was done for 20 sec occlusally. Then the remainder of cavity was filled with another horizontal increment of Sonic Bulk fill and cured similarly as the first increment for 20 sec. After removal of matrix band, composite was cured for 10sec from buccal and 10 sec from lingual side.

A similar shade (A2) was used for all the materials. The intensity of the light-curing unit was measured as 1000 mW/cm2 using an intensity meter (Optilux radiometer; Kerr, Sybron Dental Specialties, Orange, CA, USA). All restorations were finished with a graded series of aluminum oxide discs (Sof-Lex TM; 3M ESPE) and were subjected to thermocycling according to the International Organization for Standardization standard 11405 for 500 cycles at 5–55°C with a 30-sec dwell time [15].

Apical 2 mm of each tooth was sectioned, retrograde cavity was prepared and sealed with resin-modified glass ionomer cement (GC Fuji II LC, GC Corp, Tokyo, Japan). Two layers of nail varnish (Sunshine Cosmetics, Metoda, India) were applied over teeth, except for an area 1 mm around the gingival cavosurface margin of the restorations. Specimens were then immersed in 2% methylene blue dye buffered at pH = 7 (Merck Specialties Private, Mumbai, India) at 37°C for 24 h, washed, and dried. All the teeth were mounted on acrylic blocks and longitudinally sectioned mesio-

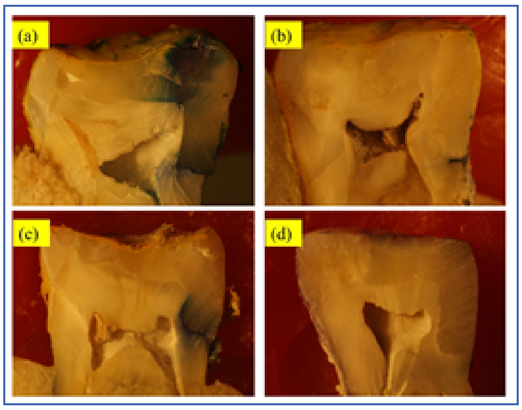
Table 2. Descriptive statistics of Kruskal-Wallis test.

GROUPS	N	Mean Rank	Chi-Square	Degree of freedom	p-Value	Significant Difference
Group I (Filtek Z350)	20	61.5				
Group II (Filtek Z350 + Ribbond)	20	29.7				
Group III (Filtek Bulk fill)	20	59.5	68.661	3	<0.001	YES
Group IV (Sonic Bulk-Fill	20	11.3				

Table 3. Mann-Whitney U-Test Exhibits Significant Difference Between Groups.

GROUP	GROUP	U-Value	p-Value (Two tailed)	Significant difference?
Group I (Filtek Z350)	Group II (Filtek Z350 + Ribbond)	0	<0.001	YES
Group I (Filtek Z350)	Group III (Filtek Bulk fill)	180	0.53	NO
Group I (Filtek Z350)	Group IV (Sonic Bulk-Fill)	0	<0.001	YES
Group II (Filtek Z350 + Ribbond)	Group III (Filtek Bulk fill)	0	<0.001	YES
Group II (Filtek Z350 + Ribbond)	Group IV (Sonic Bulk-Fill)	16	<0.001	YES
Group III (Filtek Bulk fill)	Group IV (Sonic Bulk-Fill)	0	<0.001	YES

Figure 1. (a) Representative specimen from group 1 showing score 5. (b) Representative specimen from group 2 showing score 2. (c) Representative specimen from group 3 showing score 4. (d) Representative specimen from group 4 showing score 0.



distally from the center of the restoration with a diamond disk (Sunshine Diamonds, Langenhagen, Germany) at a low speed and with continuous irrigation of water.

Dye penetration was evaluated at the gingival margin with a stereomicroscope (Motic Microscopes, Xiamen, China) at 40X magnification, and microleakage was scored according to the six-point scale: 0 = no leakage, 1 = leakage extending to the outer half of the gingival floor, 2 = leakage extending to the inner half of the gingival floor, 3 = leakage extending through the gingival floor up to one-third of the axial wall, 4 = leakage extending through the gingival wall up to two-thirds of the axial wall, and 5 = leakage extending through the gingival wall up to the dentino-enamel junction level. The degree of dye penetration was independently scored by two examiners who were blind to the procedure. In case of disagreement between their evaluations, the worst score was considered.

The median of the scores was subjected to statistical analysis using the non-parametric Kruskal–Wallis analysis of variance test and the Mann–Whitney test at a 95% significance level. Statistical analysis was done using software STATA-13 IC.

Results

Descriptive statistics including the mean ranks for Kruskal-Wallis test are shown in Table 2. The Kruskal-Wallis test revealed highly significant differences in microleakage scores among the groups ($p<0.001$).

The Mann-Whitney U-test was used to make a pairwise comparison between the four studied groups, and it showed a significant decrease in microleakage scores when a Ribbond fiber insert and sonic energy was used; that is, group 2 showed a significant decrease in microleakage ($p<0.001$) when compared to group 1, and Sonic bulk fill group 4 showed a significant decrease in microleakage ($p<0.001$) when compared to Filtek Bulk fill group 3 (Table 3).

The Mann-Whitney U-test showed that there was no significant difference in microleakage scores in the Filtek Bulk fill composite when compared to the nanohybrid composite group; that is, group 3 did not showed a significant difference in microleakage ($p=0.530>0.01$) when compared to group 1 (Table 3).

Referring to mean rank values (Table 2), we can also conclude that group 4 had the least microleakage and that group 1 and 3 has the comparable maximum microleakage scores. Figure 1 shows microleakage scores in representative specimens of test groups under a stereomicroscope.

Discussion

For the increase longevity of any restoration, marginal integrity is the most essential factor. Polymerization shrinkage occurs in composite restorations due to conversion of monomer molecules into a polymer network which exchanges Van der Walls spaces into covalent bond spaces, creating contraction stresses in the resin composite. This stress developed inside the restoration leads to compromised marginal integrity due to shrinkage and ultimately leads to microleakage[14]. Microleakage problem is more evident in Class-II restorations where the gingival margins are placed below the cementoenamel junctions. This is because bonding to dentin and cementum is more difficult as it contains a higher percentage of water and organic substance as compared to enamel [3].

The various methods to detect microleakage include the dye leakage method, the use of radioactive isotopes, color producing microorganisms, neutron activation analysis, the air pressure method, electrochemical studies, scanning electron microscopy, thermal and mechanical cycling, and chemical tracers.[16] Since there is no gold standard method for microleakage evaluation, we used the dye leakage method because it did not require the use of complex laboratory equipment and because it is nondestructive, thus allowing the longitudinal study of restorative margins [17]. Also, in a study conducted by Moosavi H *et al.,* [18] and Camps J & Pashley D [19], the reliability of the dye penetration test was justified compared to other methods used to detect microleakage.

2% methylene blue dye was used in our study because the particle size of its molecule is less than that of bacteria (2-4 μ) and dentinal tubules (1-4 μ), so it mimics the passage of bacterial toxins into dentinal tubules. Moreover, methylene blue dye provides excellent contrast with surrounding which aids in easy visualization and scoring of microleakage scores of the prepared cavity in the digital images.[20] We have buffered the methylene blue solution from pH=3 to pH=7, to eliminate the possibility of microleakage occurring due to dissolution of enamel and dentin due to acidic pH of solution. Storage time for dye penetration varies from 10 seconds to 180 days. In our study, penetration time of 24 h is used as most of the studies used same for the in-depth determination of marginal gaps [2].

The results of our study showed a significant decrease in microleakage when Ribbond fibers were incorporated at gingival margin. Placement of a fiber insert at gingival margin replaces a part of composite resin gingivally, resulting in overall decrease in volumetric polymerization contraction and gingival microleakage. Also, fibers have the strengthening effect on a composite margin, resisting pull-away from the margins toward the curing light [2, 3, 8]. Result of our study is in accordance with the study conducted by El-Mowafy *et al.,* [21], Ozel and Soyman [8], and Basavanna *et al.,* [22]where there was decrease in microleakage score after insertion of fiber insert. But also, contradictory result is been reported by Dhingra *et al.,* [23] and Belli *et al.,* [6] in which no reduction in microleakage is shown after fiber insertion. The reason for such contradictory results might be the difference in method of placing the restorations, or difference in type of fibers used.

Regarding the incrementally placed Filtek Z350 nanohybrid composite and Filtek Bulk fill group, no significant difference was found in microleakage scores in our study, indicating that the bulk fill composite did not perform more efficiently compared to incremental composite. These results are in agreement with most recent study by Habib AN *et al.,* [24] and also reported by Campos *et al.,*[25].

Results of our study reported least microleakage score when Sonic energy was used for placing the Sonic Bulk fill composite. This sonic energy provides oscillation which temporarily increases flowability of SonicFill to achieve precise filling of cavities along with close adaptation to the preparation margins. SonicFill system consist of monomers (ethoxylated bisphenol A dimethacrylate, bisphenol A dimethacrylate, and triethyleneglycol), which is highly filled (barium glass and silicon dioxide) by weight (83.5%) and also includes special modifiers that react to the sonic energy. As sonic energy is applied through the hand piece, the modifier causes the viscosity to drop (up to 87%), increasing the flowability of the composite enabling quick placement and precise adaptation to the cavity walls. When the sonic energy is stopped, the composite returns to a more viscous, nonslumping state that is perfect for carving and contouring [14]. Study conducted by Swapna MU *et al.,* [14] also reported that SonicFill Bulk Fill composite showed less microleakage than the other conventional Bulk Fill composites.

There are some limitations to the present study:

(a)As only the sectioned part of the restored cavity was examined, the observed section might not necessarily be the best representative of the total leakage distribution. Dye penetration might vary from one zone to another in the same tooth–restoration interface;
(b) Being an in vitro study, the inferences from the study might not correlate completely with similar situations clinically;
(c) even though critical care was taken at every step, human errors cannot be ruled out from the final result.

Conclusion

Within the limitations of this study, it can be concluded that the use of polyethylene fiber inserts and sonic energy significantly reduces microleakage in class II resin composite restorations with gingival margins below the cemento-enamel junction. But there is no difference in microleakage comparing Bulkfill composite without sonic activation and incrementally placed nanohybrid composite.

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