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Assessment of Microhardness of Bulk-Fill Class II Resin Composite Restorations Performed by Preclinical Students: An In Vitro Study

Ali Abdel-Halim Abdel-Azim Hassan[1] Abdulelah Sameer Sindi[2] Abeer Mohamed Atout[3] Mohamed SM Morsy[3] Khurshid A. Mattoo[3] Vishnu Teja Obulareddy[4] Ankita Mathur[5] Vini Mehta[5]

[1] Department of Maxillofacial Surgery and Diagnostic Sciences, College of Dentistry, Jazan University, Jazan, Kingdom of Saudi Arabia
[2] Department of Restorative Dental Sciences, College of Dentistry, King Khalid University, Abha, Kingdom of Saudi Arabia
[3] Department of Prosthetic Dental Sciences, College of Dentistry, Jazan University, Jazan, Kingdom of Saudi Arabia
[4] Virginia State Dental Association, Richmond Virginia, United States
[5] Department of Dental Research Cell, Dr. D. Y. Patil Dental College and Hospital, Dr. D. Y. Patil Vidyapeeth, Pune, India

Address for correspondence Vini Mehta, MDS, Department of Dental Research Cell, Dr. D. Y. Patil Dental College and Hospital, Dr. D. Y. Patil Vidyapeeth, Pune, India (e-mail: vini.mehta@statsense.in).

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Abstract

Objectives A comparable performance between bulk-fill composites (BFCs) and progressively inserted conventional resin composite (CRC) has been observed in previous studies. However, a significant number of dental institutions in India continue to employ incremental techniques for RC restorations during preclinical studies. But as BFCs are gaining popularity, they may soon be a part of the curriculum for dental students. The aim of this study was to assess the microhardness and the polymerization efficiency of bulk-fill composites versus CRC in class II slot preparations restored by second-year dental students on ivorine mandibular first molar teeth with high-intensity (HI) and low-intensity (LI) light-curing units using the standard mesial slot preparation technique.

Material and Methods Fifty preclinical dental students of second year of a dental college were recruited for the study on a voluntary basis. During their preclinical instructions, all participants were taught and made to practice the handling and curing techniques for two-surface RC restorations for 4 months. Each student was asked to perform four RC restorations: CRC-HI, CRC-LI, BFC-HI, and BFC LI. Assessment of microhardness was done using the Vickers microhardness (VMH) test.

Statistical analysis One-way and multivariate analysis of variance and Bonferroni's post hoc test tests were used for data analysis.

Results The results showed a significant decrease in the VMH readings in the horizontal axis, progressing from the uppermost to the lowermost positions ($p > 0.05$). In all the examined groups, the VMH values at the deepest reading locations were found to be higher than 80% of the values observed at the occlusal surface reading locations. Statistically significant associations were seen between the RC type and the

Keywords
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light source used in the VMH readings conducted ($p > 0.05$). However, no significant correlation was identified between the type of light source and the vertical VMH readings ($p > 0.05$).

Conclusion Instructing dental students to place RC restorations using CRC or BFC materials together with both HI and LI light-curing protocols is safe and can be considered for preclinical studies.

Introduction

Composite is a synthetic resin used in dentistry as a tooth-colored restorative material. Due to its superior strength and aesthetics, it has become the material of choice in the dental clinics.[1] Composite resin has advantageous physical properties, including a high resistance to abrasion and color stability. Composite resin restorations have evolved exponentially and significantly over the past decade in terms of their aesthetics and mechanical properties.[2] Nevertheless, other constraints can be identified, including resistance to fracture, volumetric contraction resulting from material polymerization, and the emergence of polymerization stress.[3,4] To combat the polymerization shrinkage of micro-hybrid composites, a technique for incremental placement of composite resin was developed. However, this method is time-consuming and may cause air to become trapped between successive layers of conventional resin composite (CRC).[4]

Bulk-fill composites (BFCs) have been released to the dental market with modified physical and mechanical properties to reduce the application time of incremental layering techniques in CRC restorations. BFCs can be applied in a single, one-step increment layer of 4 to 5 mm, saving considerable time during the clinical procedure in comparison to the conventional composite layering technique of 2-mm increments.[5,6] Because of their greater translucency, which improves light penetration and depth of cure, they have reduced post-gel shrinkage and higher reactivity to light polymerization than CRCs.[5–7] Roughness and microhardness, two characteristics of resin composite (RC) surfaces that are linked to the aesthetics and functionality of restorations, have become extremely important from a clinical standpoint. Indirect measurements of the degree of polymerization and the efficacy of the light cure have been made using the microhardness of composite materials.[8] In addition to influencing the physical and mechanical characteristics of the CRCs, the light-curing technique used during polymerization can also affect the physical and chemical properties of the restoration.[9] It has been demonstrated that light intensity, exposure time, and proper positioning of the light-curing tip in terms of inclination angle and distance from the RC surface have a significant impact on the radiant exposure and, consequently, the polymerization of the material.[10]

Although several studies demonstrate comparable performance between BFCs and progressively inserted RCs, dental schools have exercised caution in including training on BFCs into their preclinical curriculum for dental students.[11–13] A significant number of dental institutions in India continue to employ incremental techniques for RC restorations during preclinical studies. But as BFCs are gaining popularity, they could become a part of the curriculum for students. The aim of this study was to assess the microhardness and the polymerization efficiency of BFCs versus CRC in class II slot preparations restored by second-year dental students on ivorine mandibular first molar teeth with high-intensity (HI) and low-intensity (LI) light-curing units using the standard mesial slot preparation technique. The study hypothesized that the microhardness and the polymerization efficiency of BFCs were better or at least on par with CRC in class II slot preparations restored by second-year dental students.

Materials and Methods

Study Design

The present study used a CRC and a BFC in combination with HI and LI light-curing units. This study was conducted after approval by the institutional research and ethics committee. Fifty preclinical second-year dental students of a dental college were recruited for the study on a voluntary basis. During their preclinical instructions, all participants were taught and made to practice the handling and curing techniques for two-surface RC restorations for 4 months. Each student was asked to perform four RC restorations: CRC-HI, CRC-LI, BFC-HI, and BFC-LI. Thus, the 50 students prepared and restored 200 restorations.

Study Procedure

For both materials, the A2 shade was chosen to provide sufficient light penetration through the material and to prevent the effect of shading pigments. We employed Filtek Z350 XT for CRC and Filtek One BF Restorative for BFC as RC materials. The restorations were made in an ivorine mandibular first molar that was positioned between two adjacent teeth in a dentiform arch and held in place with a phantom head, utilizing the standard mesial slot preparation technique. The preparation measurements were 2 mm in axial depth, 3.5 mm buccolingually, and 5 mm occlusogingivally. A new tungsten carbide bur was used by each student in an air/water cooled high-speed handpiece to prepare the teeth. Before each student was summoned to put the RC restoration, a circumferential metal Tofflemire matrix band was wrapped around the tooth and kept in place with a wooden wedge. The type of RC material and light intensity of the light-curing units the students were using were masked from them. To make it easier to remove the light-polymerized restoration later, the preparations were lightly treated with glycerin prior to the restorations being placed.

For restorations in the two BFC groups, students were instructed to use Filtek One BF with a 5-mm increment, whereas for CRC groups, they were instructed to use Filtek Z350 XT with a 2-mm incremental placement technique. Using light-emitting diode (LED) lights, two distinct light-polymerization procedures were explored. In the HI groups, students were instructed to cure the restorations using the Bluephase Style curing unit (Ivoclar Vivadent AG, Schaan, Liechtenstein) delivering 1,200 mW/cm$^2 \pm 10\%$, whereas in the LI groups, the students were instructed to use the Bluephase Style M8 curing unit (Ivoclar Vivadent AG, Schaan, Liechtenstein) delivering 800 mW/cm$^2 \pm 10\%$. Before each use, the instructor used a radiometer to determine the light intensity of the curing lights.

Assessment of Microhardness

The restorations were removed from the tooth preparation after light polymerization and stored at 37°C for 24 hours in labeled containers with distilled water to permit polymerization after irradiation. Each specimen was then encased in epoxy resin and sectioned mesiodistally in the center with a water-cooled diamond disk. The Vickers pyramid indenter was pressed into the top surface of the samples for 30 seconds with a weight of 100 g to measure Vickers microhardness (VMH).

VMH (kg/mm^2) was calculated using the following formula:

$$\mathrm{VMH} = (1.8544\,P)/D2,$$

where P is the predetermined load applied to the specimen in kilograms and D is the average diagonal distance (in millimeters) of the square formed by the pyramid apex of the VMH tester. Per section, three series of microhardness measurements were taken: (1) 0.2 mm into the composite adjacent to the matrix band, (2) through the center of the restoration, and (3) 0.2 mm into the composite adjacent to the axial face of the preparation. The lower acceptable microhardness threshold was determined by calculating the 80% hardness value of the maximum specimen hardness at a depth of 0.1 mm.

Statistical Analysis

The data were entered and analyzed using the Statistical Package for Social Sciences (SPSS) for Windows, Version 28.0. (IBM Corp, Armonk, NY). Confidence intervals were set at 95%, and a p-value of ≤ 0.05 was considered statistically significant. One-way and multivariate analysis of variance and Bonferroni's post hoc test tests were used for data analysis.

Results

The findings of the present study revealed the presence of significant differences in all variables tested: type of RC ($p < 0.05$) and type of light-polymerization mode ($p < 0.05$). The microhardness measurements in both the vertical and horizontal axes were significantly influenced by both variables. Overall, within the CRC-LI group, the values of VMH were found to be significantly greater compared to the other groups, followed by the CRC-HI, BFC-HI, and BFC-LI groups. The results obtained from the vertical plane readings indicated a statistically significant decrease in the VMH reading as one moves from the outer wall to the center, and finally to the inner planes ($p < 0.05$; ►**Table 1**). In a comparable way, a significant decrease was observed in the VTH readings in the horizontal axis, progressing from the uppermost to the lowermost positions ($p < 0.05$; ►**Table 2**). In all the examined groups, the VMH values at the deepest reading locations were found to be higher than 80% of the values observed at the occlusal surface reading locations. Statistically significant associations were seen between the RC type and the light source used in the VMH readings conducted ($p < 0.05$). However, no significant correlation was identified between the type of light source and the vertical VMH readings ($p > 0.05$; ►**Fig. 1**).

Table 1 VMH test readings of RCs in different vertical planes

(I) Vertical	(J) Vertical	*p*-value
Inner	Middle	0.05[a]
	Outer	0.05[a]
Middle	Inner	0.05[a]
	Outer	0.05[a]
Outer	Inner	0.05[a]
	Middle	0.05[a]

Abbreviations: RCs, resin composites; VMH, Vickers microhardness.
[a]Statistically significant difference.

Discussion

Owing to the ease of the procedure, the use of BFC is gaining popularity among practitioners. BFCs also exhibit a lower degree of polymerization shrinkage stress compared to standard micro-hybrid composites in the context of class II posterior RC restorations, both during and after the light-curing process.[2] But since BFCs hit the market, a lot of research has been undertaken comparing the various properties of bulk-fill resins with conventional resins, with mixed findings.[14] Arbildo-Vega et al conducted a systematic review and meta-analysis (SRMA) to determine the clinical effectiveness of BFC and CRC restorations and found that no difference between CRC and BFC in the type of restoration, type of tooth restored, and restoration technique used.[15] Thus, the current study was conducted to assess whether including BFC restorative techniques in the curriculum of preclinical dental students should be encouraged. On comparison of the CRC and BFC groups, we found that microhardness readings of the CRC material were generally higher than those of the BFC material, whether the materials were polymerized using HI or LI curing modes. The microhardness measurements in both the vertical and horizontal axes were significantly influenced by both variables. Overall, within the CRC-LI group, the values of VMH were found to be significantly greater compared to the

Table 2 VMH test readings of RCs in different horizontal planes

(I) Horizontal	(J) Horizontal	*p*-value
Occlusal	1 mm from occlusal	0.05[a]
	Middle	0.05[a]
	1 mm gingival	2.00
	Gingival	0.05[a]
1 mm from occlusal	Occlusal	0.05[a]
	Middle	0.34
	1 mm gingival	0.05[a]
	Gingival	0.05[a]
Middle	Occlusal	0.05[a]
	1 mm from occlusal	0.34
	1 mm gingival	0.05[a]
	Gingival	0.05[a]
1 mm gingival	Occlusal	2.0
	1 mm from occlusal	0.05[a]
	Middle	0.05[a]
	Gingival	0.05[a]
Gingival	Occlusal	0.05[a]
	1 mm from occlusal	0.05[a]
	Middle	0.05[a]
	1 mm gingival	0.05[a]

Abbreviations: RCs, resin composites; VMH, Vickers microhardness.
[a]Statistically significant difference.

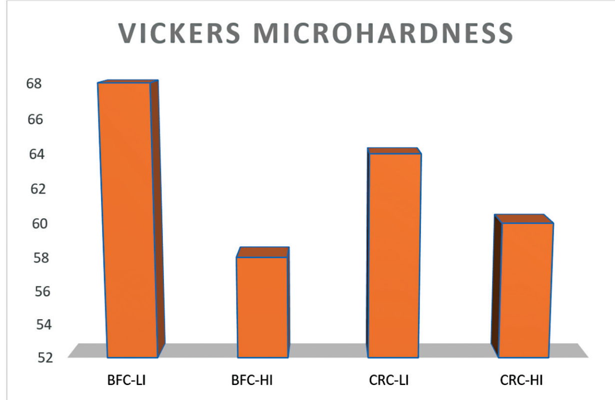

Fig. 1 Line graph showing the Vickers microhardness (VMH) values of the resin composite specimens in the different groups tested at the different reading points. BFC-HI, bulk-fill composites high-intensity; BFC-LI, bulk-fill composites low-intensity; CRC-HI, conventional resin composite high intensity; CRC-LI, conventional resin composite light intensity.

other groups, followed by the CRC-HI, BFC-HI, and BFC-LI groups. The results obtained by the students in the current study were consistent with those of other studies, reporting lower microhardness readings for BFC compared with those for CRC material.[16] Lins et al conducted a similar study and concluded that BFCs promoted less polymerization shrinkage stress than conventional microhybrid RC during and after the light-curing process in class II posterior RC restorations.[17] Another study compared several BFC materials with CRC and reported that none of the BF materials tested reached the MH values of the CRC.[18] The increased filler loading of the BF compared with the conventional material may have resulted in the increased scattering of light at the filler–matrix interface and impeded the depth of light penetration.[19] Our findings demonstrated that the average VMH readings of the BFC specimens, regardless of whether they were subjected to HI or LI treatment, were significantly lower compared to the CRC groups. This observation implies that the decreased microhardness exhibited by BFC is mostly determined by the inherent characteristics of the material itself, rather than being influenced by the precise polymerization technique employed. However, the findings of this study indicate that the BFC material that was examined exhibited microhardness values within the clinically acceptable range at all measurement locations of the restorations that were studied.

The measurement of the curing efficiency or depth of cure has been conducted by assessing the ratio between the hardness values of the bottom and top surfaces. A minimum clinically acceptable value of 80% has been established for this ratio. In accordance with prior research, the microhardness ratio (MHR) of all materials examined in this study demonstrated the ability to meet the mandated minimum value, with no notable variations seen among the ratios.[20,21] The VMH values observed in the deeper layers of the BFC material were found to be similar to those of the CRC material. Kim et al established a negative correlation between resin thickness and microhardness, indicating that an increase in resin thickness led to a decrease in microhardness. The study also determined that the BFC exhibited a bottom/top hardness ratio of around 80% or higher in specimens with a thickness of 4 mm.[22]

In the present study, two distinct poly-wave LED light-curing units were employed, each producing varying light intensities. Light-curing RCs consist of photoinitiators that incur decomposition upon exposure to visible blue light radiation. This decomposition process generates reactive species, which subsequently initiate polymerization. This indicates that a sufficient amount of light with a wavelength corresponding to the absorption spectrum of the photoinitiator is required to initiate the polymerization reaction.[7] Despite the HI light emitting a broader range of wavelengths in comparison to the LI light, both light sources adequately fulfilled the spectral criteria for the two different types of RC materials employed in the study. The recommended exposure times were generally longer for the CRC material while using LI light. This observation aligns with the results reported by Aguiar et al, which indicated that prolonging the exposure time can enhance the irradiant energy available for the conversion of carbon double bonds. Consequently, this can lead to improvements in the physical characteristics of resin-based materials activated by light, even in the absence of alterations in the intensity of the light power.[23]

In the current study, the longer exposure times with the LI light could be the reason why adequate polymerization was achieved throughout the restorations completed by both the Conv-RC and the BF material. Reis et al in an SRMA found that independent of the specific "in vitro" method used, BFC demonstrated a partial ability to meet the crucial criterion of adequate curing at a cavity depth of 4 mm, as assessed by depth of cure and/or degree of conversion. Additionally, it was noted that BFCs with low viscosities generally exhibited superior polymerization efficiency in comparison to BFCs with high viscosities.[24]

In the current study, students were able to position the selected RCs using two light sources and two placement techniques without compromising the restoration properties, as measured by cross-section VMH readings at various locations. Despite the shortened curing time, the use of HI polymerization protocols resulted in higher MH values in the restorations when compared to the use of lower intensity polymerization protocols. In a recent 2022 SRMA, it was revealed that increasing the light cure distance and the depth of the tested BF had a substantial impact on both VMH and MHR. All of the BF materials that were evaluated did not exhibit an adequate MHR at the depths ranging from 4 to 6 mm.[25]

When analyzing VMH readings in the vertical and horizontal planes, the highest values were found in the external wall (closest to the matrix band) in the vertical axis and in the most occlusal reading sites in the horizontal axis. Polymerization efficiency and irradiant exposure are directly proportional and can be affected by exposure duration, light power intensity, and distance from the resinous material surface to the light-curing unit's guide tip.[26] Consequently, these observations could be explained by the decrease in irradiance achieved on the bottom surface of the restorative material as a result of the increased distance between the guide tip of the light-curing unit and the surface of the resin-based material, as well as by light scattering from the filler particles and resinous matrix and by the thickness of the RC.[27–32] After the removal of the band in the current study, the students were instructed to polymerize the material from the buccal and lingual surfaces for an additional cycle. This served to bring the light sources closer to the exterior surfaces of the RC, resulting in higher VMH values.

The present study had a few limitations. First, the distance of the light cure tip to the surface of the restorations was not measured. This was intentionally avoided to prevent student performance bias. Second, the methodology used required the removal of the restorations from the prepared Ivorine tooth prior to VMH testing, preventing the assessment of the fit of the restorations using the different material and placement techniques. That was not the objective of the study, but future studies assessing the fit of the restorations using BFC material in comparison with CRC when performed by dental students would be valuable.

Conclusion

The success and durability of the restorations may hinge upon the efficacy of the polymerization process of the material during its placement. In our study, microhardness readings of the CRC material were generally higher than that of the BFC. The scarcity of data pertaining to the extended clinical efficacy of BFC, coupled with the limited technical competence of dental students, could potentially account for the hesitancy in regularly including BF content into the curriculum for preclinical dental students for dental colleges. However, we would like to recommend BFC using the standard mesial slot preparation technique to also be included in the preclinical studies of dental students as they should be able to use it in the clinical scenarios; they seem capable. Instructing dental students to install RC restorations using CRC or BFC materials together with both HI and LI light-curing protocols is safe.

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Conflict of Interest
None declared.

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