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Evaluation of Marginal Integrity and Depth of Cure for Three 'Bulk Fill' Composites: SDR, Tetric EvoCeram Bulk Fill Composite and EverX Posterior Bulk Fill Composite – An In Vitro Study

Rajeshwar Singh[1*] Purva Sharma[1] Shakti Singh Meena[1] Mahima Mathur[1] Suparna Ganguly Saha[1] Mahendra Dave[2]

[1] Department of Conservative Dentistry & Endodontics, Index Institute of Dental Science, Indore, Madhya Pradesh, India.
[2] Department of Prosthodontics and Crown & Bridge, Index Institute of Dental Science, Indore, Madhya Pradesh, India.

ABSTRACT

Background: The degree of polymerization of resin composites is an important determinant of their mechanical properties, dimensional stability, solubility, and clinical longevity. Bulk-fill composites have been introduced to simplify restorative procedures by permitting placement in thicker increments while minimizing polymerization-related stresses. Adequate depth of cure and marginal integrity are essential for successful restoration.

Materials and Methods: Forty composite resin specimens were divided into four groups (n=10 each): Group I – Smart Dentin Replacement (SDR), Group II – Tetric-N-Ceram Bulk Fill, Group III – ever-X Posterior, and Group IV – Filtek Z350 XT Universal Restorative Composite. Depth of cure was evaluated using the ISO 4049 scraping method and Vickers Hardness Number (VHN) method. Marginal integrity was assessed by dye penetration and stereomicroscopic evaluation. The obtained data were statistically analyzed using one-way ANOVA, Tukey post-hoc test, and chi-square test.

Results: Mean depth of cure was highest for Group III (5.816 ± 0.0455 mm), followed by Group II (5.524 ± 0.1248 mm), Group I (5.171 ± 0.1469 mm), and Group IV (4.505 ± 0.751 mm), with a statistically significant difference among groups (P<0.001). VHN values were highest for Group I (0.903 ± 0.0499), followed by Group II (0.882 ± 0.0312), Group III (0.823 ± 0.0400), and Group IV (0.736 ± 0.0470), with significant intergroup differences (P<0.001). Microleakage distribution also differed significantly among groups (P<0.05).

Conclusion: The tested restorative materials demonstrated significant differences in depth of cure and marginal integrity. Ever-X Posterior showed the greatest depth of cure by ISO 4049, whereas SDR demonstrated the highest VHN values.

Keywords: Bulk-fill composite, Marginal integrity, Depth of cure, SDR, Tetric EvoCeram Bulk Fill, EverX Posterior, Resin-based composites.

INTRODUCTION

Resin composites are widely used in restorative dentistry because of their esthetic properties, adhesive potential, and versatility in restoring both anterior and posterior teeth. However, polymerization shrinkage, inadequate depth of cure, and marginal degradation remain important challenges that may compromise the longevity of composite restorations.[1] Conventional incremental placement is recommended to improve light penetration and limit the effects of polymerization

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***Correspondence Dr Rajeshwar Singh.**
Department of Conservative Dentistry & Endodontics, Index Institute of Dental Science, Indore, Madhya Pradesh, India.
Email: drsingh1291@gmail.com

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shrinkage. Nevertheless, this technique increases chairside time and may introduce voids or interfacial defects between successive increments. These limitations have driven the development of bulk-fill resin composites designed to simplify restorative procedures while maintaining adequate polymerization and marginal adaptation.[2]

Bulk-fill composites incorporate modifications in resin chemistry, filler characteristics, translucency, and polymerization kinetics to facilitate light transmission and permit placement in increments of up to 4–5 mm, depending on the material. These modifications aim to improve curing efficiency and manage polymerization-induced stress.[3] However, differences in formulation and material structure may influence their depth of cure, mechanical properties, and adaptation to cavity margins. Therefore, the clinical performance of bulk-fill composites cannot be assessed solely on the basis of their recommended placement thickness.

Depth of cure is an important determinant of the physical and mechanical properties of resin composites. Inadequate polymerization may reduce hardness and wear resistance, increase residual monomer release, and adversely affect the biocompatibility and durability of the restoration.[4] The scraping method specified in ISO 4049 provides a standardized approach for estimating depth of cure, whereas Vickers microhardness testing offers an indirect assessment of polymerization through surface hardness measurements. Evaluating these parameters using complementary methods provides a more comprehensive understanding of curing performance.

Marginal integrity is equally important for the long-term success of composite restorations. Polymerization-induced stress, influenced by material properties and cavity configuration, may compromise the tooth–restoration interface. Marginal gaps can facilitate microleakage, potentially contributing to postoperative sensitivity, marginal staining, recurrent caries, and pulpal irritation.[5] Dye penetration assessed under stereomicroscopic examination is a commonly used in vitro method for comparing marginal leakage among restorative materials.

Smart Dentin Replacement (SDR), Tetric-N-Ceram Bulk Fill composite and ever-X Posterior represent distinct approaches to bulk-fill composite design. Their differing formulations warrant comparative evaluation of curing performance and marginal integrity.

Therefore, this in vitro study aimed to evaluate and compare the depth of cure of these three bulk-fill composites using the ISO 4049 scraping method and Vickers microhardness testing, and to assess their marginal integrity using dye penetration under stereomicroscopic examination.

MATERIALS & METHOD

The sample size was determined based on statistical considerations to ensure adequate power for the study. The sample size calculation revealed that a minimum of 7 samples per group was required to detect a mean difference between any two groups, with an alpha level of 0.05 and a statistical power of 80%. A p-value of <0.05 was considered to indicate statistical significance. To provide an adequate number of specimens and account for possible variations during specimen preparation and evaluation, it was proposed to include more than 7 samples in each group.

Accordingly, 10 samples per group were fabricated for the evaluation of depth of cure using the ISO 4049 method and Vickers Hardness Number (VHN) method. In addition, 10 teeth per group were prepared for the assessment of marginal integrity by dye penetration. Thus, the study utilized an appropriate number of specimens for evaluation of the different parameters under investigation.

A total of 40 freshly extracted human premolars with mature apices were collected. The selection of freshly extracted teeth was undertaken to provide specimens suitable for the planned experimental procedures.

Inclusion Criteria: Only sound teeth with adequate dentinal support and fully developed root apices were included in the study to ensure structural integrity and standardization of the experimental specimens.

Exclusion Criteria: Teeth with caries, fractures, internal or external root resorption, immature root apices, calcified root canals, developmental anomalies, or previous root canal treatment were excluded from the study to minimize the influence

of pre-existing structural alterations on the experimental outcomes.

I. Evaluation of Depth of Cure Using the ISO 4049 Method

Four composite materials were evaluated: Group I, SDR; Group II, Tetric N-Ceram Bulk Fill; Group III, everX Posterior; and Group IV, Filtek Z350 XT Universal Restorative Composite (control). Specimens were fabricated using a plastic tube with an internal diameter of 6 mm and a height of 4 mm, placed on a glass slide separated by a Mylar strip. The mold was filled with composite, covered with another Mylar strip and glass slide, and light-cured for 20 seconds using an LED curing unit with an intensity of 800 mW/cm^2. Immediately after curing, specimens were removed from the mold, and uncured material was gently scraped from the bottom surface using a Bard-Parker blade. The remaining length was measured at three points using a digital vernier caliper. The mean length was calculated and divided by two to determine the depth of cure according to ISO 4049.

II. Evaluation of Depth of Cure Using Vickers Hardness Number

Specimens measuring 10 mm in diameter and 4 mm in depth were prepared using a custom-made brass mold closed at one end. The upper surface was covered with a Mylar strip and glass slide before light-curing for 20 seconds using an LED unit delivering 800 mW/cm^2. After removal from the mold, the top and bottom surfaces were identified and polished with silicon carbide paper to remove the resin-rich layer and facilitate accurate indentation. Specimens were stored in distilled water at room temperature for 24 hours and subsequently mounted in acrylic molds. Vickers microhardness was measured on both surfaces using a diamond pyramid indenter under a load of 4.903 N applied for 5 seconds. Three indentations were made on each surface to minimize measurement variability. The bottom-to-top Vickers hardness ratio was calculated to assess the relative curing efficiency of each composite.

III. Evaluation of Marginal Integrity Using Dye Penetration

Forty freshly extracted human premolars, removed for therapeutic reasons, were cleaned and stored in 0.05% thymol solution at 37°C for one month. Standardized Class II cavities were prepared using calibrated diamond burs under air-water cooling, with an occlusal depth of 4 mm, buccolingual width of 4 mm, and axial depth of 2 mm. Cavity margins were refined using fine diamond burs, and matrix bands were adapted to standardize restoration placement. All cavities underwent total-etch conditioning for 15 seconds, followed by application of Single Bond Universal Adhesive. Teeth were randomly allocated to four groups and restored with the respective composite materials. Restorations were light-cured occlusally for 20 seconds, followed by additional curing from the buccal and lingual aspects for 20 seconds each. The restorations were polished using flexible discs and stored in saline for 24 hours.

Root apices and external tooth surfaces were coated with two layers of acetone-based nail varnish, leaving a 1-mm-wide margin around the restorations exposed. Specimens were stored in distilled water at 37°C for 24 hours and thermocycled for 500 cycles between 5°C and 55°C, with a dwell time of 30 seconds and transfer time of 5 seconds. Subsequently, specimens were immersed in 2% methylene blue for 24 hours, rinsed under running water, and cleaned using rubber cups, brushes, and polishing compounds. Each tooth was sectioned mesiodistally through the middle of the restoration using a diamond disc. Dye penetration along the restoration interface was examined under a stereomicroscope at ×20 magnification, and photographs were analyzed using a modified five-point ordinal scale (scores 0–4).

Marginal leakage scoring: Score 0 indicated no dye penetration. Score 1 indicated penetration along or into the restoration up to half the length of either lateral wall. Score 2 indicated penetration along one entire lateral wall to the pulpal wall. Score 3 indicated penetration up to half the length of both lateral walls. Score 4 indicated penetration along both lateral walls to the pulpal wall. Higher scores represented greater dye penetration.

RESULTS

Depth of Cure by ISO 4049 Method

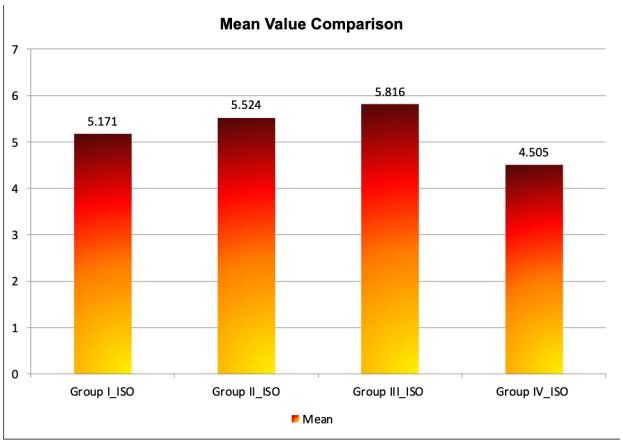
The mean depth of cure was found to be 5.1710 ± 0.1469 mm for Group I (SDR), 5.5240 ± 0.1248 mm for Group II (Tetric-N-Ceram), 5.8160 ± 0.0455 mm for Group III (ever-X Posterior), and 4.5050 ± 0.751 mm for Group IV (Filtek Z350 XT). Thus, Group III showed the highest mean depth of cure, whereas Group IV showed the lowest mean value.

One-way ANOVA showed a statistically significant difference among the four groups ($P < 0.05$), indicating that the mean depth of cure was significantly different between the groups. Post-hoc Tukey comparison showed that the difference between Group I and Group II was not statistically significant. Table 1, Graph 1

Similarly, Group II and Group III did not show a statistically significant difference. However, the remaining pair-wise comparisons showed statistically significant differences ($P < 0.05$).

Table 1: Comparison of mean depth of cure assessment by the "ISO-4049 method"

Group	Number	Mean	Std. Dev.	F Value	P Value
Group I SDR	10	5.1710	0.1469		
Group II Tetric-N-Ceram	10	5.5240	0.1248		
Group III ever-X posterior	10	5.8160	0.0455	21.12	0.000
Group IV Filtek Z 350 XT	10	4.505	0.751		



Graph 1: Mean Value comparison of DOC obtained by ISO 4049.

Depth of cure by Vicker's Hardness Number

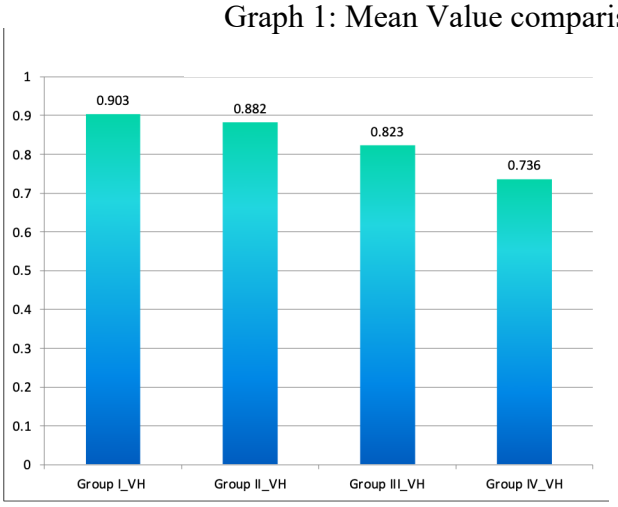
The mean values obtained were 0.9030 ± 0.0499 for Group I, 0.8820 ± 0.0312 for Group II, 0.8230 ± 0.0400 for Group III, and 0.7360 ± 0.0470 for Group IV. The results showed a decreasing trend in the mean VHN values from Group I to Group IV.

One-way ANOVA demonstrated a statistically significant difference among the groups ($P < 0.05$). Post-hoc Tukey analysis showed no significant difference between Group I and Group II ($P > 0.05$), while all other pair-wise comparisons showed statistically significant differences ($P < 0.05$). Table 2, Graph 2

Group	Number	Mean	Std. Dev.	F Value	P Value
Group I SDR	10	0.9030	0.0499		0.000
Group II Tetric-N – Ceram	10	0.8820	0.0312	30.77	
Group III ever-X posterior	10	0.8230	0.0400		
Group IV Filtek Z 350 XT	10	0.7360	0.0470		

Table 2: Comparison of mean value of depth of cure by "Vickers hardness number method"

Graph 1: Mean Value comparison of DOC o



Graph 2: Mean Value Comparison of DOC obtained by VHN

Marginal Integrity

Group I showed predominantly low scores, while higher scores were more frequently observed in

Groups III and IV. This indicates differences in marginal integrity among the tested restorative materials. Table 3.

Table 3 - Dye penetration grades (0-4) for all the samples.

Marginal Integrity			
Group I	**Group II**	**Group III**	**Group IV**
0	*0*	*4*	*2*
0	*1*	*3*	*2*
0	*1*	*3*	*2*
0	*1*	*3*	*4*
1	*1*	*0*	*4*
0	*0*	*0*	*3*
0	*0*	*1*	*2*
0	*0*	*1*	*4*
0	*1*	*3*	*2*
1	*1*	*3*	*2*

Microleakage

Group I showed 80% of samples with Grade 0 and 20% with Grade 1. Group II showed 40% Grade 0 and 60% Grade 1. Group III showed 20% Grade 0, 20% Grade 1, 50% Grade 3, and 10% Grade 4. Group IV showed 60% Grade 2, 10% Grade 3, and 30% Grade 4.

The chi-square test showed a statistically significant difference ($P < 0.05$) in the distribution of microleakage grades among the four groups. Higher counts of Grade 0 and Grade 1 were observed in Groups I and II, whereas higher grades of microleakage, particularly Grades 2, 3, and 4, were distributed more frequently in Groups III and IV. Table 4

Overall, the findings demonstrated significant differences among the four restorative materials in terms of depth of cure and microleakage, with variations also observed in marginal integrity.

Table 4. Association of Micro Leakage Grading with outcome of different groups.

Micro Leakage Grading	Micro Leakage Groups				Total
	Group I SDR (n=10)	Group II Tetric-N-Ceram (n=10)	Group III ever-X posterior (n=10)	Group IV Filtek Z 350 XT (n=10)	
0	8 (80.0%)	4 (40.0%)	2 (20.0%)	0 (0.0%)	14 (35.0%)
1	2 (20.0%)	6 (60.0%)	2 (20.0%)	0 (0.0%)	10 (25.0%)
2	0 (0.0%)	0 (0.0%)	0 (0.0%)	6 (60.0%)	6 (15.0%)
3	0 (0.0%)	0 (0.0%)	5 (50.0%)	1 (10.0%)	6 (15.0%)
4	0 (0.0%)	0 (0.0%)	1 (10.0%)	3 (30.0%)	4 (10.0%)
Total	**10 (100.0%)**	**10 (100.0%)**	**10 (100.0%)**	**10 (100.0%)**	**40 (100.0%)**

DISCUSSION

Dental composites have become a widely accepted material for posterior restorations because of their favourable aesthetics, conservative tooth preparation, adequate strength, ease of manipulation, repairability, biocompatibility and versatility in direct and indirect restorative procedures. However, polymerization shrinkage, shrinkage stress and inadequate depth of cure remain important limitations. These factors may contribute to marginal gap formation, microleakage, recurrent caries, postoperative sensitivity, marginal discoloration and reduced longevity of restorations.[6] During photopolymerization, monomers form a polymer network and the resin composite undergoes volumetric contraction. The resulting stresses at the bonded cavity walls may cause interfacial defects, enamel fracture, cuspal movement and microcracks, ultimately contributing to microleakage.

The incremental layering technique, traditionally performed using increments of approximately 2 mm, has been used to minimize polymerization stress by reducing the bonded-to-unbonded surface ratio and consequently the configuration factor (C-factor) during polymerization. Although this technique provides adequate curing and stress control, it increases clinical working time, particularly in extensive restorations, and may also increase the risk of voids or contamination between successive increments. Bulk-fill composites were therefore introduced to simplify restorative procedures by permitting placement of thicker increments, generally up to 4 mm, while maintaining acceptable polymerization and mechanical properties.[7] The present study evaluated the depth of cure and microleakage of three bulk-fill composites—Smart Dentin Replacement (SDR), Tetric-N-Ceram Bulk Fill and ever-X Posterior—with Filtek nanohybrid composite serving as the control.

Depth of cure is an important determinant of the clinical performance of light-cured resin composites because inadequate polymerization can adversely affect mechanical properties, biocompatibility and colour stability. The present study used both the ISO 4049 scraping method and Vickers microhardness testing to evaluate depth of cure. According to ISO 4049, ever-X Posterior demonstrated the greatest depth of cure, whereas Filtek nanohybrid composite showed the lowest value. SDR and Tetric-N-Ceram Bulk Fill demonstrated intermediate results. However, because the ISO scraping method may overestimate depth of cure, Vickers microhardness testing was additionally performed to provide a more meaningful assessment of polymerization throughout the specimen.

Using Vickers hardness testing, SDR and Tetric-N-Ceram Bulk Fill demonstrated the highest depth of cure, with no significant difference between the two materials. ever-X Posterior also showed substantial curing but exhibited lower values than SDR and Tetric-N-Ceram Bulk Fill. These findings differ from the ISO 4049 results and highlight the importance of using more than one method for evaluating polymerization. The present findings are consistent with those reported by J-H Hang et al. (2015), who found favorable curing of SDR in 4-mm increments.[2]

The superior curing performance of SDR may be attributed to its relatively translucent matrix, which permits greater transmission of curing light, together with the incorporation of a functional photoactive group in its methacrylate matrix.[8] The increased translucency and modified filler characteristics of bulk-fill materials facilitate deeper light penetration. Variations in depth of cure among materials may also be influenced by light scattering at filler-matrix interfaces, absorption by photoinitiators and pigments, and differences in resin chemistry and filler composition. Bulk-fill composites are designed with modified monomer and filler systems, increased translucency and polymerization modulators or initiation boosters to permit curing of thicker increments.[9]

In the present study, micro hardness values obtained from bulk-fill materials placed in 4-mm increments were not inferior to those obtained from the conventional composite placed in 2-mm increments. Nevertheless, these findings should be interpreted with caution because the experiment was performed under ideal laboratory conditions using a high-performance curing light with direct access and minimal distance between the light tip and specimen. Such conditions may not always be achievable clinically, and the degree of polymerization may therefore be lower in deep or difficult-to-access cavities.

Marginal integrity is another important factor determining the longevity of posterior restorations. Polymerization shrinkage may compromise the tooth-restoration interface and permit the passage of bacteria, fluids, molecules or ions, resulting in microleakage.[10] Clinically, microleakage may contribute to postoperative sensitivity, recurrent caries and pulpal complications. Since Class II cavities frequently extend toward or beyond the CEJ, cervical margins may be located on cementum or deep dentin, where achieving an effective marginal seal can be challenging. Therefore, the present study evaluated micro leakage using standardized Class II cavities to simulate clinically relevant conditions.

Thermocycling was performed between 5°C and 55°C with a 15-second dwell time to simulate thermal changes occurring within the oral environment. Micro leakage was assessed using 2% methylene blue dye following 24 hours of immersion. The dye penetration method is simple, economical and does not require sophisticated laboratory equipment. In the present study, SDR exhibited the least dye penetration, followed by Tetric-N-Ceram Bulk Fill. ever-X Posterior and the Filtek control group demonstrated significantly greater dye penetration.

The superior marginal sealing ability of SDR may be related to its flowable nature, increased wettability and stress-reducing resin technology. Flowable composites can adapt closely to cavity walls, while reduced polymerization stress may decrease the forces acting at the adhesive interface. Previous studies have similarly reported favorable micro leakage behaviour for SDR, although contradictory findings have also been reported, with some studies demonstrating superior marginal adaptation for ever-X Posterior or Tetric-N-Ceram.

Tetric-N-Ceram Bulk Fill also demonstrated relatively favourable marginal integrity. Its sculptable, non-flowable consistency allows placement and modelling in a single increment. The material contains different filler systems, including barium aluminium silicate glass, ytterbium fluoride, spherical mixed oxide and polymer fillers. Its patented Isofiller acts as a shrinkage-stress-relieving component. With a lower elastic modulus than the surrounding glass fillers, the Isofiller can accommodate polymerization stresses and contribute to maintenance of the marginal seal. The findings of the present study are consistent with Patel et al. (2016), who reported promising marginal integrity with Tetric-N-Ceram Bulk Fill.[11]

In contrast, ever-X Posterior demonstrated the highest dye penetration in the present study. This finding differs from studies by Patel et al. (2016) and Bavaria et al. (2017), which reported favourable marginal adaptation with ever-X Posterior. The discrepancy may be related to differences in study design and methods used to evaluate marginal leakage. ever-X Posterior contains resin matrix, inorganic fillers and horizontally oriented E-glass fibres. Although the fibres may reduce volumetric contraction and contribute to stress absorption, their orientation within the restoration may permit greater vertical shrinkage, which could contribute to micro leakage.[12]

Overall, the present study demonstrated that bulk-fill composites can achieve adequate depth of cure when placed in 4-mm increments under controlled laboratory conditions. SDR demonstrated the most favourable overall performance, particularly in terms of microleakage and Vickers microhardness, while Tetric-N-Ceram Bulk Fill also showed good depth of cure and marginal integrity. ever-X Posterior demonstrated the highest depth of cure using ISO 4049 but comparatively lower microhardness and greater dye penetration. These findings indicate that the performance of bulk-fill composites is influenced by their resin chemistry, filler characteristics, translucency, flo.wability and stress-modifying components. Further studies under clinically simulated conditions are required to corroborate these findings and determine their long-term clinical significance.

CONCLUSION

Within the limitations of the present study, it can be stated that depth of cure and microleakage vary according to differences in the composition and viscosity of the tested materials. Among the materials evaluated, SDR may therefore be preferred over Tetric-N-Ceram and ever-X posterior to minimize microleakage and obtain superior depth of cure.

Although in vitro studies provide less reliable evidence than in vivo studies, assessments of depth of cure and microleakage may serve as useful preliminary evaluations of new restorative materials. Further in vivo studies are required to substantiate these findings and determine the long-term clinical longevity of these materials.

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