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Comparative Evaluation of the Microleakage of Bulk Fill Composites with Three Different Light Cure Directions (An In Vitro Study)

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ABSTRACT
Purpose: This study estimated microleakage in vitro in Bulk fill (Class I) composite restorations of premolars under different light directions.
Materials and Methods: Freshly extracted 27 healthy premolar permanent teeth were extracted for reasons unrelated to the study, and Filtek P-60TM composite resin was used as the restorative material. Class I restorations were performedand divided into three groups (n = 9): Buccal and lingual light-direction group(BLLD), Tooth Composite bond light-direction group(TCBLD), and occlusal light-direction group(OLD).All groups were subjected to manual thermocycling and were then immersed in 2% methylene blue for 24 h. Subsequently, the samples were washed, dried, sectioned, and observed under a stereoscopic microscope for any cracks.
Results: In the BLLD group, no teeth were identified for grades 2 and 3, whereas six teeth (66.7%) did not show filtration (Grade 0), and 3 teeth (33.33%) showed grade 1. For the OLD group, most specimens (55.55%) had (Grade 3) filtration (dye penetration to the pulpal floor), whereas 33.33% of specimens in this group had grade 2. However, only one sample (11.11%) in this group revealed grade 1, and no sample had (Grad 0). Lastly, grade 2 presented the highest prevalence (dye penetration only to the pulpal floor) of the samples in the TCBLD group (44.44%), and 33.3% showed no infiltration, while only 22.22% exhibited grade 1.
Conclusions: BLLD did not cause any microleakage, whereas OLD was associated with a higher degree of filtration.

Keywords: Bulk Fill Composite, Premolar, Light cure directions, Thermocycling, Microleakage**.**

INTRODUCTION

During polymerization, the conversion of monomer molecules into a polymer network results in a closer packing of the molecules, leading to bulk contraction [1]. The degree of polymerization of the material was determined by determining the degree of conversion of monomers into polymers. The value increased with the degree of conversion and decreased with increasing monomer molecular weight. The polymerization of dimethacrylate-based composites is always accompanied by substantial volumetric shrinkage in the range of 2%–6% [2]. Residues from polymerization shrinkage remain a challenge in restored teeth and one of the leading causes of secondary caries around resin-based composites (RBCs), which is the primary reason for clinical replacement of the RBCs[3, 4]. Research has focused on improving placement techniques, materials, and composite formulations to develop systems with reduced polymerization shrinkage and polymerization shrinkage stress [4, 5].

Although composite resins with low shrinkage are desirable, note worthy that there are several factors determine the shrinkage stress of a restoration, including cavity geometry, material type, and application technique [6]. During tooth restoration with bulk-fill composites and the incremental insertion technique, a longer working time is required, especially in deep cavities, because the maximum incremental thickness is generally limited to 2 mm. In addition, it is relatively sensitive, with an increased risk of contamination by mouth fluids and air bubble formation between the increments [7]. Furthermore, bond failure between composite layers and difficulty in insertion into small cavities may also occur [7, 8].

Microleakage is an important contributor to resin restoration failure. Therefore, to achieve successful posterior direct composite restorations, it is vital to maintain the marginal integrity of the composite tooth. The marginal sealing of direct composites involves several factors: the cavity configuration, the physical-mechanical and viscoelastic properties of the composite resin, the adhesive bond, the restoration technique, and the curing method, etc.[9-11]. The ability to generate adequate marginal integrity of the restorations is closely related to the shrinkage and polymerization stress of the materials used, which is considered one of the major drawbacks of direct composite restorations[12]. Polymerization shrinkage produces stress between the tooth-restoration interface, weakening its integrity. Polymerization shrinkage can result in cuspal deflection, tooth cracking, or failure of interfacial bonding, permitting the passage of bacteria that will produce recurrent caries or postoperative sensitivity, thereby reducing the longevity of the restoration [12-15]. The cavity configuration factor (C-factor)is the ratio of the bonded surface area in the tooth cavity to the unbonded surface area[16]. The C-Factor is related to the flow capacity of resin-based composite materials, which relies on relieving contraction tensions at the tooth–restoration interface [8]. It has been observed that the higher the C factor, the higher the tension at the adhesive interface, independent of the volume increments in chemically activated resins[17, 18]. To relieve these tensions, there must be a considerably free area (low C-Factor) and a longer pre-gel phase allowing better resin flow and tension relief[18]. Despite having a lower C factor than class I cavities, the C factor can potentially have deleterious effects on marginal integrity and gap formation can occur [19].

To limit PSS, incremental filling techniques have been introduced, where resin composite layers are built up in increments and then cured separately[20]. Although the incremental filling technique reduces PSS, it causes problems such as void formation among layers and extends the time required to place restorations [21]. In an attempt to decrease microleakage and shorten the working time, a new generation of resin composites with novel monomer contents and enhanced curing properties, known as bulk-fill composites (BFC), were recently introduced. The BFC has gained success among clinicians owing to its user-friendly application, particularly for posterior restorations. The BFC can be cured in a maximal increment thickness of 4 mm with limited shrinkage, allowing clinicians to fill the cavity in a single step[22]. The aim of this study was to investigate the effect of different LCU directions on the microleakage of bulk fill composites. The tested null hypothesis is stated to be: there is a nonsignificant effect of light cure direction on the microleakage of class I bulk fill restoration.

MATERIALS AND METHODS

Materials

This study was performed using the composite resin Filtek P-60TM (3M Dental Products, St. Paul, MN, EUA) 18, shade A3, which is suitable for direct and indirect fillings. Bulk-fill composite resins have been introduced in the market with the aim of simplifying the process of pouring the material into cavities and its polymerization. Twenty-seven freshly extracted human premolars teeth were collected for orthodontic treatment. The teeth were cleaned with periodontal curettes, and all debris and tissue remnants were removed and stored in 0.1% thymol solution in glass containers until use. Based on internal ethical guidelines and the 1964 Helsinki declaration, consent was obtained from the patients concerning the use of the extracted teeth for research.

Tooth restoration procedure and grouping

To facilitate Class I cavity preparation, the extracted teeth were mounted in an acrylic base so that their roots were retained up to 2 mm of the cementoenamel junction (Figure 1a). Cavities were prepared on the occlusal surfaces of the teeth. To meet the specified requirements, cavities with a width of 2 mm bucco-lingually, 5 mm Mesio-distally, and 2mm occlusogingivally were prepared in the teeth (Figure 1b). The cavities were prepared by a single dentist using a high-speed hand piece and #245 burs under an air and water spray coolant. The cavities were etched using a 37% phosphoric acid etching gel. Phosphoric acid etchant was first applied to the enamel, followed by dentin for 15 s, rinsed with water for 15 s, and dried without over drying. Etching of the dental surface was performed to remove the smear layer and open enamel rods, to increase the retention of resin sealant, and to promote mechanical retention. The surface was then washed well. Afterwards, a bonding agent of low viscosity was applied on the tooth surface, and a strong bond was applied to the entire preparation's walls using a disposable saturated applicator and rubbed in for 20 s, followed by a gentle stream of air over the liquid for about 5 s until it no longer moved and the solvent evaporated completely. The bonding agent was cured with an LED for 20 s to form a shiny thin film.

The teeth were divided into three groups of nine teeth in each group (n = 9) to perform highly intensive light curing from different directions.

1-Group (BLLD) Buccal and lingual light direction: LED Light cure device (Perfection plus, UK) with power intensity equal to 800 mw/cm2. The light intensity was measured before curing using a radiometer

(OPTILUX Radiometer, Kerr Corporation, USA). Highly intensive light curing for 20 s at the lingual, 20 s at the buccal, and 20 s at the center of the occlusal surface(Figure 2).

2-Group(OLD)Occlusal light direction: Highly intensive light cure for 20 s directed to the center of the occlusal surface, as in (Figure 3).

3-Group (TCBLD)Tooth Composite bond light direction: Highly intensive light cure for 20 s directed to buccal surface with metal retainer (Figure 2b) placed above the bulk of the composite and lingual cusp, highly intensive light cure for 20 s directed to lingual surface with metal retainer on buccal surface and bulk of the composite, and lastly highly intensive light cure for 20 s directed to occlusal surface on center(Figure 4). The restorations were finished and polished using the Enhance finishing system according to manufacturer's instruction.

The restored teeth were stored in distilled water at room temperature for 24 h, and then, they were subjected to 1,000 thermal cycles between 0 ^{o}C to 100 ^{o}C in a water bath with a dwell time of 5 s between the baths. In 100 ^{o}C water bath, teeth were placed for 30 s, followed by a dwell time of 5 s, and finally, in a freezing (0^{o}C) water bath for 30 s. Then, each tooth was painted with two coats of transparent nail polish, which covered all tooth surfaces except 1 mm before and after the occlusal cavosurface margin. The teeth were then immersed in 2% methylene blue solution for 24 h at 37 °C under a copious water spray (Horico, Diaflex, Berlin, Germany).

2.3 Microleakage evaluation

With the use of a bioactive metal disk (mean two surface or two sided of the disk active), longitudinal cuts under copious water spray were made in the vestibule-lingual direction and transverse cuts were made at the level of the third root in the teeth at the level of the occlusal surface. The samples were placed on a slide and examined under a SZX7 Olympus stereomicroscope at ×20, (Miami, USA) using a micrometer to evaluate the degree of penetration of the marker agent. The following classification system [19] was used to evaluate dye penetration: Grade 0 = No dye penetration; Grade 1 = Dye penetration only into enamel; Grade 2 = Dye penetration to dentin, but not to pulp floor; and Grade 3 = Penetration of the dye into the pulp floor or axial wall as in (Figure 5).

2.3 Statistical analysis

Frequencies and percentages were calculated to determine microleakage among the evaluated groups. The data of this study were collected and analyzed using the statistical package for social science SPSS (SPSS for Windows, IBM Corp., version: 20) to perform the inferential statistics, and chi-square analysis was used to determine the association between the degree of microleakages and the direction of light with a significance level of $P < 0.05$.

RESULT

According to the grading system used to evaluate day penetration, no teeth were identified for Grades 2 and Grade 3, whereas six teeth (66.7%) did not show filtration (Grade 0), and 3 teeth (33.33%) showed Grade 1 classification (Table 1); (Figure 6).

For the OLD group, most specimens (55.55%) had (Grade 3) filtration (dye penetration to the pulpal floor), whereas 33.33% of specimens in this group had grade 2. However, only one sample (11.11%) in this group was classified as grade 1, and no sample had (Grad 0).

Lastly, Grade 2 presented the highest prevalence (dye penetration only to the pulpal floor) of the samples in the TCBLD group (44.44%), with 33.3% showing no infiltration and 22.22% exhibiting grade 1.

A static significant difference was found between the BLLD and OLD groups ($p = 0.002$), between the TCBLD and OLD groups ($p = 0.037$), and between all groups ($p = 0.002$), whereas there was no significant difference between the BLLD and TCBLD groups (0.074), as shown in (Table 2); (Figure 6).

DISCUSSION

The main goal of any composite restorative or cosmetic procedure is longevity, which cannot be achieved with marginal leakage at the interface between the composite restoration and tooth structure. Microleakage is an inherent shortcoming of dental restorations. If restoration's margins are not completely sealed, fluids, bacteria, and debris can enter the cavity. Leaky margins cause caries, pulpal irritation, tooth sensitivity, and margin staining. Thus, microleakage is an important property that has been used to assess the success of restorative materials. Microleakage refers to microscopic openings between the margins of the resin filling and tooth structure; thus, dye penetration tests are valid tools for determining marginal gaps in vitro studies [14, 15]. The selection of a restorative material for occlusal Class I is a difficult task because there is always a constant application of masticatory load, which has a destructive effect on the tooth structure. The 3M™ Filtek™ P60 Posterior Restorative was the material of choice because of its adaptability to direct and indirect composites. Borba et al. (2009) evaluated the flexural strength and hardness of direct and indirect composites and concluded that direct composite systems with higher filler contents have higher mean values than indirect composites

[20].The shrinkage stresses generated during polymerization (in all type chemical, dual and light curing) of resin composite restoration create a force that competes with the adhesive bond and disrupts the bond to the cavity walls. This is considered the main cause of marginal failure and subsequent microleakage [21] Microleakage of composite restorations occurs due to stresses applied along the tooth-restoration interface (butt joint) due to polymerization shrinkage, temperature fluctuations in the oral environment, and mechanical fatigue cycling through repetitive masticatory loading that apply continuous detach forces on the butt joint [22]. Contaminants infiltrate the formed gap, and subsequent sequelae, such as postoperative hypersensitivity and recurrent caries, may warrant restoration replacement [23].The idea of the current research originated from the fact that light-cured composite materials shrink when exposed to light, so when we have a composite bulk and are covered by a barrier and expose other parts of the composite bulk to the light cure. What happens does not require discussion or disagreement; shrinkage will occur in the composite part that is exposed to light, and the shrinkage stress will be relieved from the composite part that is covered by a barrier that is not exposed to light.The technique used in this study involves light curing of the composite in two steps. First, it was started in the critical part of the restoration, which is that part of the micro hybrid bond tooth tissues to the composite restoration (butt joint), and second, it was light curing the other part of composite that did not cure in the first step of light curing. In this technique, the butt joint was protected from polymerization shrinkage stress and then from debonding or leakage in the butt joint area. Several methods have worked for decreasing or minimizing the shrinkage of composite but no one work on light controlling in the composite at the composite-tooth interface before the curing in the center but in this study we use different pattern of curing start at the composite-tooth interface then cure composite in the center, so according to research, the shrinkage of composite starts from center of composite bulk which pull the composite from margin so in this research we do change in composite light controlling, during curing process, the density of composite increase result in decrease in composite volume which cause polymerization shrinkage [23].

The sequence of shrinkage of composite debonding of restoration along tooth-restoration interface resulting in internal and marginal gaps[24]To partially overcome the shrinkage stresses in the current study, controlling of the light cure direction were applied on the composite tooth butt joint micro hybrid bonding zone to manage this zone firstly polymerization curing than other zones in composite bulk, such as: occurs in (TCBLD) and (B&LLD) groups and appear excellent bonding especially (B&LLD) group, and the discus of this result, the bonding surface (butt joint) of composite with the tooth when beginning in polymerization curing and have a stress in the composite due the polymerization shrinkage of this area will relieved from adjacent composite area that not exposed to the light cure (unpolymerized composite), so in this current study we do one bulk fill composite and achieve an increment light cure direction of the composite and make a new technique (selective light cure zone technique), briefly the light beginning curing in the important zone composite tooth bonding zone (butt joint) to protect this butt joint from the composite shrinkage stress and prevent started a leakage and prevent relieve of the shrinkage stress from the butt dual composite zone. On the other hand, the (OLD) group will appear statistically significant difference than other groups and this is discussed by the light cure directed to the center of the bulk fill composite so the polymerization will start at the center of the composite, the stress in composite act due to polymerization will occur on the center of restoration, and the stress will relieved from the surrounding area called composite tooth bonding zone (butt joint) so we conclude that the light cure should be started from the composite tooth bonding zone, unless if difficult confirm the controlling the light cure apply on the bonding area so the other choice fallow the increment composite technique to prevent microleakage on the composite restoration

CONCLUSION

Within the limitations of this in vitro study, we determined that tooth restoration using bulk-fill resin composites with different light directions significantly affected the degree of microleakage. The occlusal light direction (OLD) showed significant differences between the buccal and lingual light directions (BLLD) and Tooth Composite bond light direction (TCBLD) groups. In terms of the degree of microleakage, the effect of light direction can be arranged in ascending order: BLLD > TCBLD > OLD.

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Conflicts of Interest

The authors declare no conflict of interest.

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Figure Legends

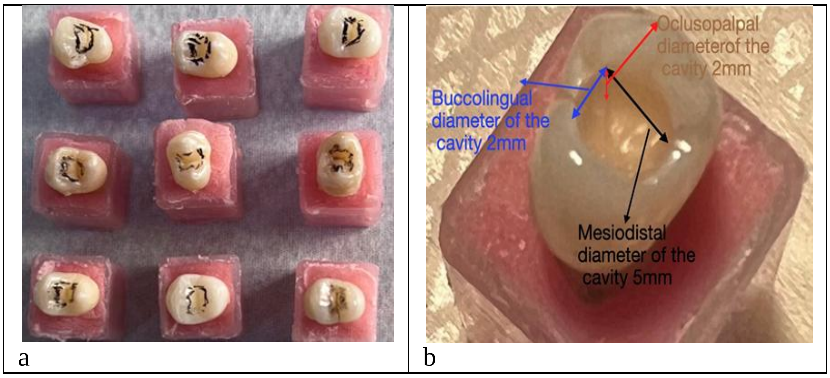


Figure 1: (a) Tooth samples in acrylic block and (b) tooth with Class I cavity.

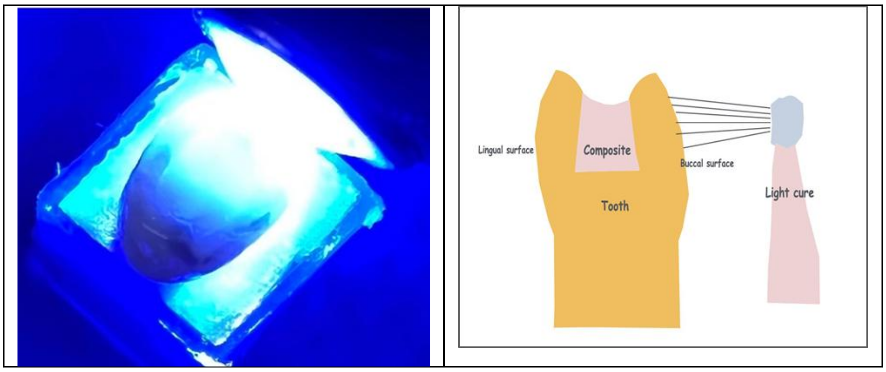


Figure 2: Buccal and lingual light cure direction

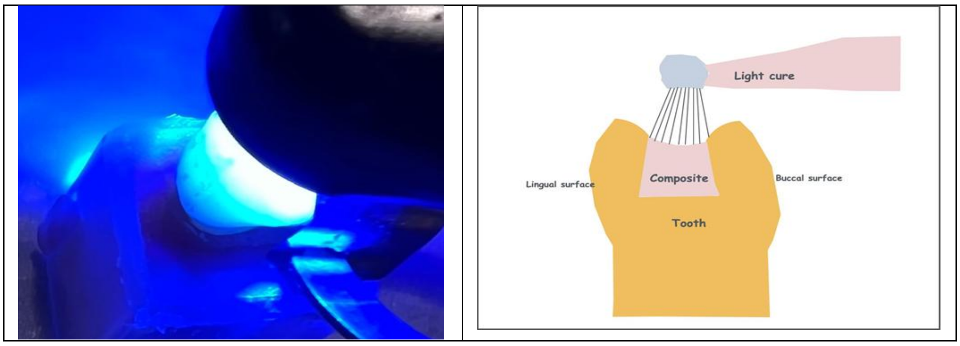


Figure 3: Direction of occlusal light curing.

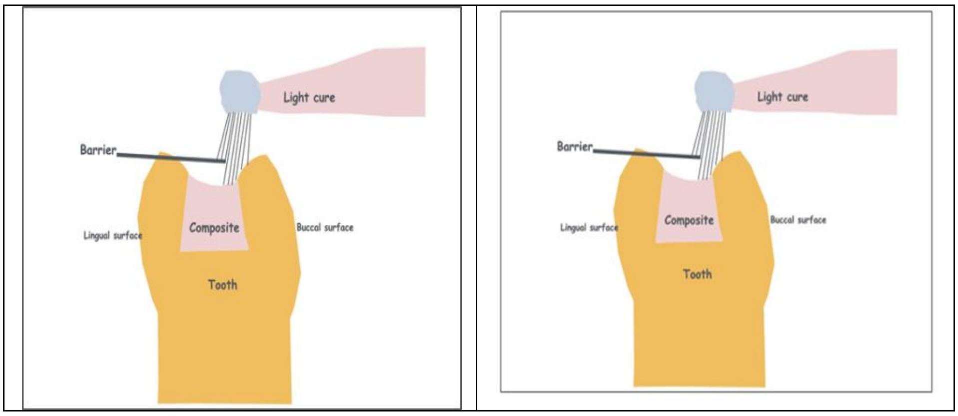
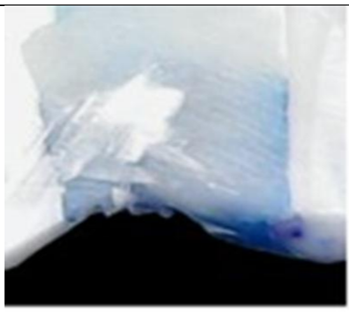


Figure 4: Light curing of tooth-composite bond in the light direction.

Grade 0: No dye penetration.

Grade 1: Dye penetration into the enamel



Grade 2: Dye penetration into dentin

Grade 3: Dye penetration into pulpal floor

Figure 5: Dye penetration grades.

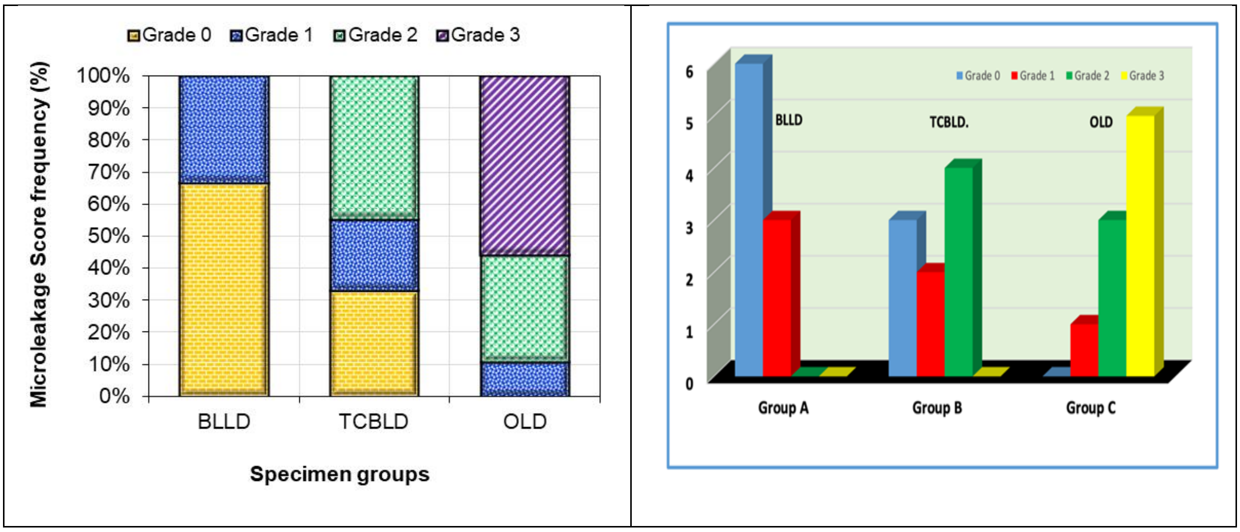


Figure 6: Frequency of penetration degree among different groups

Table 1: The data of microleakage around three groups: buccal and lingual light direction. (BLLD), Tooth Composite bond light direction (TCBLD), and occlusal light direction. (OLD)

Groups	**Grade**								**P value**
	0		**1**		**2**		**3**		
	No teeth	(%)	No teeth	(%)	No teeth	(%)	No teeth	(%)	
BLLD	6	66.66%	3	33.33%	0	0%	0	0%	0.002*
TCBLD	3	33.3%	2	22.22%	4	44.44%	0	0%	
OLD	0	0%	1	11.11%	3	33.33%	5	55.55%	

Group A= bucal and lingual light direction. (BLLD), Group B = tooth composite bond light direction. (TCBLD), and Group C=Occlusal light direction (OLD).

Table 2: Statistical differences between different groups in terms of degree of penetration.

Group	**Grade**				**χ2**		**p-value**
	Grade 0	**Grade 1**	**Grade 2**	**Grade 3**			
BLLD	6	3	0	0	BLLD and TCBLD	5.200	0.074
TCBLD	3	2	4	0	BLLD and OLD	15.00	0.002*
OLD	0	1	3	5	TCBLD and OLD	8. 48	0.037*
					BLLD, TCBLD, and OLD	20.71	0.002*