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Evaluation of Gap Distance of Different Types of Resin-Based Composites on Extracted Permanent Molars: In-Vitro Study

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Resin, composite, flowable, Filtek, Marginal leakage.

Abstract

Background: To overcome the time-consuming incremental cavity-filling technique with conventional resin-based composites, bulk-fill resin-based composites have been developed. This newly developed kind of resin-based composite claims to allow the use of material increments up to 4 mm in thickness with low volumetric polymerization shrinkage and resulting low polymerization shrinkage stress.

Methods: A total of 24 caries-free extracted human mandibular molars were used in this study (n=12 per group). Teeth were measured using an electric digital caliper to be of comparable size. The teeth were visually examined under 3X magnification using univet magnifying loupes for any hypoplastic defects or fracture/craze lines. The cleaned teeth were then stored in saline at room temperature until use. All the prepared teeth were randomly divided into two main groups (n=12 per group) according to the type of resin-based composite used. The groupings were as follows: In Group 1, teeth were restored with Filtek™ Bulk Fill Posterior Restorative. In Group 2, teeth were restored with Filtek™ Z350 XT Universal Restorative.The collected data was tabulated and statistically analyzed using two-way ANOVA.

Results: It was found that in group I (Filtek™Bulk Fill Posterior Restorative), the median microleakage score was 2.0 which is significantly higher than the median microleakage scores of group II (Filtek™Z350 XT Universal Restorative) which was 0.5. There was a statistically significant difference with a *P* value = 0.037. While the marginal gap distance for group I scored (0) there was no penetration at the mesial wall and pulpal wall while the distal wall showed a 1.53µm marginal gap distance. In group II (Filtek™Z350 XT Universal Restorative) there was no penetration at the mesial wall, distal wall, and pulpal wall for score (0).

Conclusion: Marginal microleakage was higher in Filtek™Bulk Fill Posterior Restorative than in Filtek™Z350 XT Universal Restorative resin-based composite..

1 Introduction

With the advancement of dental materials, along with higher patient expectations for aesthetics, resin-based composites have become the predominant choice for restorative dental procedures. They are now widely utilized not only for front teeth but also for back teeth to achieve aesthetic dental restorations [1,2].

While resin-based composites possess favorable physical characteristics, their primary drawbacks include polymerization shrinkage and stress, which lead to internal microcracks within the material. These issues can also cause the bonding agent to detach from the cavity wall, resulting in gaps, marginal leakage, postoperative sensitivity,

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discoloration, recurrent decay, enamel microcracks, tooth deformation, wear, and reduced restoration fracture resistance [3,4,5].

Over the past six decades, there has been a notable rise in the use of resin-based composites for direct restorations in both front and back teeth[6]. There is a possibility that they could eventually replace silver amalgam for direct restorations[7]. The primary objective is to improve the durability and usability of resin-based composites (RBCs). Since their inception in dentistry, RBCs have seen advancements in filler [8], matrix [9], and initiator technologies[10]. Practical approaches include adapting cavity designs with a low C-factor, exploring different light-curing methods[11], employing flowable cavity liners[12], and refining restoration placement techniques[13].

Resin-based composite manufacturers now provide bulk-fill materials, aiming to streamline cavity-filling procedures. These materials allow for single increments up to 4mm, reducing clinical steps by enabling efficient and predictable placement with a single filling material and increment [14,15,16,17].

A drawback of resin-based composites (RBCs) is their tendency to shrink upon polymerization due to radical polymerization. This shrinkage leads to polymerization stress[18], which impacts the bonding interface and adjacent dental tissue, resulting in issues such as cuspal deflection[19], enamel cracks, marginal breakdown, gap formation, and microleakage[20]. These issues can potentially lead to secondary caries and premature restoration failure. While collecting clinical evidence linking shrinkage stress to in situ failure is challenging[21], in vitro studies underscore the necessity of developing strategies to minimize resin-based composite shrinkage stress[22].

To streamline the traditional incremental cavity-filling technique used with conventional resin-based composites, bulk-fill resin-based composites have been introduced. These newer materials allow for thicker increments, up to four mm in thickness, claiming to minimize volumetric polymerization shrinkage and resulting polymerization shrinkage stress.

Practitioners are increasingly adopting bulk-fill resin-based composite (RBC) materials. Yet, there is a noticeable lack of clinical literature assessing their performance and understanding the debonding dynamics at the tooth-restoration interface compared to conventional RBCs. Consequently, current research primarily centers on in vitro studies to address these knowledge gaps.

Modern composite resins exhibit superior durability, improved handling properties, reduced shrinkage, enhanced polishability, stronger bond strengths, and achieve highly aesthetic results. However, composite placement remains technique-sensitive and polymerization shrinkage is a problem [23,24]

Bulk fill resin-based composites:

Restoring posterior teeth with resin-based composites traditionally involves a time-consuming process. The incremental technique, recommended with two mm thickness increments, is widely practiced[25,26]. However, when filling extensive cavities in posterior teeth, this approach risks trapping air bubbles or contaminants between the layers[27]. Both clinicians and patients seek efficient, high-quality dental care with minimal chair time.

To simplify procedures, manufacturers have introduced bulk-fill resin-based composites. These materials enable faster placement by allowing single increments of up to four mm, thereby reducing the number of clinical steps involved. Their high color translucency facilitates deeper light penetration, aided by their low shrinkage and high filler content, which minimize shrinkage stresses and allow for thicker application layers. Additionally, these composites feature universal shades, simplifying the color-matching process and requiring less time for finishing and polishing the restorations[28,29]. The newly developed bulk fill resins offer composites including low-viscosity (flowable) and high-viscosity (sculptable) material types. The high-viscosity bulk fill material was tested in this in vitro study.

Children and patients stand to gain significantly from the time-saving benefits, enhanced aesthetics, and reliable marginal sealing offered by modern dental materials. These advantages help prevent issues such as microleakage, which can lead to clinical problems like marginal discrepancies, staining along restoration edges, recurrent caries, sensitivity, and discomfort[30].

2 Materials and Methods

2.1 Ethical Approval:

The method employed in this study was approved by the research ethical committee (Faculty of Dentistry - MSA University). The research was granted confirmation of conductance number (ETH37).

2.2 Materials :

Two types of commercially available resin-based composites were selected for this study: Bulk Fill resin-based composite (Filtek™Bulk Fill Posterior Restorative) and conventional resin-based composite (Filtek™Z350 XT Universal Restorative), as shown in **(Fig. 1, 2).**

Figure 1. A photograph showing the Bulk Fill resin-based composite (Filtek™Bulk Fill Posterior Restorative).

Figure 2. A photograph showing the conventional resin-based composite (Filtek™Z350 XT Universal Restorative).

2.3 Samples selection:

A total of 24 caries-free extracted human mandibular molars were used in this study (n=12 per group) as shown in **(Fig. 3)**. Teeth were collected from the National Institute of Diabetes and Endocrinology. Teeth were measured using an electric digital caliper to be of comparable size. The teeth were visually examined under 3X magnification using univet magnifying loupes for any hypoplastic defects or fracture/craze lines. The surface deposits and stains were carefully removed with ultrasonic scaling1. The cleaned teeth were then stored in saline at room temperature until use.

Figure 3. A photograph showing some of the caries-free extracted human mandibular molars used in the study.Teeth without soft tissue remnants or calculus.

2.4 Samples preparation:

For each tooth, the removal of the cusp tip was made. This type of reduction was necessary to provide a flat occlusal surface having centrally located enamel so that the light curing units could be held at a repeatable distance of 2mm from the occlusal margin[31].

Following cusp tip removal, a standardized Class I cavity was prepared (4x4 ± 0.2 mm) within each tooth under copious water irrigation and high-speed handpiece[2] using intensive stones Ser-inlay set I [31].

All dimensions of each preparation were measured using a digital caliper and Williams periodontal probe[3]. Preparations in which pulp exposure was noticed were excluded from the study.

2.5 Classification of samples:

All the prepared teeth were randomly divided into two main groups (n=12 per group) according to the type of resin-based composite used. The groupings were as follows:

In Group 1, teeth were restored with Filtek™ Bulk Fill Posterior Restorative.

In Group 2, teeth were restored with Filtek™ Z350 XT Universal Restorative.

2.6 Restorative procedures:

The selection of material for each cavity preparation was randomized using a method where containers were shuffled to ensure an equal probability of each tooth being assigned to any group. Containers were unlabeled to maintain complete blinding and minimize bias. All cavities underwent acid etching for 20 seconds, followed by rinsing with water for ten seconds.

After drying the surfaces using an airway syringe, a single layer of Single Bond Universal Adhesive was applied using a micro brush, gently air-dried, and light-cured for 20 seconds. Following this preparation step, the teeth were restored using either conventional or bulk-fill resin-based composite materials according to the manufacturer's guidelines. For conventional resin-based composite, each cavity was filled in two increments, each two mm thick, and each increment was cured for 20 seconds. In contrast, the bulk-fill resin-based composite was applied in a single 4 mm thick increment per cavity and also cured for 20 seconds. Subsequently, the restorations were finished using a fine-grit diamond bur and polished using graded abrasive discs, rubbers, and polishing paste, following standard protocols [32].

2.7 Thermocycling:

Afterwards, the restored teeth were thermocycler[4] as shown in **(Fig. 4)** for 500 cycles between 5 ± 2°C and 55 ± 2°C with a dwell time of 30 seconds in each bath and 20 seconds intervals between baths[33, 34].

Cavitron select SPS, Dentsply

(Sirona dental system GmbH,D-64625 Bensheim, Germany)
(NOVR,N0093-O, England)
Petrotest GmbH, Dahlewitz, Germany thermocycling machine.

Figure 4. A photograph showing the Petrotest GmbH, thermocycler.

2.8 Dye penetration:

After thermocycling the restored teeth, the root apices were sealed with pink wax[35]. Each tooth was then coated with two layers of fingernail varnish, leaving approximately 1mm of the area around the tooth/restoration interface uncovered. This step aimed to prevent dye penetration from invisible cracks or areas lacking enamel or cementum[36]. Next, all teeth were embedded in epoxy resin blocks parallel to their long axes using a custom-made rubber mold, positioned apically to the cemento-enamel junction, as depicted in **(Fig. 5)**. The embedded teeth were kept in physiological saline for 24 hours to hydrate the desiccated tissues.

Subsequently, the restored teeth were immersed in a 1% methylene blue solution for 24 hours at 37°C. Following dye exposure, the teeth were rinsed under tap water for one minute[37].

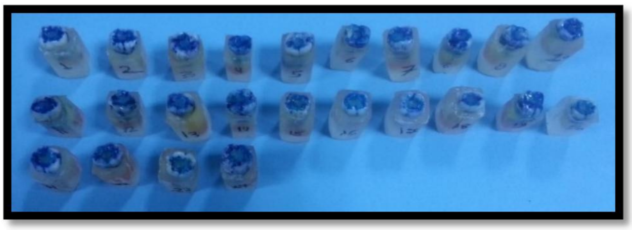


Figure 5. A photograph showing the prepared samples used for the evaluation of marginal integrity tests.

2.9 Teeth sectioning:

Each tooth was mounted on a cutting machine[5] as shown in **(Fig. 6)**. The teeth were sectioned mesiodistally into two halves in a vertical plane parallel to the long axis of the tooth under water coolant. The sectioning was performed using a diamond disc of 4mm diameter x 0.3 mm thickness with wear-resistant Ti-C coating for the low-speed saw.

(Bronwill; E. McGrath Inc, 35 Osborne Street Salem MA 01970 v: 978-744-3546 f: 978-741-4020)

Figure 6. A photograph showing the cutting machine used for sectioning the teeth specimens.

2.10 Marginal integrity measurements:

2.10.1 Marginal leakage (depth of dye penetration):

The depth of dye penetration (marginal leakage) was measured in each restoration along the side walls for both halves of each tooth to determine three-dimensional microleakage using a stereomicroscope[6] at 10X magnification[38, 39] as shown in **(Fig. 7)**. The images were analyzed using a modified five-grade scale for both groups[37].

Figure 7. A photograph showing the stereomicroscope used for examining the marginal leakage.

<u>**Score details:**</u>

(0) No dye penetration along the filling-tooth interface.

(1) Dye penetration along the filling-tooth interface up to half of either the lateral walls A or B.

(2) Dye penetration along the filling-tooth interface along all of either the lateral walls A or B (till the bottom of the cavity, pulpal wall).

(3) Dye penetration along the filling-tooth interface up to half of both lateral walls A and B.

(4) Dye penetration along the filling-tooth interface along

Leica microsystem,Ltd.ch.9435 Heerbrugg,Switzerland
stereomicroscope
(Image J 1.43U, National Institute of Health, USA)
(Scope Capture Digital Microscope, Guangdong, China)
SEM (QUANTA FG 250)

both lateral walls A and B (till the bottom of the cavity, along the pulpal wall) as shown in **(Fig. 8 & 9)**.

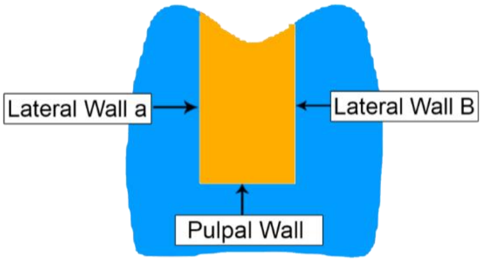


Figure 8. A Schematic drawing showing microleakage assessment along the longitudinal cross-section.

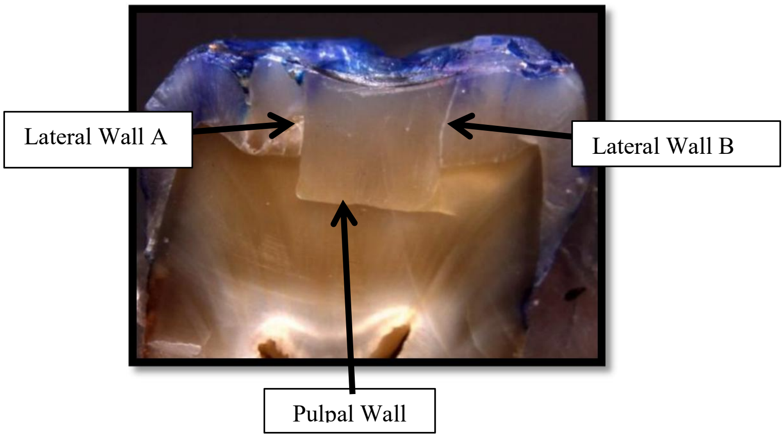


Figure 9. A stereomicroscope photograph showing microleakage assessment along the longitudinal cross-section of the tooth.

2.10.3 Digital Microscope Assessment:

The dye penetration along the cavity walls was further assessed using a USB Digital microscope[7] at 25× magnification in which the image was captured and transferred to a computer equipped with the image analysis software program[8]. Within the Image J software, all limits, sizes, frames, and measured parameters are expressed in pixels. Therefore, system calibration was done to convert the pixels into absolute real-world units. Calibration was made by comparing an object of known size (a ruler in this study) with a scale generated by the Image J software. Then, the images of the traced dye path were overlaid to calculate dye penetration depth. The total dye penetration depth along the restoration-tooth interface was measured in (mm).

2.10.2 Marginal gap assessment:

A single representative sample from each score of both groups was prepared for examination using a Scanning Electron Microscope (SEM), as illustrated in Figure 10. The samples were affixed onto aluminum stubs using an adhesive material, and a layer of carbon paste was applied to one side of each sample.

Subsequently, the stubs were placed in a sputtering coater device for ten seconds to apply a thin coating of gold, which acts as an electrical conductor. After coating, the stubs were securely attached to the standard specimen holder used for SEM examination. Finally, the specimen holder was mounted onto the SEM's specimen chamber mounting table for analysis.

Figure 10. A photograph showing SEM used for evaluation of marginal gap.

All the samples were examined at 1600X magnification to detect marginal gaps along the restoration/enamel interfaces at mesial, distal, and pulpal regions. The measurement of marginal gap width (the distance between the dental wall and the restoration) in each tooth was taken at three points in the pulpal region, six points at the proximal region [39] points on the mesial side, and three points on the distal side) [40] as shown in **(Fig. 11)**. The largest marginal gap width from the three points on each side of the region was recorded in micrometers (μm) by Tescan image processing software[9].

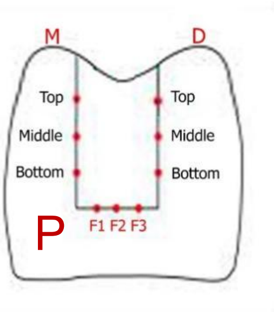


Figure 11: A Schematic drawing showing the location of the points (•) in each region.

3 Results

The present study shows the marginal integrity of two different groups of resin-based composites.

Group I: Filtek™Bulk Fill Posterior Restorative (Intervention).

Group II: Filtek™Z350 XT Universal Restorative (control group).

The study was done using sound-extracted human molars.

(Atlas softversion 3.5, Germany)

3.1 Marginal leakage (depth of dye penetration using stereomicroscope):

The marginal microleakage was done on sound-extracted human molars using a stereomicroscope. It was found that in group I (Filtek™Bulk Fill Posterior Restorative), the median microleakage score was 2.0 which is significantly higher than the median microleakage scores of group II (Filtek™Z350 XT Universal Restorative) which was 0.5. There was a statistically significant difference with a P value = 0.037 as shown in **(Fig. 12)**.

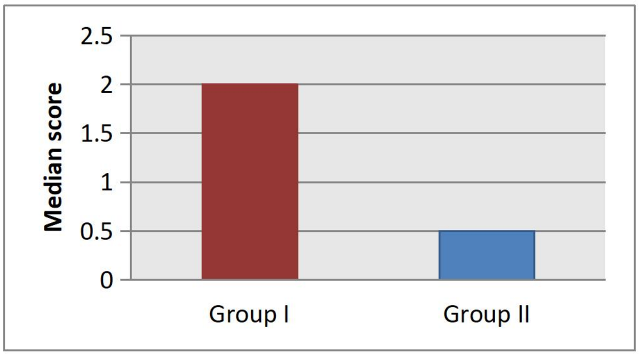
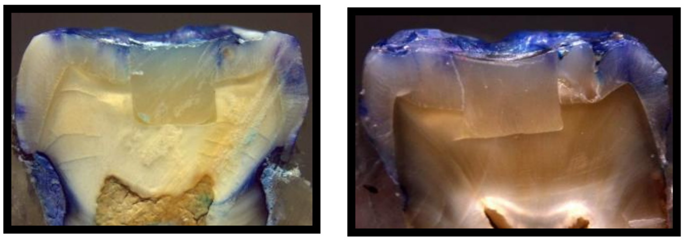


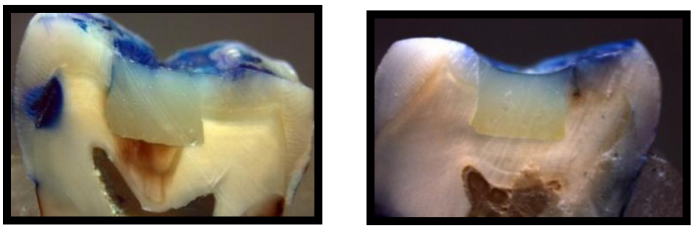
Figure 12. A bar chart showing the median leakage scores in both groups.

Representative microleakage score images for both groups using a stereomicroscope:



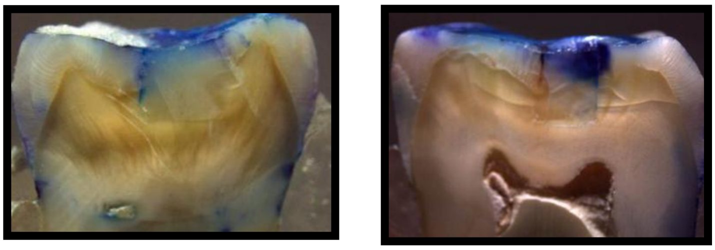
(A) **(B)**

Figure 13. Stereomicroscope photographs showing score (0) for group I (A) and group II (B).



(A) **(B)**

Figure 14. Stereomicroscope photographs showing score (1) for group I (A) and group II (B).



(A) **(B)**

Figure 15. Stereomicroscope photographs showing score (2) for group I (A)and group II (B).

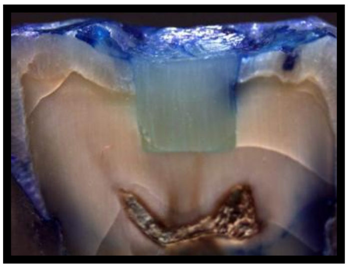
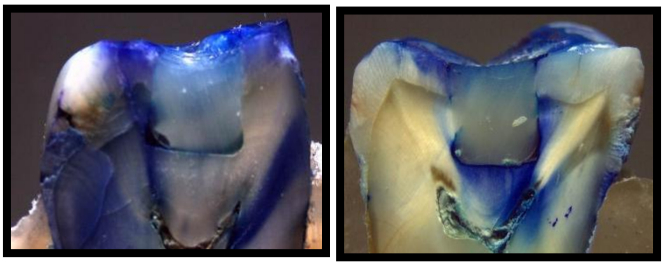


Figure 16. A stereomicroscope photograph showing a score (3) for group II.



(A) **(B)**

Figure 17. Stereomicroscope photographs showing score (4) for group I in (A) and group II in (B).

3.2 Marginal leakage (depth of dye penetration using a digital microscope):

The dye penetration depth was done on sound-extracted human molars using a digital microscope. It was found that in group I (Filtek™Bulk Fill Posterior Restorative), the median dye penetration depth was 2.5 mm which is significantly higher than the median dye penetration depth of group II (Filtek™Z350 XT Universal Restorative) which was 0.2 mm. There was a statistically significant difference with a P value = 0.015, as shown in **Table 1**.

Table 1. Comparisons between the median dye penetration depth (mm) in both groups.

Group	Median	Minimum	Maximum	95% CI		*P*-value
				Lower bound	Upper bound	
Group I	**2.5**	**0.0**	**8.7**	**1.9**	**4.3**	**0.015 ***
Group II	**0.2**	**0.0**	**6.2**	**0.5**	**2.2**	

*: Significant at P ≤ 0.05

3.3 Marginal gap distance (SEM):

The marginal gap assessment was done on sound-extracted human molars using a scanning electron microscope along the composite/enamel interfaces at mesial, distal, and pulpal regions. The marginal gap distance for group I (Filtek™Bulk Fill Posterior Restorative) for score (0) there was no penetration at the mesial wall and pulpal wall while the distal wall showed 1.53µm marginal gap distance. The same was obtained for scores (1) and (2) with a marginal gap distance at distal wall 539.6 µm and 332.23 µm respectively. Concerning score (3) there were no specimens with this score in group (I). The marginal gap distance for score (4) was 4.03µm at the mesial wall, 226.56µm at the distal wall, and 3.85µm at the pulpal wall.

In group II (Filtek™Z350 XT Universal Restorative) there was no penetration at the mesial wall, distal wall, and pulpal wall for a score (0). For score (1) no penetration at the mesial wall and pulpal wall while the distal wall showed a 305.8µm marginal gap. The same was obtained for score (2) there was no penetration at the mesial wall and pulpal wall while the distal wall showed a 3.49µm marginal gap. For score (3) the marginal gap was 687.8µm at the mesial wall, 286.03µm at the distal wall, and no penetration at the pulpal wall was shown. Score (4) was evaluated with 411.87µm at the mesial wall, 511.99µm at the distal wall, and 3.71µm at the pulpal wall, as shown in Figure (18).

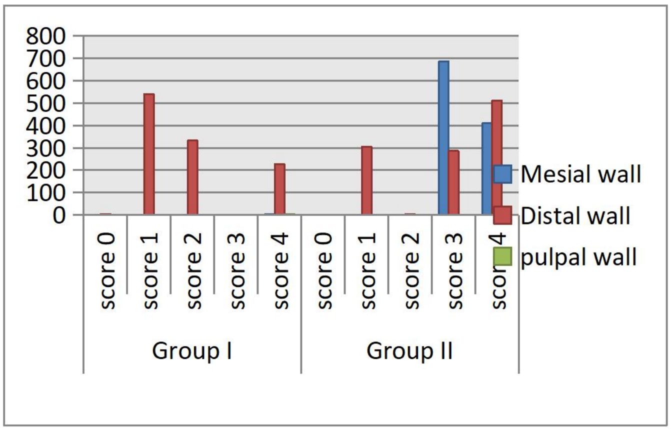
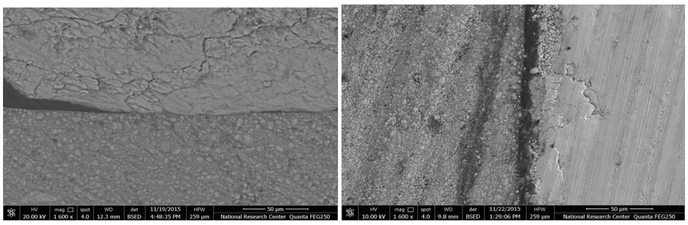


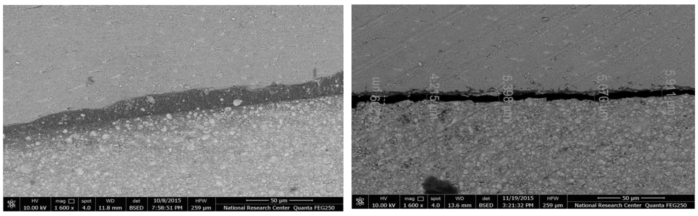
Figure 18. A bar chart showing the median marginal gap distances in both groups.

Representative marginal gap assessment images for both groups (Scan Electron microscope)



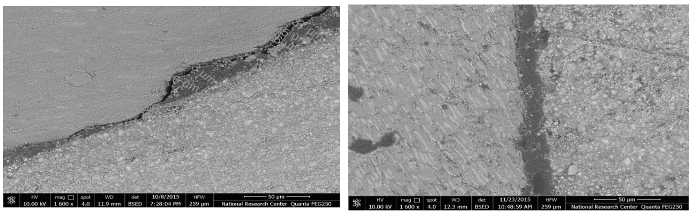
(A) (B)

Figure 19. Scan electron microscope photos showing gap distance of score (0) as (A) for the mesial wall in group I and (B) in group II for the distal wall.



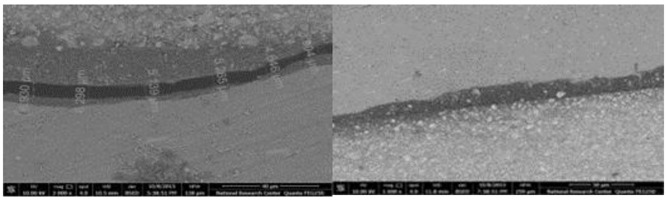
(A) (B)

Figure 20. Scan electron microscope photos showing the gap distance of score (1) as (A) for the mesial wall in group I and (B) in group II for the distal wall.



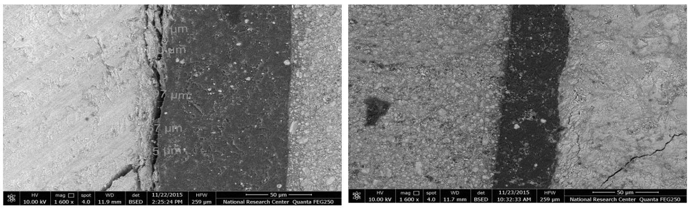
(A) (B)

Figure 21. Scan electron microscope photos showing the gap distance of score (2) as (A) for the mesial wall in group I and (B) in group II for the distal wall.



(A) (B)

Figure 22. Scan electron microscope photos showing gap distance of score (3) as (A) for the mesial wall in group I and (B) in group II for the distal wall.



(A) (B)

Figure 23. Scan electron microscope photos showing the gap distance of score (4) as (A) for the mesial wall, (B) for the distal wall, and (C) for the floor.

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4 Discussion

Recently, a new type of resin composite has emerged: bulk-fill resin composites, which include both low-viscosity (flowable) and high-viscosity (sculptable) materials. Achieving favorable clinical results with these materials requires several conditions to be met: thick layers must be adequately cured, while minimizing polymerization shrinkage and stress, all without compromising marginal integrity [41]. Bulk-fill materials represent an advancing category within resin-based dental composites, purportedly allowing for the construction of restorations in thick layers, up to 4 or even 5mm in depth[42].

The Filtek™ Z350 XT Universal resin-based composite was chosen as the control group because it is a nano-filled RBC known for its high translucency, excellent polishability, and ability to retain polish similar to microfilled resin-based composites. Despite these qualities, it maintains physical properties and wear resistance comparable to several hybrid composites. The inclusion of nanofillers allows for a high filler content of 78.5% by weight, which effectively mitigates polymerization shrinkage and substantially enhances overall physical performance[43].

To ensure consistency in results, the same total-etch system was employed with both types of resin-based composites (RBCs), as recommended by Furness et al., 2014. The conventional etch-and-rinse system is widely regarded as the gold standard and the most dependable adhesive system for restoring both enamel and dentin[44,45,46].

Single Bond Universal Adhesive (3M ESPE) was selected as the adhesive of choice. It was the first commercially available universal adhesive[47,48,49,50], known for causing less post-operative sensitivity compared to traditional etch-and-rinse adhesives[51,52].

The present study investigated the marginal integrity in the form of microleakage scores, dye penetration depth, and marginal gap. Marginal integrity is essential for the longevity of any restoration[53]. This integrity is compromised when microleakage occurs resulting from polymerization shrinkage. Microleakage evaluation is the most common method of assessing the sealing efficiency of a restorative material [54].

Human teeth were selected as substrates due to their properties such as modulus of elasticity, thermal conductivity, bonding characteristics, and strength, which closely resemble those found in clinical situations, making them superior to plastic, metal, or animal teeth[55,56]. For standardization purposes, mandibular human molars were specifically chosen for this study. The cavity dimensions were standardized to a class I preparation size (4mm x 4mm) to minimize variability in both preparation and restoration dimensions. All teeth were prepared by a single clinician to maintain consistency in technique.

In this study, thermocycling was used in the aging process. Dental restorations are exposed to significant and frequent temperature fluctuations in the oral environment[57], and thermocycling simulates these conditions to evaluate the sealing ability of restorative materials[58]. Thermal stresses induced during thermocycling, due to differences in the coefficients of thermal expansion between the restorative material and natural tooth structure, can potentially lead to gap formation and microleakage[59]. Previous research has underscored thermocycling as a critical factor influencing the assessment of microleakage[60].

Dye penetration is a method for investigating marginal microleakage along tooth-restoration interfaces and is generally assessed after cutting the teeth in the longitudinal direction[61,62]. Various tracer dyes are available for microleakage studies, methylene blue is one of the most common tracers and can be used at different concentrations[63]. Almeida[64] stated that methylene blue enabled easy visualization of the prepared cavity by providing an excellent contrast with the surrounding environment.

Marginal microleakage is most commonly assessed by numerically scoring the tooth-restoration interface on a scale from 0 to 4[65]. However, this method is influenced by the scorer's ability to evaluate substrate microleakage and poor inter-examiner reliability has been reported, highlighting the subjective nature of evaluating microleakage by numerically scoring dye penetration[66]. To address this issue in the present in vitro study, the dye penetration depth along the cavity wall was further assessed using a USB Digital microscope at 25× magnification in which the image was captured and transferred to a computer equipped with the image analysis software program and was calculated in mm.

Marginal gap assessment along the composite/enamel interfaces at mesial, distal, and pulpal regions was conducted using scanning electron microscopy (SEM). Recent studies investigating various resin composite and combination restorations have utilized SEM directly[67,68] or, more commonly, used replicas[69].

Bulk-fill resin-based composites (RBCs) include urethane dimethacrylate (UDMA) in their matrix. UDMA has demonstrated higher final degree of conversion (%DC) values compared to Bis-GMA found in conventional RBCs. UDMA possesses a relatively high molecular weight (UDMA 470.0, Bis-GMA 510.6), a high concentration of double bonds (UDMA 4.25 mol/kg, Bis-GMA 3.90 mol/kg), and lower viscosity (UDMA 23.1 Pa s, Bis-GMA 1200 Pa s)[70]. The co-polymerization of Bis-GMA with UDMA or triethylene glycol dimethacrylate (TEGDMA) is commonly employed to enhance conversion rates and create densely cross-linked, rigid polymer networks[71].

However, the increase in the degree of conversion in the bulk fill RBCs was associated with an increase in polymerization shrinkage and eventually polymerization stress. This was reflected by the higher marginal leakage scores, depth of penetration, and gap distance compared to the conventional type[72].

The marginal integrity was investigated on sound-extracted molars of resin-based composites. Furness[31] In agreement with our present findings, they concluded that no significant differences in gap-free margins were found between placement methods within a given product per location. Except for SDR, the percentage of gap-free margins was significantly lower at the pulpal floor interface than at the enamel interface for bulk fill. On the other hand, Rengo et al., 2015[73] disagreed with our present study where they concluded that the marginal leakage demonstrated by new bulk-fill resin composites was similar to that of their precursors for conventional layering technique. These findings might be due to the differences in the methodology between the two studies and the materials used.

Regarding the marginal gap assessment using a scanning electron microscope, Idriss et al., 2003[74] in agreement with our present findings concluded that the method of placement of a given material had no significant effect on the quality of its marginal adaptation. Moreover, they concluded that none of the three different composite/enamel interface restorative materials tested in their study prevented micro gap formation at composite/enamel interfaces of Class II MO cavity.

The limitations of this study were:

(1) This study is considered as an in vitro one and in vivo testing is the ultimate test for the performance of restorations.

(2) Natural teeth variation in terms of morphology, age, and storage medium may affect the results.

(3) No dynamic fatigue was done.

5 Conclusion

Within the limitation of this study, we conclude that:

Marginal microleakage was higher in Filtek™Bulk Fill Posterior Restorative than in Filtek™Z350 XT Universal Restorative resin-based composite.

Recommendations

(1) Further studies with large sample sizes are required for bulk-fill resin-based composite materials to evaluate their performance in other cavity designs.

(2) Further studies are needed to investigate the bulk-fill resin-based composite materials clinically with long-term follow-up.

Conflict of interest

The authors declare that they hold no competing interests.

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