Influence of the Type of Bulk-Fill, Resin-Based Composite on Internal Adaptation in Class V Restorations

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ABSTRACT

Objective: To investigate the effects of bulk-fill, resin-based composite types (high or low viscosity) on the internal adaptation of Class V restorations.

Study Design: Experimental study.

Place and Duration of the Study: Hefei Stomatological Hospital, Hefei, China, from October 2022 to December 2023.

Methodology: A total of 140 extracted human premolars were collected. Class V cavities were prepared on the buccal surface of each tooth, which was randomly divided into seven groups (n = 20). Cavities were restored by two low-viscosity and three high-viscosity bulk-fill resin-based composites or two conventional resin-based composites. All the samples were artificially aged. The percentage of debonding formation (D%) was calculated at baseline and 6 months later using optical coherence tomography (OCT). The OCT data were statistically analysed using one-way ANOVA, and the effects of composite type and artificial ageing were analysed *via* two-way ANOVA.

Results: For Class V restorations, two low-viscosity bulk-fill resin-based composites generated significantly lower D% ($p < 0.05$). Two-way ANOVA revealed that both composite type and artificial ageing significantly influenced internal adaptation ($p < 0.05$).

Conclusion: The low-viscosity bulk-fill resin composites demonstrated better internal adaptation both before and after artificial ageing.

Key Words: *Bulk-fill resin composite, Debonding formation, Artificial ageing, Optical coherence tomography, Class V*.

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INTRODUCTION

In recent years, bulk-fill resin-based composites have been widely used in direct restorations. Improvements in the modified matrix, nanofillers, and new initiators increased the depth of curing of the resin composites to one increment of at least 4 mm in thickness and simplified the operation with low polymerisation shrinkage.[1] According to their consistency, bulk-fill resin-based composites are divided into two types: Low-viscosity and high- viscosity.[2] Low-viscosity bulk-fill resin-based composites have excellent self-levelling effects.[3] High--viscosity bulk-fill resin-based composites, which exhibit high flexural strength, compressive strength, and favourable wear resistance, are more suitable for posterior fillings.[4]

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Marginal integrity is considered one of the most important influencing factors for the long-term success rate of restoration.[5] A breach in marginal integrity can lead to microleakage, which may result in recurrent caries, pulpal inflammation, or even restoration failure. To evaluate the marginal integrity, tracer penetration, scanning electron microscopy (SEM), and other sectioning methods have been used.[5,6] OCT is a new, non-destructive, cross-sectional imaging technology that has been used to inspect dental problems such as caries or demineralisation, tooth fractures, and periodontal diseases.[7] OCT is faster and more sensitive for obtaining sample images in a short time without causing damage. It generates different light signals based on the coherent properties of dental tissues and displays high-resolution, cross-sectional images.[8] The aim of this *in vitro* study was to evaluate the effect of bulk-fill, resin-based composites on internal adaptation in Class V restorations both before and after artificial ageing using OCTs using the conventional resin-based composites as controls.

METHODOLOGY

This *in vitro* experimental study was conducted from October 2022 to December 2023 in the Laboratory of Anhui Medical University and the Department of Endodontic Conservative

Dentistry, Hefei Stomatology Clinical College of Anhui Medical University, China. Review Committee's approval was obtained (No. 20231007, dated: 10-01-2023). A total of 140 extracted human premolars were collected, cleaned, and kept in a 0.01% thymol solution until use within three months. Inclusion criteria for experimental teeth: Teeth must be free from caries, no cracks or fractures present, no prior root canal treatment conducted and complete apical development. Exclusion criteria for this study: Presence of dental defects, teeth with existing restorations, dental caries detected or enamel hypoplasia observed.

A standard Class V cavity (h×w×l = 2mm×2mm×2mm) was prepared in the lower-third of the buccal surface of the tooth, above the enamel-cemental junction. The dimensions were confirmed using a Vernier caliper (Guanglu Corporation, China). Cavities were randomly divided into seven groups (n = 20) using a web programme (www.randomizer.org) based on the type of resin composites used (Table I). Each cavity was cleaned and etched with phosphoric acid gel for 15 seconds. The surfaces were rinsed and air-dried. Bonding agents and resin-based composites were subsequently applied and light-cured for 20 seconds. The materials used in this study are summarised in Table I. After the restoration filling was complete, each tooth underwent a thermal cycling process consisting of 1,000 cycles ranging from 5 ± 2°C to 55 ± 2°C, with a dwell time of 60 seconds. Following this treatment, the teeth were immersed in artificial saliva (Table II) for a duration of 6 months.

The percentage of debonding formation in each restoration was calculated using OCT both before and after artificial ageing. The centre wavelength of the super luminescent diode light source was 870nm. The axial resolution was 11µm in air and 7µm in the tooth structure, and the lateral resolution was 17µm. All restorations were scanned in a buccolingual direction. Two images were acquired for each resin restoration to obtain the average interfacial debonding. The percentages of debonding (D%) as the ratio between debonding length and overall restoration-tooth interface length were calculated. D% was calculated by MATLAB software.

The experimental data from all groups at baseline and after artificial ageing were statistically analysed using one-way analysis of variance (ANOVA) with the Bonferroni correction at the 95% confidence interval in SPSS version 19.0 (IBM, USA). The effect of the composite type and artificial ageing was statistically analysed using two-way ANOVA at a 95% confidence interval. A $p < 0.05$ was considered statistically significant.

RESULTS

For Class V restorations, the percentage of debonding formation (D%) in OCT images at baseline for all groups was as follows in ascending order: Group 3 (SD), Group 2 (FBF).

After artificial ageing, the lowest microleakage (D%) was observed in Group 3 (Table II). Group 2 and Group 3 showed significantly less microleakage than other groups. Although the D% of the high-viscosity bulk-fill resin composites in Groups 1 and 4 were lower than those of the conventional resin composites, the difference was not statistically significant among these groups.

A representative OCT image of the interface in a Class V restoration is shown in Figure 1. The y-axis shows the penetration depth of the materials (3mm, 5.3 µm/pixel), and the x-axis shows the width of the scan field (4.5 mm, 5.0 µm/pixel). The interfacial contact between the tooth structure and resin composite was a curved line with high brightness.

Table I: Resin-based composites and adhesive systems used for restorations.

Group	Resin-based composite	Manufacturer	Code	Type	Filler content wt / vol %	Resin matrix	Bonding agent	LOT number (resin / bonding)
Group 1	Filtek Bulk-Fill Posterior	3 M ESPE	FBP	B.H.	77/59	AUDMA, UDMA, and 1, 12-dodecane-DMA	Single bond universal	N629198 /623865
Group 2	Filtek Bulk-Fill Flowable	3 M ESPE	FBF	B.L.	65/43	Bis-GMA, UDMA, Bis-EMA, Procrylat resins	Single bond universal	N502059 /623865
Group 3	SDR	Dentsply	SD	B.L.	68/45	Modified UDMA EBPADMA/TEGDMA	Xeno V Plus	924 /1701000887
Group 4	SonicFill	Kerr	SF	B.H.	86/66	Bis-GMA, TEGDMA, EBPADMA	OptiBond versa	4839377 /5853173
Group 5	Tetric N-Ceram Bulk-Fill	Ivoclar Vivadent	TB	B.H.	81/61	Bis-GMA, UDMA Dimethacrylate comonomers	Tetric N-Bond universal	T28271 /T34374
Group 6	Z350	3 M ESPE	Z3	C.H.	78/59	Bis-GMA/EMA, UDMA	Single bond universal	10333516 /623865
Group 7	CLEARFIL Majesty ES Flow	Kuraray	CF	C.L.	75/59	TEGDMA, hydrophobic aromatic dimethacrylate	SE Bond	760127 /B20358

B: Bulk-fill; C: Conventional; H: High-viscosity; L: Low-viscosity.

Table II: The mean percentage of debonding formation (D%) in Class V restorations (one-way ANOVA).

Group	1	2	3	4	5	6	7
Baseline	32.2[a]	14.7[b]	15.4[b]	33.4[a]	42.8[c]	38.6[c]	31.4[a]
After artificial ageing	46.3[A]	16.2[B]	18.7[B]	44.5[A]	55.5[A]	47.9[A]	48.6[A]

Different letters indicate that there were significant differences among groups (p <0.05). The same letters indicate no significant difference. There was no interaction between capital and lowercase letters.

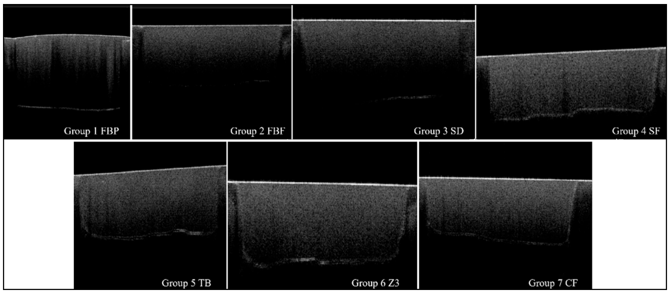

Figure 1: Representative OCT images of the interface in a Class V restoration among the groups.

According to the OCT results, two-way ANOVA revealed that the type of resin composite and artificial ageing significantly influenced internal debonding ($p < 0.05$). There was no interaction effect between them ($p = 0.075$, $p > 0.05$). Less interfacial debonding was observed at baseline than after artificial ageing using the same resin composite.

DISCUSSION

The low-viscosity bulk-fill resin-based composites (FBF and SD) showed the lowest microleakage among all groups both before and after artificial ageing. Two-way ANOVA revealed that both the type of resin composite and artificial ageing significantly influenced internal microleakage ($p < 0.05$). More interfacial debonding was observed after artificial ageing with the same resin composite.

For Class V cavities, the marginal seal plays an important role in caries treatment outcomes.[9] The low-viscosity bulk-fill resin-based composites (FBF and SD) showed the lowest microleakage among all the groups. Studies have shown that—factors for instance, polymerisation shrinkage, bond strength, viscosity of materials, types of resin composites, filling techniques, and C factors—affect the percentage of microleakage of resin restorations.[10] When the polymerisation shrinkage stress exceeds the interfacial bond strength, microleakage may occur at the interface. According to Fox's equation,[11] shrinkage stress is positively correlated with the elastic modulus. Low-viscosity resin-based composites with a low modulus[12] may exhibit a decreased shrinkage force,[13] increased shear-bond strength, and decreased microleakage. Another reason for this is that FBF and SD had a better self-levelling effect, especially in the buccal or MOD cavities.[14] The modified resin matrix and fillers in these new composites may increase the translucency by matching refractive indices, which improves the polymerisation efficiency and results in lower microleakage.[15] Although OCT can be used to locate interfacial debonding, the distribution of microleakage formation was not significantly different between the groups in the present study. Some bubbles were found in the OCT images in Group 4 (SF). This was reported in a previous study using micro-CT.[16] It may not generate a perfect self-levelling effect, especially after injection. The internal adaptation of SonicFill is similar to that of conventional composites,[17] which was consistent with the present study's findings that Group 4 (SF) and Group 6 (Z3) showed the highest D%. No relationship existed between the number or location of bubbles and D%. Some studies have shown that bulk-fill resin-based composites contain aggregated zirconia/silica filler to reduce scattering and refraction to increase light transmission and conversion,[18] leading to improved properties such as filling convenience, operational time, and curing efficiency. But high-viscosity bulk-fill resin composites did not exhibit significant advantages over traditional resin-based composites in this study. This could be attributed to the shallow cavity preparation (2mm depth), which may not fully demonstrate the advantages of bulk-fill resin-based composites. In clinical practice, both bulk-fill and traditional resin-based composites were acceptable in terms of Class V restoration retention and success.

Using the same resin composite, more microleakage was observed after artificial ageing than at the baseline for Class V cavities. Restorations treated with artificial saliva exhibited increased debonding. When debonding occurs, the white line in the OCT images appears even whiter and occupies a larger proportion. Following artificial saliva treatment, the restoration margins may undergo dissolution and debonding, potentially due to the activation of metalloproteinases in demineralised dentin by acid etching, leading to destruction of the resin-dentin interface.[19] In this investigation, the use of distinct resin composites was associated with the corresponding self-etch adhesives recommended by their respective manufacturers. The aim was to ensure an optimal bonding effect.[20] However, when compared to the adhesive system, the type of resin material and the interface location were found to have a more significant impact on internal microleakage. Furthermore, the findings of this study confirmed that despite the application of a uniform bonding agent, single bond universal, in Group 1, 2, and 6, variations arose due to the selection of different resin composites. However, the impact of surface polishing was not examined, and future research can include a control group to further investigate this aspect. The sample size of this study was relatively small. Thermo-cycling and artificial saliva treatment were unable to fully simulate the oral environment. In the future, the sample size can be further expanded, and more biomechanical studies can be incorporated to obtain more accurate results, thereby providing stronger evidence support for clinical use.

CONLUSION

Based on the above results, the low-viscosity bulk-fill resin-based composites (FBF and SD) had a better internal adaptation than the high-viscosity bulk-fill composites and conventional composites. The type of bulk-fill resin compo-site significantly influenced the internal adhesion.

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ETHICAL APPROVAL:
The HeFei Stomatological Hospital Medical Ethics Committee approved the study with protocol number 2023/1007, dated 26 October 2023.

PATIENTS' CONSENT:
The study was conducted on the medical records of patients who had provided informed consent.

COMPETING INTEREST:
The authors declared no conflict of interest.

AUTHORS' CONTRIBUTION:
QG: Designed the scheme and organised materials.
TH: Organised materials and collected data.
AW: Collected data.
QS: Collected data and consulted materials.
FZ: Consulted materials.
LZ: Conducted overall analysis and organised thoughts.
All authors approved the final version of the manuscript to be published.

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