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COMPARATIVE EVALUATION OF COLOR STABILITY AND NANOLEAKAGE OF BIOACTIVE FLOWABLE RESIN COMPOSITES VERSUS CONVENTIONAL FLOWABLE RESIN COMPOSITE AS A RESTORATION FOR DECIDUOUS MOLARS: AN IN VITRO STUDY

AREEJ TAWFIK MOHAMED SALEH

Teaching Assistant of Pediatric Dentistry, Preventive Dentistry and Dental Public Health, Faculty of Dentistry, Badr University, Cairo, Egypt. Email: AreejTawfeek@buc.edu.eg

SHAIMAA MOHAMED MAHFOUZ OMER

Professor of Pediatric Dentistry, Preventive Dentistry and Dental Public Health, Faculty of Dentistry, Suez University, Suez, Egypt. Email: shaimaa.mahfouz@den.suezuni.edu.eg, ORCID: 0000-0001-6131-3535

YOUSRA SAMIR HELMY

Associate Professor of Pediatric Dentistry, Preventive Dentistry and Dental Public Health, Faculty of Dentistry, Suez Canal University, 41522 Ismailia, Egypt.

Abstract

Background: This study evaluated the color stability and nanoleakage of a self-adhering bioactive flowable composite (Beautifil Kids SA), a bioactive flowable composite (Beautifil Flow), and a conventional flowable composite (3M Filtek Supreme Flowable Restorative) used for Class V restorations in primary molars. **Methods:** Seventy-two extracted primary molars with standardized buccal Class V cavities (2 × 2 mm) were randomly divided into three groups (n = 24). Color stability was assessed by spectrophotometry using the CIELAB system after pH cycling and 1,000 thermocycles. Nanoleakage was assessed by scanning electron microscopy (SEM) and ImageJ analysis after silver nitrate penetration and thermocycling. **Results:** For color stability, the self-adhering bioactive flowable composite showed the highest ΔE (4.48 ± 0.26), followed by the bioactive flowable composite (3.57 ± 0.20) and the conventional flowable composite (3.08 ± 0.20). For nanoleakage, the highest mean value was recorded for the bioactive flowable composite (103.0 ± 8.58), followed by the conventional flowable composite (94.29 ± 11.27), whereas the self-adhering bioactive flowable composite showed the lowest value (87.86 ± 9.23). **Conclusion:** Within the limitations of this in vitro study, Beautifil Kids SA showed the highest color change but the lowest nanoleakage value among the tested materials, indicating a trade-off between color stability and interfacial sealability.

Keywords: Primary Molars; Flowable Composite; Bioactive Composite; Self-Adhering Composite; Color Stability; Nanoleakage.

INTRODUCTION

Dental caries is a prevalent chronic infectious disease driven by cariogenic bacteria, including Streptococcus mutans, which metabolize fermentable carbohydrates and produce acids that demineralize tooth structure (1). This multifactorial disease is influenced by dietary, microbial, psychological, behavioral, and social factors and affects approximately 46.2% of primary teeth globally, with higher rates reported in developing countries because of disparities in education, socioeconomic status, oral hygiene, nutrition, and access to dental care (2). Early childhood caries (ECC), defined as one or more decayed, missing, or filled primary teeth in children aged 5 years or younger, may

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initially present as white-spot lesions at the gingival margins of the upper primary incisors and may progress to extensive tooth destruction if untreated (3). Untreated lesions affect approximately 621 million children worldwide and may cause pain and compromise health, development, and quality of life (4). Infants have unique risk factors, including developing oral microbiota, erupting teeth with potential developmental defects, and dietary transitions involving breast- or bottle-feeding and solid foods. Prolonged or inappropriate nighttime bottle-feeding with sugar-containing drinks may further increase the risk of caries (5). Although buccal surfaces may have a relatively lower caries risk, effective restoration remains important to prevent lesion progression and recurrence and to restore function and esthetics (6). Modern restorative dentistry emphasizes minimally invasive approaches and the use of resin-based composites because of their favorable physical and mechanical properties, compressive strength, wear resistance, esthetic potential, and ease of use (7,8). Bioactive restorative materials, including alkaline resins and materials containing surface pre-reacted glass-ionomer (S-PRG) fillers, may release ions such as fluoride, strontium, sodium, aluminum, borate, and silicate and may contribute to remineralization, acid neutralization, and antibacterial effects (9,10). Flowable composites have favorable injectability and adaptation because of their lower viscosity and reduced filler content and may be used in Class I–V restorations, liners, and fissure-related applications; however, polymerization shrinkage and marginal leakage remain concerns (11,12). Self-adhering flowable composites incorporate functional monomers that allow simultaneous surface conditioning and chemical interaction with hydroxyapatite, thereby simplifying the restorative procedure and potentially reducing technique sensitivity (13,14). Color instability may result from extrinsic factors, including penetration of pigments from foods and beverages and exposure to pediatric medications, as well as intrinsic factors such as filler characteristics and inadequate polymerization (15). Nanoleakage refers to nanoscale leakage within or around the resin–dentin interface and may occur because of incomplete infiltration, polymerization-related changes, or degradation within the hybrid layer, potentially compromising interfacial sealing and restoration longevity (13).

Therefore, this study evaluated and compared the color stability and nanoleakage of a self-adhering bioactive flowable composite (Beautifil Kids SA), a bioactive flowable composite (Beautifil Flow), and a conventional flowable composite (3M Filtek Supreme Flowable Restorative) in Class V restorations in primary molars.

METHODS

Ethical Statement

Seventy-two unidentified primary molars, extracted for non-study-related reasons, were collected from the Outpatient Dental Clinic, Pediatric Dentistry, Preventive Dentistry and Dental Public Health Department, Faculty of Dentistry, Suez Canal University. The study was waived from ethical approval by the Research Ethics Committee (REC), Faculty of Dentistry, Suez Canal University (No. 619/2023).

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Study Setting

This in vitro study used 72 unidentified extracted primary molars (mandibular and maxillary) that had been extracted for non-research reasons. The sample size was determined by a priori sample size calculation (Table 1).

Sample Size Calculation

Sample size was calculated using G*Power version 3.1.9.2 (16). Based on an effect size (f) of 0.48, α = 0.05, and β = 0.05 (power = 95%), the calculated sample size was 24 specimens per group, giving a total of 72 specimens. The calculation was consistent with previous studies (17).

Table 1: Sample Grouping

Groups	Name	Test one	Test two	Total
		Color stability	Nanoleakage	
Group I	Self-adhering bioactive flowable Composite	17	7	24
Group II	Bioactive flowable composite	17	7	24
Group III	Conventional flowable composite	17	7	24
Total		51	21	72

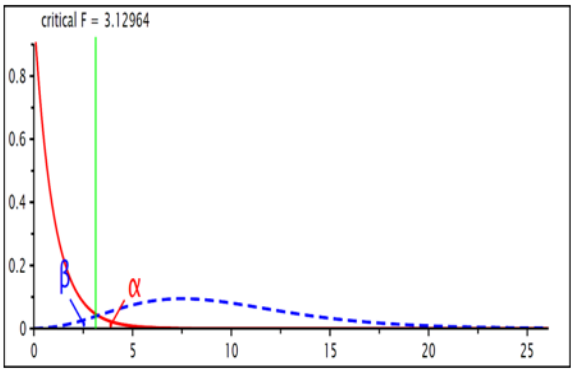


Figure 1: B and ∝ for Sample Size,

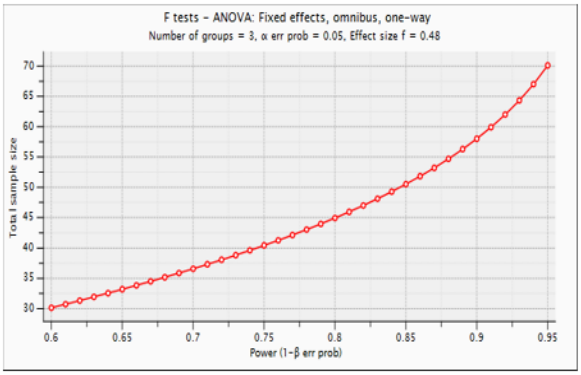


Figure 2: Power (1- B Err Prob) For Sample Size

Sample Selection

The teeth were selected according to the following criteria:

Inclusion criteria (18,19):

- No obvious cracks, structural flaws, or cervical abrasion, as assessed using a stereomicroscope.
- No enamel or dentin structural defects.
- No cervical caries.
- Exclusion criteria:

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- Less than one-third of the root structure remaining (20).
- Erosion, structural defects, or fracture occurring during extraction (21).

Study Procedures

Tooth preparation:

The teeth were washed, debrided, disinfected with thymol, and stored in saline at room temperature (Fig. 3) (19). The roots were embedded in epoxy resin to a standardized depth/width of 1 mm (Figs. 4 and 5) (21).



Figure 3: Primary molars stored in saline



Figure 4: Standardized mould for extracted teeth



Figure 5: Teeth Were Embded in an Epoxy Resin

Operative Procedures

Cavity preparation:

Standardized rounded Class V cavities measuring 2 mm in depth and 2 mm in diameter were prepared in the gingival one-third of the labial surfaces using a #330 carbide bur with a high-speed hand piece under water coolant (Figs. 6 and 7) (22). Cavity dimensions were verified using a graduated periodontal probe (Fig. 8) (23). Burs were replaced after every four preparations (24). The cavity outline followed conventional resin restoration preparation guidelines (25), and the bur head was used as a guide for cavity depth (26).

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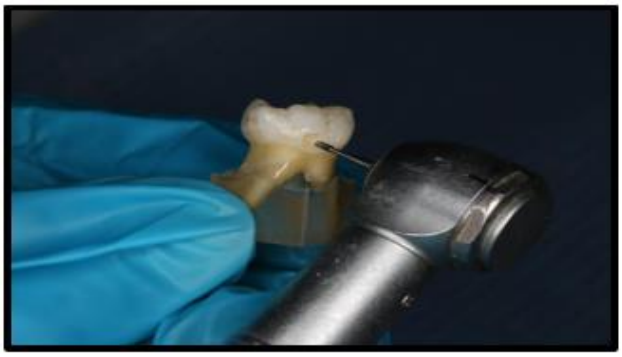


Figure 6: Class V Cavity Preparation Using Carbide Bur Size #330 with a High-Speed Handpiece



Figure 7: Standardized rounded Class V cavities

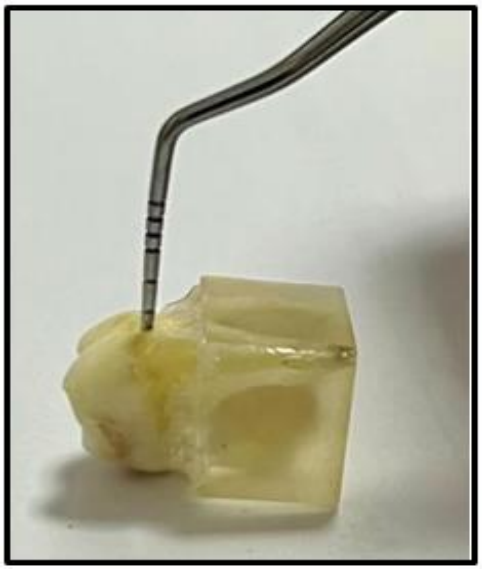


Figure 8: Using Graduated Periodontal Probe to Check Cavity Walls' Length and Depth

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Sample Grouping

The 72 primary molars were randomly allocated into three restorative-material groups (n = 24 per group) using a randomization website. Each group was subdivided according to the evaluation method:

- Group I: Self-adhering bioactive flowable composite, Beautifil Kids SA (Shofu). Subgroup Ia (n = 17): color stability; subgroup Ib (n = 7): nanoleakage.
- Group II: Bioactive flowable composite, Beautifil Flow (Shofu), used with 37% phosphoric acid and 3M ESPE Single Bond Universal. Subgroup IIa (n = 17): color stability; subgroup IIb (n = 7): nanoleakage.
- Group III: Conventional flowable composite, 3M Filtek Supreme Flowable Restorative (3M ESPE), used with 37% phosphoric acid and 3M ESPE Single Bond Universal. Subgroup IIIa (n = 17): color stability; subgroup IIIb (n = 7): nanoleakage.

Methods of Evaluation

Samples were evaluated according to the following methods:

a. Color stability: reflectance spectrophotometry.

b. Nanoleakage: scanning electron microscopy (SEM) with ImageJ analysis.

Assessment of Color Stability

Subgroups Ia, IIa, and IIIa were assessed using a reflectance spectrophotometer (Cary 5000, Agilent, USA) at the National Institute of Standards, Giza.

Baseline (T0):

The restorations were stored in distilled water for 24 h, then washed and dried. L*, a*, and b* values were measured using the CIELAB system with a D65 illuminant and a 10° standard observer. L* represents lightness (0–100), a* represents the red (+) to green (−) axis, and b* represents the yellow (+) to blue (−) axis.

Post-challenge (T1):

The specimens underwent 10 days of pH cycling. Each day, specimens were immersed for 30 min in Coca-Cola, orange juice (Beyti), and chocolate milk (Juhayna), for 10 min in each beverage (Fig. 26). This was followed by 7.5 h in a demineralizing solution (50 mM acetic acid, 2.2 mM NaH_2PO_4, and 2.2 mM $CaCl_2$; pH 4.8) and 16 h in a remineralizing solution (0.15 M KCl, 1.5 mM $CaCl_2$, and 0.9 mM NaH_2PO_4; pH 7). The specimens were subsequently subjected to 1,000 thermocycles between 5°C and 55°C, with a dwell time of 30 s (Figs. 27–30) (27).

The spectrophotometer automatically recorded the mean ΔL*, Δa*, and Δb* values based on measurements obtained at T0 and T1.

Color change was calculated using the following equation:

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

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Assessment of Nanoleakage

Subgroups Ib, IIb, and IIIb were evaluated after thermocycling using scanning electron microscopy (Quattro S, USA) at the British University Nanotechnology Center.

The specimens were prepared with a 1-mm margin apical to the restoration, and the root apex was sealed with sticky wax and two coats of nail varnish (Fig. 9). Specimens were immersed in 50% silver nitrate ($AgNO_3$) solution for 24 h in a light-protected container, rinsed, exposed to a photographic developing solution for 8 h under fluorescent light, and rinsed again. After 1,000 thermocycles, the specimens were sectioned buccolingually using an IsoMet™ 4000 Linear Precision Saw (Fig. 10). SEM images were obtained at ×1,000 magnification, and silver penetration was quantified using ImageJ version 1.46r (NIH) (Figs. 11–13) (28).

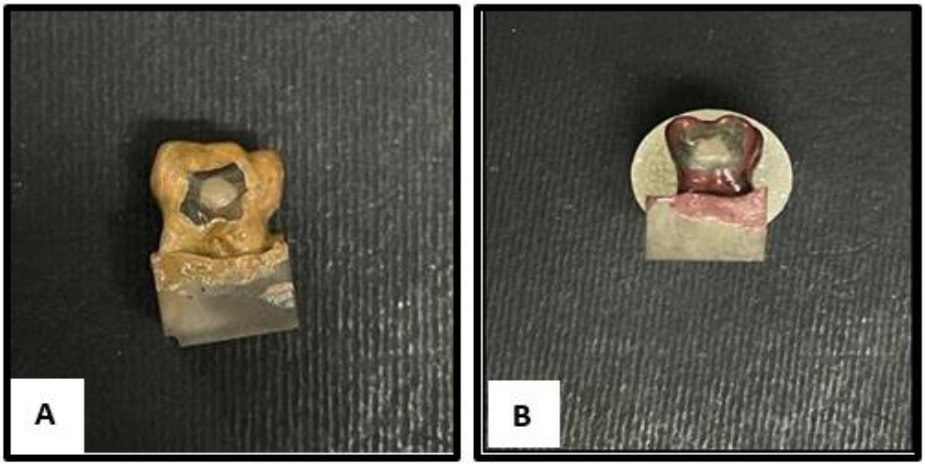


Figure 9: Preparaing Sample For Nanoleakage Test. (A) Sealing With Sticky Wax. (B) Coating with Nail Varnish

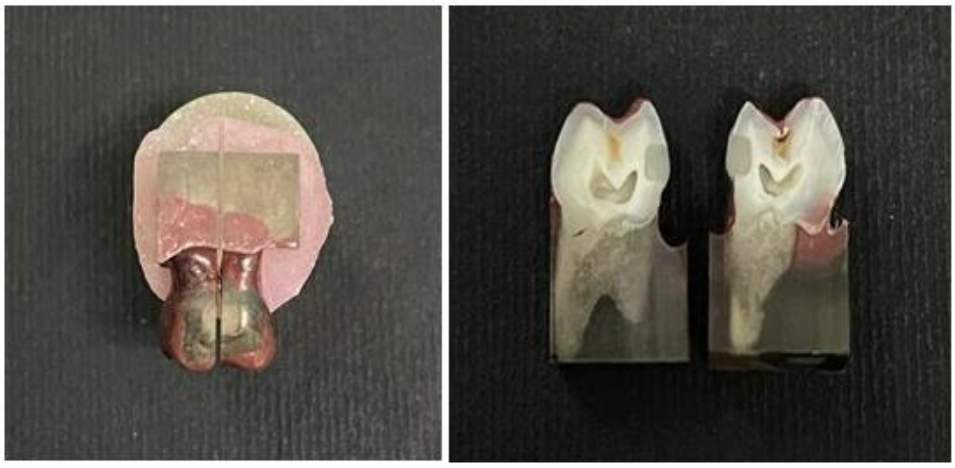


Figure 10: Separated Parts of Specimen

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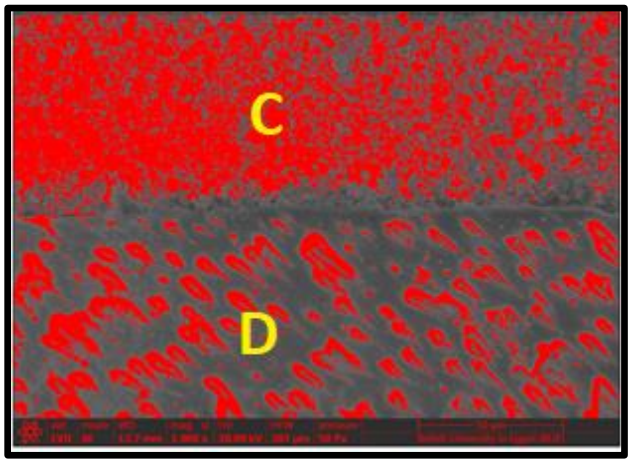


Figure 11:Self-Adhering Bioactive Flowable Composite (Beautifil Kids SA) In Longitudinal Section of A Class V Cavity Preparation Showing Ag Deposition at the Composite–Dentin Interface after Thermocycling (×1,000). Elemental Distribution Of Ag Within Dentin And Composite Was Analyzed Using Imagej Version 1.46r (NIH). C, Composite Resin; D, Dentin; Black Arrows, Ag Deposition

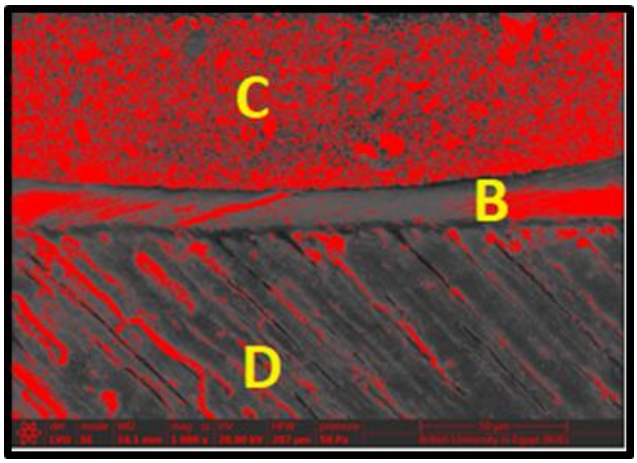


Figure 12: Beautifil Flow (Shofu) In Longitudinal Section of a Class V Cavity Preparation Showing Ag Deposition at the Composite–Dentin Interface after Thermocycling (×1,000). Elemental Distribution Of Ag Within Dentin And Composite Was Analyzed Using Imagej Version 1.46r (NIH). C, Composite Resin; D, Dentin; B, Bond; Black Arrows, Ag Deposition

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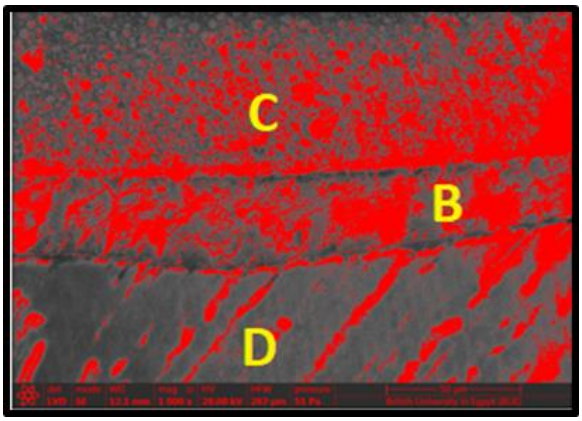


Figure 13: Conventional Flowable Composite Resin (3M Filtek Supreme Flowable Restorative; 3M ESPE) In Longitudinal Section of A Class V Cavity Preparation Showing Ag Deposition at the Composite–Dentin Interface after Thermocycling (×1,000). Elemental Distribution Of Ag Within Dentin And Composite Was Analyzed Using Imagej Version 1.46r (NIH). C, Composite Resin; D, Dentin; B, Bond; Black Arrows, Ag Deposition

Statistical Analysis

Data were tabulated and statistically analyzed using appropriate statistical tests. The Shapiro–Wilk test was used to assess normality. Descriptive statistics were presented as mean ± standard deviation (SD). A paired-samples t test was used to compare measurements before and after the experimental challenge. One-way analysis of variance (ANOVA) was used to compare the study groups, followed by Bonferroni post hoc tests for pairwise comparisons. A P value ≤ 0.05 was considered statistically significant. Statistical analysis was performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA).

RESULTS

Evaluation of Color Stability Using Spectrophotometry

Comparison between groups for color stability:

Table 2 shows statistically significant differences among the three groups in ΔL, Δa, Δb, and ΔE (one-way ANOVA, $P < 0.001$ for all parameters). Pairwise comparisons showed significant differences between each pair of groups. The self-adhering bioactive flowable composite group showed the highest mean Δa (1.22 ± 0.12), Δb (3.50 ± 0.29), and ΔE (4.48 ± 0.26). The bioactive flowable composite group showed the lowest mean ΔL (−1.98 ± 0.23), whereas the conventional flowable composite group showed the lowest Δa, Δb, and ΔE values (Fig. 14).

Intergroup comparison for hue angle: There was a statistically significant difference among the groups after thermocycling ($P = 0.002$, one-way ANOVA) (Fig. 15, Table 3).

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Intragroup comparison for hue angle: Significant pre- to post-thermocycling changes were observed in the self-adhering bioactive flowable composite group ($P < 0.001$) and the bioactive flowable composite group ($P < 0.001$), whereas no significant change was observed in the conventional flowable composite group ($P = 0.131$). The reported percentage changes were −17.7%, −6.8%, and −5.2%, respectively (Fig. 15, Table 3).

Intergroup comparison for chroma (a*): A statistically significant difference was observed among the groups after thermocycling ($P < 0.001$, one-way ANOVA) (Fig. 16, Table 4).

Intragroup comparison for chroma (a*): Significant pre- to post-thermocycling changes were observed in all groups ($P < 0.001$, paired-samples t test). Chroma increased after thermocycling, with percentage changes of 32.7% in the self-adhering bioactive flowable composite group, 32.2% in the bioactive flowable composite group, and 31.2% in the conventional flowable composite group (Fig. 16, Table 4).

Table 2: Comparison between Groups for Color Stability

	ΔL	Δa	Δb	ΔE
Self-adhering bioactive flowable composite	2.49±0.23 a	1.22±0.12 a	3.50±0.29 a	4.48±0.26 a
Bioactive flowable composite	-1.98±0.23 c	1.09±0.13 b	2.74±0.28 b	3.57±0.20 b
Conventional flowable composite	1.59±0.15 b	0.97±0.11c	2.44±0.24 c	3.08±0.20 c
F test	213.61	19.88	68.82	170.5
P value	<0.001**	<0.001**	<0.001**	<0.001**
**** and different letters means significant difference between groups at P<0.05**				

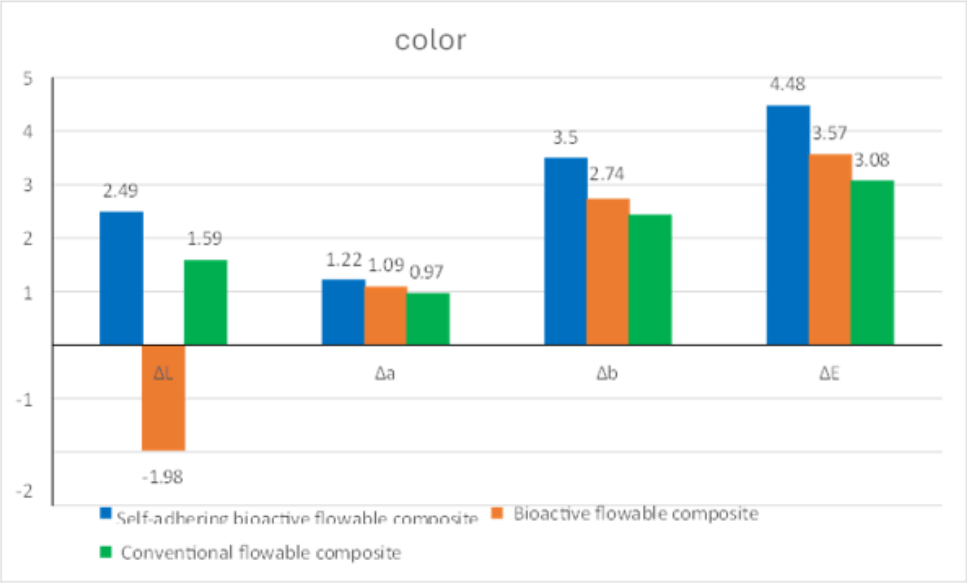


Figure 14: Comparison between Groups for Color Stability

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Table 3: Inter and Intra Group Comparison for Hue (Deg) (B*)

	Before	After	%change	Paired T test	P value
Self-adhering bioactive flowable composite	95.022±0.55	78.194± 3.2 c	-17.7	40.519	<0.001**
Bioactive flowable composite	93.948±0.62	87.569±0.75 a	-6.8	39.06	<0.001**
Conventional flowable composite	86.576±0.79	82.034±0.87 b	-5.2	1.591	0.131
F test	813.64	12.605			
P value		0.002**			
**** and different letters means significant difference between groups at P<0.05**					

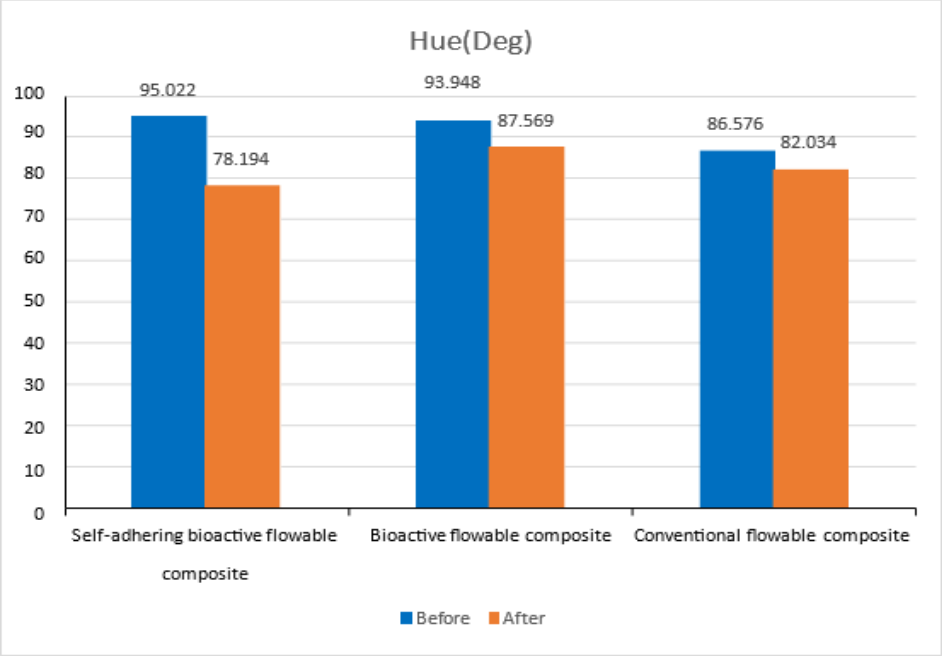


Figure 15: Comparison between Groups for Hue Angle

Table 4: Inter and Intra Group Comparison for Chroma (A*)

	Before	After	%change	Paired T test	P value
Self-adhering bioactive flowable composite	10.585±0.22	14.050±0.37a	32.7	29.91	<0.001**
Bioactive flowable composite	8.756±0.18	11.490±0.31b	32.2	43.25	<0.001**
Conventional flowable composite	7.849±0.19	10.375±0.36c	31.2	50.35	<0.001**
F test	838.44	501.08			
P value		<0.001**			
**** means significant difference between groups at P<0.05**					

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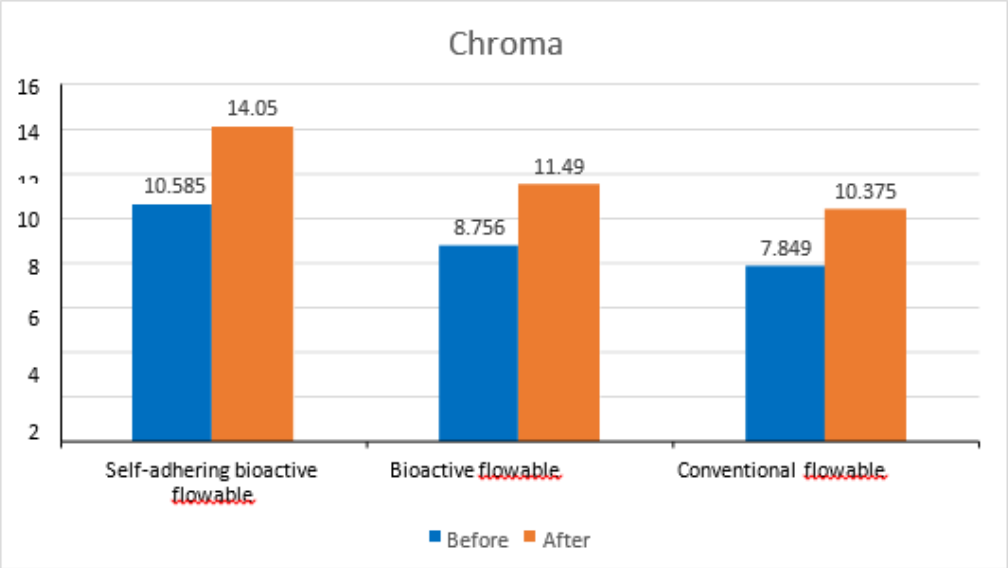


Figure 16: Comparison between Groups for Chroma before and After Thermocycling

Evaluation of Nanoleakage Using Scanning Electron Microscopy and Imagej Analysis

At ×1,000 magnification, silver deposition along the resin–dentin interfaces was quantified using ImageJ version 1.46r (NIH, USA) (Figs. 11–13). Mean ± SD and minimum–maximum nanoleakage values are presented in Table 5 and Fig. 17.

A statistically significant intergroup difference was observed (one-way ANOVA: F = 4.254, P = 0.031). Pairwise comparisons showed that the bioactive flowable composite group had significantly greater nanoleakage than both the self-adhering bioactive flowable composite group and the conventional flowable composite group ($P < 0.05$). No significant difference was observed between the self-adhering bioactive and conventional flowable composite groups. The highest mean value was observed in the bioactive flowable composite group (103.0 ± 8.58), followed by the conventional flowable composite group (94.29 ± 11.27), while the self-adhering bioactive flowable composite group had the lowest mean value (87.86 ± 9.23).

Table 5: Comparison between Groups for Nanoleakage

	Mean	SD	Minimum	Maximum	F test	P value
Self-adhering bioactive flowable composite	87.86[b]	9.23	80.00	107.00	4.245	0.031**
Bioactive flowable composite	103.00[a]	8.58	89.00	117.00		
Conventional flowable composite	94.29[b]	11.27	80.00	108.00		
**** and different superscript letters mean significant difference at P<0.05**						

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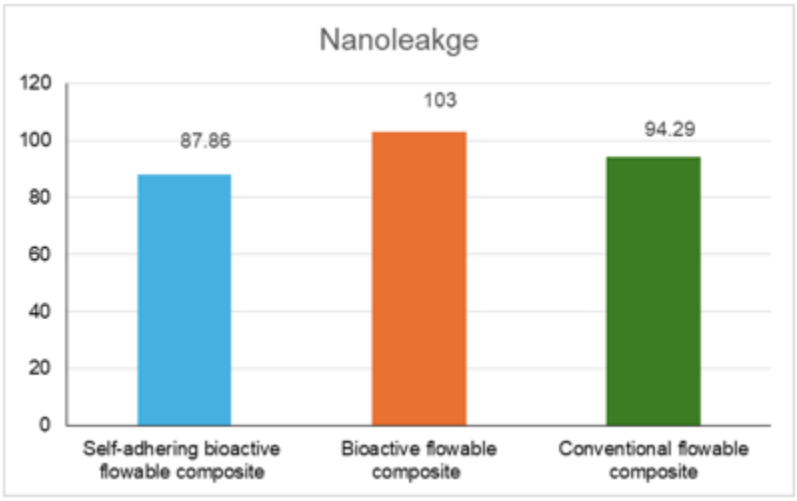


Figure 17: Comparison between Groups for Nanoleakge

DISCUSSION

Composite resin restorations are widely used in pediatric dentistry because of their esthetic properties, mechanical performance, mercury-free composition, and ability to preserve tooth structure (29). Reducing placement time may improve patient cooperation; therefore, self-adhering flowable composites may simplify the restorative procedure and reduce the number of operative steps (30,32). Beautifil Kids SA uses a modified polyacid system (MOPOS) for adhesion without a separate etching step. This approach is consistent with the findings of Jordehi et al., who reported that simplified self-adhering restorative procedures can reduce application time and procedural steps (33).

Flowable composites can adapt well to Class V cavities because of their low viscosity and reduced elastic modulus, which may contribute to marginal adaptation (34). Standardized 2 × 2 mm buccal Class V cavities were prepared according to the approach described by Al-Agha et al. (22). Burs were replaced after every four preparations because bur wear may influence smear-layer characteristics and cavity preparation consistency (22,35). Specimens without cracks or structural defects were selected because such defects could compromise the restorative interface and influence leakage measurements (36,37). The teeth were individually embedded in epoxy resin to facilitate standardized handling during the experimental procedures (38).

Over-etching of primary and permanent dentin may produce deeper demineralization of the collagen network, potentially affecting adhesive infiltration and bond integrity (39). In the present study, the bonding agent was applied with a brush to facilitate uniform distribution on the dentin surface (40). In contrast, Beautifil Kids SA does not require separate etching or bonding steps, which may simplify clinical application.

The light-curing tip was positioned perpendicular to the composite surface at a controlled distance to standardize polymerization conditions. Light intensity decreases as the

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distance from the composite surface increases, which may affect the degree of conversion, polymerization shrinkage, and marginal integrity (41). Lighting conditions can influence color measurements. To minimize measurement variability, a white background and a standardized illuminant were used during color assessment (15). Because polishing can influence the color and surface characteristics of composite resins, all specimens were polished under identical conditions to minimize the effect of surface roughness. Thus, observed color changes were evaluated after exposure to the selected beverages and pH-cycling protocol (42). Composite resin restorations are routinely exposed to food, beverages, and saliva, all of which may affect color, surface characteristics, and cleanliness. In the present study, Coca-Cola, orange juice, and chocolate milk were selected as challenge beverages because such beverages may influence the color stability of restorative materials (42,43).

Temperature and pH changes may affect the structural integrity and color stability of composite resin restorations. Therefore, the specimens underwent daily pH cycling for 10 days to provide an experimental challenge intended to simulate relevant oral environmental conditions (17). Thermocycling is commonly used to simulate thermal aging of dental materials by exposing specimens to repeated temperature fluctuations. In the present study, thermocycling was performed between 5°C and 55°C. Repeated exposure to temperature changes and water may contribute to hydrolytic degradation and changes in resin-matrix behavior (44).

All samples were subjected to 1,000 thermocycles between 5°C and 55°C. The selected protocol was based on the cited literature regarding thermal cycling of dental restorative materials (45). Spectrophotometry provides an objective method for quantifying color changes in dental restorative materials. Accordingly, a reflectance spectrophotometer was used in the present study to quantify changes in the CIELAB parameters.

The observed color change after exposure to the challenge beverages may be related to their acidic environment and the presence of pigments. Acidic conditions may alter surface characteristics and increase the susceptibility of restorative materials to pigment uptake. This interpretation is consistent with the findings of Habib et al., who reported color changes in resin composites after exposure to children's beverages (15).

The observed color changes are also consistent with reports that artificial colorants and acidic components in beverages may promote discoloration of restorative materials (47,48). Briso et al. reported that acidic challenges can alter the surface characteristics of restorative materials, including surface roughness and microhardness, and that exposure duration may influence these changes (49). Such alterations may contribute to changes in color stability. Similarly, Habib et al. reported clinically significant color changes in resin composites exposed to children's beverages, with pronounced changes observed after repeated exposure (15). In the present study, the self-adhering bioactive flowable composite showed the highest Δa, Δb, and ΔE values, followed by the bioactive flowable composite, whereas the conventional flowable composite showed the lowest values for these parameters. The bioactive flowable composite showed the lowest ΔL value. These differences may be related to differences in resin chemistry, hydrophilicity,

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water sorption, and filler characteristics. The greater water sorption reported for some self-adhesive materials may increase susceptibility to discoloration (42,51). In contrast, Alhumaid et al. reported good clinical color stability for self-adhering flowable composite restorations during an 18-month clinical follow-up, while conventional flowable composite restorations showed lower clinical ratings (52). The difference between these findings and the present in vitro results may be related to differences in study design, exposure conditions, and outcome assessment.

Nanoleakage was assessed to investigate leakage patterns at the resin–dentin interface. Nanoleakage may reflect pathways within the hybrid layer and may be associated with hydrolytic degradation of collagen or adhesive resin, potentially affecting the long-term stability of the bonded interface (53). For nanoleakage assessment, the specimens were sectioned longitudinally through the center of the restoration in a buccolingual orientation using an IsoMet™ 4000 Linear Precision Saw. Silver nitrate was used as a tracer because its penetration can reveal nanoscale porosities at the tooth–restoration interface. When combined with high-magnification SEM, silver nitrate tracing permits visualization and quantification of silver deposition at the bonded interface (53,54). Manikandan et al. described silver nitrate as a useful tracer for identifying nanoporosities within the hybrid layer because of its ability to penetrate small pathways and produce visible deposits at the interface (53).

In the present study, nanoleakage was quantified based on the extent of silver deposition at the material–tooth interface, consistent with the approach described by Abo El Naga et al. (13). The highest mean nanoleakage value was observed in the bioactive flowable composite group (103.0 ± 8.58), followed by the conventional flowable composite group (94.29 ± 11.27), whereas the self-adhering bioactive flowable composite group showed the lowest mean value (87.86 ± 9.23). The difference between the self-adhering bioactive and bioactive flowable composite groups was statistically significant. Within the conditions of this in vitro experiment, the lower silver deposition observed with Beautifil Kids SA suggests better interfacial sealability than that observed with Beautifil Flow.

These findings differ from those of Sachdeva et al., who reported lower sealability for a self-adhesive flowable composite than for conventional flowable composites, and from Mobarak and Seyam, who reported nanoleakage in self-adhesive systems when compared with self-etch adhesive systems (18,55). Differences may be related to variations in material composition, adhesive strategy, substrate, specimen preparation, and aging protocol. Sachdeva et al. suggested that the mild etching effect of self-etching primers modifies rather than completely removes the smear layer. Retention of hybridized smear plugs within dentinal tubules may reduce silver deposition and contribute to dentin sealing (18). The present findings are also consistent with Zidan, who reported that self-etch adhesive systems can modify the hybrid layer and reduce silver nitrate penetration at the resin–dentin interface when evaluated by SEM (56). Conversely, Tay et al., Hashimoto et al., and El-Badrawy et al. reported greater nanoleakage in self-adhesive restorations than in self-etching systems (57–59). Such differences may be related to

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water retention and the chemical characteristics of hydrophilic monomers, including HEMA, which may influence silver uptake and interfacial degradation.

Limitations

This study has several limitations. First, hybrid-layer thickness was not measured, limiting direct assessment of the underlying bonding mechanism. Second, spectrophotometric and SEM analyses require specialized and relatively costly equipment. Third, the sample size was limited to 72 specimens, and the in vitro design limits direct extrapolation of the findings to clinical conditions.

CONCLUSION

Within the limitations of this in vitro study, the self-adhering bioactive flowable composite (Beautifil Kids SA) showed the highest color change (ΔE), whereas the conventional flowable composite (3M Filtek Supreme Flowable Restorative) showed the lowest ΔE. Nanoleakage differed significantly between the bioactive flowable composite and both the self-adhering bioactive and conventional flowable composite groups ($P < 0.05$), while no significant difference was observed between the latter two groups. Beautifil Kids SA therefore showed lower color stability but lower silver deposition at the interface under the tested conditions.

Recommendations

- Further in vitro and in vivo studies are recommended to evaluate the mechanical, physical, and long-term clinical performance of Beautifil Kids SA in primary teeth.
- Studies with larger sample sizes and standardized clinical follow-up are recommended to improve the external validity of the findings.
- Based on the present in vitro findings, Beautifil Kids SA may be considered a promising material for Class V restorations in primary teeth; however, clinical studies are required before making definitive clinical recommendations.

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