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Original Research Article.

Comparative Evaluation of Sealing Ability of Newer Materials Used As Dentin Substitutes in Class II Sandwich Restorations: An In Vitro Study

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ABSTRACT

Introduction: Even with the advances and innovations in restorative dentistry, microleakage is regarded one of the main problems in this area.

Objective: To evaluate in vitro marginal microleakage of Biodentine, Fuji II LC and SDR at the cervical level and at the interface these materials with Tetric N Ceram Bulk fill composite and also to note the marginal microleakage when these materials were used as bulk fill materials.

Materials and Methods: Cavities, standardized on the mesial and distal surfaces, were prepared in thirty molars and randomly assigned to two groups (n = 30), according to the mode of restoration done.Goup1 (control) in which test materials were used as bulk fill. These were further subdivided into subgroups according to the material. SG1: Biodentine (SEPTODONT); SG2: Fuji II LC (GC); SG3: SDR (Dentsply). Group2 (experimental) in which test materials used as dentin-substituent in class II sandwich technique followed by restoration with Tetric N Ceram (Ivoclar vivadent). These were also divided into subgroups, SG4: Biodentine + Tetric N Ceram; SG5: Fuji II LC + Tetric N Ceram; SG6: SDR + Tetric N Ceram. After storage for 24 hours in an incubator (37 °C), the samples were submitted to the thermocycling test (500 cycles: 5 °C/55 °C). They were later waterproofed, immersed in 1% methylene blue solution and sectioned in the mesial-distal direction for evaluation under stereomicroscope at 30x magnification (Nikon SMZ 1500 *Zoom* Stereomicroscope) *Scores* from 0 to 3 using the ISO microleakage scoring system (ISO/TS 11405:2003). The ANOVA Test and Post- hoc Test, with a significance level of 5%, were used for statistical analysis.

Conclusion: The study concluded that SDR (SD 2.38) showed the least amount of microleakage both at the occlusal and at the cervical levels in open sandwich restorations and also when used as bulk fill materials as compared with Biodentine (SD 1.73) and Fuji II LC (SD 1.00).

Key words: SDR, Biodentine, Fuji II LC, Microleakage, Stereomicroscope.

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INTRODUCTION

Amalgam has been used as a dental restorative material since the 19th century, over 150 years ago, and has been used as the preferred material for nearly all restorations not requiring high levels of aesthetics.[1,2] During the past 60 years, the use of composite resin for direct restorations in anterior and posterior teeth has increased significantly[3], largely due to the esthetic demands of the patients and concerns regarding mercury in amalgam fillings.[4] Because composite resins require little to no preparation, minimally invasive procedures can be used to preserve tooth structure and provide natural-looking results.[5] Composite resins also may eventually replace silver amalgam for direct restorations.[6]

Although composites are now the material of choice for most restorations[7], their polymerization shrinkage remains a problem.[8,9] The contraction stress associated with this shrinkage can cause debonding at the composite/tooth interface and can contribute to post-operative sensitivity, enamel fracture, recurrent caries, marginal staining and eventual failure of the restoration.[10,11] The effects of microleakage include pulpal irritation, marginal discoloration and secondary caries.[11-13] It may be defined as the clinically undetectable passage of bacteria, fluids, molecules or ions between a cavity wall and the restorative materials applied to it.[14] Most restorative materials show varying degrees of marginal leakage because of dimensional changes and a lack of adaptability to cavity walls.[15] These effects are due to the presence of bacteria, their nutrients or hydrogen ions, originating from plaque on the surface, leaking into the interfacial space.[16,17]

The open-sandwich technique was proposed to solve the problem of cervical micro-leakage of deep Class II composite restorations by making use of the self-adhesive nature of the glass-ionomers. Recent advances in the properties of this family of materials may continue to make the technique relevant today.

McLean and Wilson[18] first described the open-sandwich technique in 1977, proposing it as a method to improve adhesion of resin composite restorations. The technique was developed to limit the shortcomings of posterior composite restorations, particularly their lack of permanent adhesion to dentine, which could result in microleakage and postoperative sensitivity. Mount[19] advocated that the glass-ionomer (GI) at the cervical margin be left exposed to allow released fluoride to protect the surrounding tooth structure. This became known as the open-sandwich technique.

The open-sandwich technique failed clinically when conventional GI's were used to restore the cervical margins of Class II restorations, mainly because of a continuous loss of material.[20-23] Consequently, the then newly developed resin-modified glass ionomers (RMGI) were used in place of conventional GI.

One of the most popular brands for RMGI is FUJI II™ LC from GC. These materials have been used for restoration of highly caries–active patients such as bulimics, radiation–therapy patients, chemotherapy patients, or those with senile caries with notable clinical success.

Another material which can be used under open sandwich restorations is flowable composites. Flowable composite resins have gained popularity in the last decade and have been used in a wide range of composite resin restorations. The viscosity is lower due to the reduced filler load (Gallo et al. 2010).[24]

Researchers at DENTSPLY have now developed modified monomers which, in combination with conventional methacrylate-based monomers, lead to significantly reduced polymerization stress independent of the filler load. With this, the idea was created to develop a flowable material that allows an efficient and safe cavity filling technique. As a flowable consistency is not ideal for either the occlusal reconstruction or the required wear resistance, the occlusal capping with a universal composite was considered from the beginning. In other words, dentine can be cleverly replaced with SDR™ - Smart Dentin Replacement.

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.[25]

To the best of our knowledge, no study has compared the sealing ability of Biodentine, SDR and Fuji II LC in class II sandwich technique. Therefore, the aim of the current study was to compare the marginal adaptation and sealing ability of an RMGIC, a flowable composite and biodentine as a dentin substitute in Class II sandwich restorations.

METHODS

Thirty freshly extracted human, non-carious maxillary molar were used in this study. The visual inspection with a light microscope was done to ensure that the teeth did not present any caries or cracks due to extraction. The extracted teeth were cleaned thoroughly to remove both hard and soft deposits and were kept in saline solution at room temperature to maintain hydration of the samples being used for mechanical testing.

Cavity Preparation

Standardized Class II mesial and distal simple box cavities were prepared in each tooth, with the gingival margins of the cavities placed approximately 1 mm above the CEJ. The cavity preparation was done on thirty teeth, on both mesial and distal surfaces of the tooth, making it sixty cavities. The dimensions of the cavity were 3 mm in the buccolingual dimension at occlusal level; 3 mm in the buccolingual dimension at the gingival floor, 2 mm mesiodistally and 5mm depth of proximal box. They were prepared using standard/ 106- 125µm diamond burs SF-41 (Straight Flat End, DIA- BURS MANI, INC.) and 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.

Cavity Restoration

All the prepared samples (sixty prepared cavities) were randomly divided into two groups, control group and the experimental group (n=30), depending on the mode of restoration (bulk fill or class II open sandwich restoration). The control group was divided into three subgroups i.e. subgroup I, subgroup II and subgroup III. Each group (n=10) were restored with Biodentine (n=10), Fuji II LC (n=10) and SDR (n= 10) respectively, which were used as Bulk fill materials. The experimental group was also further divided into three subgroups i.e. subgroup IV, subgroup V and subgroup VI (n=10). They were filled by Biodentine, Fuji II LC or SDR which were used as dentin substitutes respectively, followed by Tetric N-Ceram composite (shade A1) which was used for all restorations.

Dye Penetration

After the restoration procedure, the teeth were stored in distilled water and incubated at 37°C for 24 hours. The teeth were then subjected to 500 thermocycles in a thermocycling machine (Thermomixer comfort by Eppendorf) at temperature range of 5⁰C ± 2⁰C and 55⁰C ± 2⁰C with a dwell time of 30 sec and a transfer time of 10sec between two temperature ranges. This was done in order to stimulate temperature fluctuations found in oral cavity.

Microleakage Testing

After the completion of thermocycling the apices of the specimens were sealed with epoxy resin (Araldite, Brascola Ltda, Sao Bernardo do Campo, Brazil) and coated with two applications of fingernail polish except for an area approximately 2mm from the periphery of the restoration. Each layer of nail polish was allowed to dry before the next layer was applied. The coated teeth were then immersed in 1% methylene blue solution (fisher scientific by Thermo Fisher Scientific) for 24 hours at normal room temperature.

Microleakage Measurement

The samples were removed out of the dye and thoroughly washed for 5 minutes. They were cleaned with a sterile number 15 BP blade to remove any excess of nail varnish 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 attached to a slow speed micro motor handpiece in a buccolingual direction through the centre of the tooth to separate the two proximal (mesial and distal) class II restorations. They were also sectioned mesiodistally from the centre of the restoration so that it divides into two equal halves in order to evaluate the dye penetration at the tooth/ restoration interface. The sectioned specimens were observed with a steromicroscope at 30x magnification (Nikon SMZ 1500 *Zoom* Stereomicroscope) to measure the depth of dye penetration at the cervical levels and also at the interfaces of the restorative materials used as dentin substituent and the bulk fill material. The score was evaluated using the ISO microleakage scoring system (ISO/TS 11405:2003).

The cervical microleakage scoring criterion was:

0 = No dye penetration
1 = Dye penetration into ½ of the cervical wall
2 = Dye penetration into all the cervical wall
3 = Dye penetration into cervical and axial wall towards pulp

The occlusal microleakage scoring criterion was:

0 = No dye penetration
1 = Dye penetration into enamel
2 = Dye penetration into dentine, not including the pulpal wall
3 = Dye penetration into dentine including the pulpal wall

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 data collected was tabulated and subjected to statistical analysis to compare the microleakage using ANOVA Test and Post- hoc Test.

Table 1: Various distribution of microleakage scores along the cervical margin

Dye Penetration scores	Sub Group I	Sub Group II	Sub Group III	Sub Group IV	Sub Group V	Sub Group VI
Score 0	1	2	6	2	3	5
Score 1	1	2	1	4	4	3
Score 2	4	2	1	0	1	2
Score 3	4	4	2	4	2	0

Table 2: Various distribution of microleakage scores along the occlusal margin

Dye Penetration scores	Sub Group IV	Sub Group V	Sub Group VI
Score 0	3	4	3
Score 1	3	2	5
Score 2	3	4	2
Score 3	1	0	0

Table 3: Statistical analysis of mean microleakage of different groups

Group	Upper value	Lower Value	Standard Deviation	Variance	Margin of Error
Sub Group I	4	1	1.73	3.00	2.75
Sub Group II	4	2	1	1.00	1.59
Sub Group III	6	1	2.38	5.67	3.78
Sub Group IV	4	0	1.91	3.67	3.04
Sub Group V	4	1	1.29	1.67	2.05
Sub Group VI	5	0	2.08	4.33	3.31

Table 4: Statistical analysis of mean microleakage of different groups

Group	Upper value	Lower Value	Standard Deviation	Variance	Margin of Error
Sub Group IV (Biodentine + Tetric N Ceram)	3	1	1.00	1.00	1.59
Sub Group V (Fuji II LC + Tetric N Ceram)	4	0	1.91	3.67	3.04
Sub Group VI (SDR + Tetric N Ceram)	5	0	2.08	4.33	3.31

RESULTS

The table 1 and table 2 show the distribution of dye penetration scores along the cervical and the occlusal margins respectively. The result of the present study in table 3 demonstrated that there was statistical significance between various groups ($p < 0.05$). Maximum dye penetration was seen in Fuji II LC (subgroup II) SD 1.00 ($p < 0.005$), and minimum dye penetration occurred in SDR (subgroup III) SD 2.38 when evaluated along the cervical margins. Biodentine (subgroup I) also showed a considerable amount of dye penetration (SD 1.73) which was slight less than that of Fuji II

LC (subgroup II). Similarly, when evaluated along the occlusal margins of tooth and restoration in class II sandwich restorations, table 4 depicts SDR + Tetric N Ceram (subgroup VI) showed the minimum amount of dye penetration (SD 2.08), which was significant i.e. $p < 0.05$. Fuji II LC + Tetric N Ceram (subgroup V) also showed close amount of dye penetration (SD 1.91). Biodentine + Tetric N Ceram (subgroup IV) showed considerable a high amount of dye penetration (SD 1.00).

DISCUSSION

In vitro tests remain an indispensable method for initial screening of dental materials and set a theoretical maximum amount of leakage that could be present in vivo.[26] Several techniques have been devised to test the microleakage of restorations in vitro. In vitro studies include the use of stains, radioactive isotopes, air pressure, bacteria, neutron activation analysis, scanning electron microscopy, artificial caries technique, autoradiography and elective conductivity. According to Myers margins of restoration possess dynamic micro crevices that contain a busy traffic of ions and molecules.[27,28]

Dye penetration is one of the most frequent used methods to evaluate microleakage.[29,30] In the current study, a dye penetration test was used because it is simple and relatively cheap and provides quantitative and comparable results. This method does have some limitations, however such as subjectivity of reading and high diffusability of dyes due to their low molecular weight.[31]

In the present study, we compared and evaluated the microleakage at cervical margin of BIODENTINE (SEPTODONT; St Maur Des Fosses, Val de-Marne, France), Fuji II LC resin-modified GIC (GC America Inc) and Posterior Bulk Fill Flowable Base SDR (Dentsply Caulk, USA) when used as bulk fill materials, microleakage at the interface of BIODENTINE (SEPTODONT; St Maur Des Fosses, Val de-Marne, France) /Tetric-N-Ceram Bulk fill composite (Ivoclarvivadent, India), Fuji II LC resin-modified GIC (GC America Inc) / Tetric-N-Ceram Bulk fill composite (Ivoclarvivadent, India) and Posterior Bulk Fill Flowable Base SDR (Dentsply Caulk, USA) / Tetric-N-Ceram Bulk fill composite (Ivoclarvivadent, India), in posterior class II open sandwich restoration and also the marginal sealing efficacy of above mentioned materials used as dentin substitutes at cervical margins, in a posterior class II open sandwich restoration. Thirty maxillary molars were selected as samples. Class II box only cavities were prepared on both the proximal surfaces. All the class II cavities had similar dimensions with no bevel so as to standardize the preparations. Class II termination involving dentin type cavities has been studied by numerous authors.[32-37] The class II type wells have cervical margin in dentin, have a determining factor for longevity of same, the occurrence of infiltration by marginal leakage. In an attempt to minimize problems inherent restorations have appeared in numerous market restorative materials with physical and mechanical properties seeking to better dissipate stress, thereby causing a lower leakage.[33]

All the teeth were stored in an incubator at 37^{o}C and 100% relative humidity for 24 hours to prevent dehydration.[38] In vitro evaluation of restorative materials fails to simulate the intraoral thermal changes during eating and drinking. Thermocycling is a widely acceptable method used in microleakage studies to simulate the effects that restorations are subjected to in the mouth.[39-41] Some researchers, however, consider it a questionable method since the temperature used may not be the real temperatures of hot and cold beverages tolerated by patients.[16,42] Thermal cycles ranging between 200 and 1000 were used in some studies (Bertrand et al., 2006; Sungurtekin and Oztas, 2010). In this present study 500 thermal cycles were used.

Hembree et al., 1984; suggested that samples of different groups should be sealed with different colors of nail varnish leaving 2mm of margin from the periphery of the restoration. The reason is that; first it gives easy identification between samples of all groups and secondly to seal the channels of bacterial penetration and dye penetration such as apical foramen, lateral canals and any cracks on the coronal and the radicular surface of the samples.

1% methylene blue dye was chosen as the agent of dye penetration to measure microleakage because it is simple, inexpensive, and does not require the use of complex laboratory equipment. Also, the particle size of this dye is less than the internal diameter of the dentinal tubules (1-4µm), so it is able to show dentin permeability.[43] The specimens were soaked in the dye for twenty four hours which is considered to be a standard time span for dye to penetrate.

In the present study, stereomicroscopic observations were done for the microleakage in the interfaces which is an established method and gives a clear in depth image with the help of recent image processors and software's.

Biodentine exhibited a reduction in the chlorine peak and calcium silicon ratio when etched. Biodentine exhibited leakage both when it was etched and also when the surface was left unprepared. When used as a dentine replacement material in the sandwich technique over layered with composite, significant leakage occurred at the dentine to material interface.[44] Raskin et al[45] found that Biodentine when used in cerival restorations as dentine substitutes seems to perform better with or without any conditioning treatment than Resin modified GIC (Fuji II LC).

The best result have been shown by group III and group VI which were restored by SDR as bulk fill material and dentin substitute in class II open sandwich restoration respectively.

Smart dentin replacement (SDR) (Dentsply, Konstanz, Germany), includes a photoactive group in a modified urethane dimethacrylate resin. Activated resin has demonstrated a relatively slow radical polymerization rate, suggesting that the photo initiator incorporated into the resin affects the polymerization process; moreover, the incorporation of activated resin results in 60-70% less shrinkage stress when compared to conventional methacrylate-based resins.[46,47] SDR was initially marketed as a flowable composite resin whose reduced polymerization stress allowed it to be applied in bulk in a single layer up to 4 mm thick, followed by a mandatory 2-mm cover layer of conventional composite resin. However, despite ongoing debates regarding, the use of flowable composite resin material to relieve stress, and promote adaptation, its aforementioned usages have yet to be confirmed in any clinical study. In the only study, conducted to date that describes the relevant parameters for SDR, the polymerization stress level of SDR was reported to be considerably lower than that of conventional flowable materials.[46,48]

Koltisko et al.[49] found the polymerization stress of SDR to be lower than that of other flowable composites, whereas no differences were found in flexural modulus and volumetric shrinkage (3.5% volume) of the composites tested. According to, Burgess et al.[50] the chemistry of SDR is designed to slow the polymerization rate, thereby reducing polymerization shrinkage stress without affecting polymerization shrinkage levels. Jin et al.[47] found that the new SDR resin system in unfilled, as well as in various differently filled formulations, exhibited less curing stress than conventional resin.

Another study done by Farhad[51] to determine and compare the shear bond strength and microleakage properties of active restorative with other bulk-fill restorative materials surefil (SDR), Biodentine, ever X posterior. They found that SDR (surefil) showed better shear bond strength and better microleakage properties compared with the other test materials.

Lotfi et al[52], evaluated gingival microleakage in class II composite restorations using different flowable composites as liner and found that Surefil SDR flow as a liner had lower microleakage than other flowable composites (tetric flow, grandio flow, filtek supreme xt flow). Elhawary et al[53] found that the Bulk fill flowable composite SDR has better degree of conversion in comparison to other flowable composites used in the study. It was also concluded that it had the best marginal seal in both in both occlusal and cervical margin among all the groups.

Tetric N-Ceram was used as a main restorative material in class II sandwich technique for group IV, group V and Group VI. Tetric N-Ceram is a light-curing, radiopaque nano-hybrid composite based on nano-optimized technology for direct restorative procedures. It can be universally applied to restore teeth in the anterior and posterior region. Its nano-optimized filler technology is responsible for the material's unique chameleon effect and natural esthetic results.

CONCLUSION

Based on this above study, while evaluating the microleakage of the test materials along the cervical and the occlusal margins, it was concluded that within limitations of this study;

1. Among the three different dentin substitute materials tested SDR (Sub Group III), when used as Bulk fill material showed the best sealing ability at the cervical margins and Fuji II LC (Sub Group II) showing the least sealing ability.
2. SDR + Tetric N Ceram (Group VI), when used as test material in Class II open sandwich restoration showed the least microleakage, thus the best sealing ability at the cervical margin.
3. At the occlusal margin, SDR + Tetric N Ceram (Group VI) showed the least microleakage amongst all materials, thus showed a satisfactory result, whereas Biodentine + Teteric N Ceram (Sub Group IV) showed the least satisfactory results.
4. There is a significant difference between Biodentine, Fuji II LC and SDR when used as test materials at both the cervical and the occlusal levels.
5. The sealing ability of three different materials tested in descending order are; SDR > Biodentine > Fuji II LC when evaluated at the cervical levels.
6. The sealing ability of three different materials tested in descending order are; SDR > Fuji II LC > Biodentine when evaluated at the occlusal levels.

SureFil SDR has been a "game changer" in the placement of Class I and II posterior composites. Research shows that the proximal box is the area where the negative effects of polymerization shrinkage are most significant. Deeper fillings have greater polymerization contraction stress in the cavity configuration due to less flow capacity of the composite.[54]

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