



Influence of Pineapple Juice Immersion on the Color Stability and Surface Microhardness of Single-Shade Universal Composite Resins

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ABSTRACT

Introduction: While single-shade universal resin composites streamline clinical workflow, their hydrophilic resin matrix renders them vulnerable to acidic environments that compromise color stability and mechanical integrity. Pineapple juice (*Ananas comosus* (L.) Merr.), an acidic beverage rich in beta-carotene pigments, poses a potential risk of altering these physical characteristics.

Objective: This study aimed to assess the impact of pineapple juice immersion on the color stability and surface microhardness of single-shade universal composite resins.

Method: This pretest-posttest controlled laboratory experiment used 32 cylindrical specimens (10×2 mm) of two single-shade universal composites (Omnichroma and Zenchroma), randomized into four groups (n=8). Treatment cohorts were immersed in pineapple juice for 6 hours daily for 7 days at 37°C, while controls used distilled water. Color variations (ΔE) and surface microhardness were evaluated using a spectrophotometer and Vickers Hardness Tester, respectively, and analyzed using two-way ANOVA.

Outcome: Two-way ANOVA revealed that the immersion medium exerted a statistically significant effect on both color variation and surface microhardness ($p < 0.05$). All experimental groups displayed ΔE values below 1, confirming that color alterations were clinically imperceptible. Conversely, exposure to pineapple juice induced a significantly more marked decline in microhardness than distilled water ($p < 0.05$), with Omnichroma exhibiting the most substantial reduction.

Conclusion: While immersion in pineapple juice does not cause clinically meaningful discoloration in single-shade universal composite resins, it produces a significant reduction in surface microhardness.

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INTRODUCTION

Growing patient interest in facial esthetics has heightened the demand for restorative biomaterials capable of providing harmonious shade matching while fully restoring oral function. Unaddressed carious lesions frequently impair dental appearance and overall facial harmony. Continuous innovations in dental technology have yielded advanced materials capable of fulfilling the complex demands of mastication, phonetics, and esthetic integration.¹

Resin composites remain among the most popular tooth-colored restorative biomaterials owing to their superior appearance and anatomical fidelity. Structurally composed of an organic resin matrix, inorganic filler particles, and a silane coupling agent, these materials solidify through light-activated polymerization.^{2,3} The ultimate mechanical resilience and optical behavior of a composite are primarily dictated by its microstructural configuration and elemental formulation.⁴ Beyond superior esthetics, composite restorations permit conservative cavity preparation, possess favorable biocompatibility, and achieve strong adhesive bonding with enamel and dentin.^{1,4} Furthermore, their substantial compressive resistance supports reliable placement in both anterior and posterior teeth.⁵

The polymer matrix predominantly comprises dimethacrylate cross-linking monomers, including bisphenol A-glycidyl methacrylate (Bis-GMA), urethane dimethacrylate (UDMA), and triethylene glycol dimethacrylate (TEGDMA), which jointly govern polymer conversion, mechanical strength, and chemical durability. Inorganic filler particles incorporated at specific size distributions serve to fortify structural rigidity, minimize volumetric shrinkage during polymerization, and mitigate fluid sorption.⁶ A silane coupling agent mediates the cohesive interface between organic and inorganic phases, thereby preserving structural stability under intraoral conditions.^{6,7}

Dental composite formulations are conventionally categorized according to filler dimensions into macrofilled, microfilled, nanofilled, hybrid, and nanohybrid materials.^{8,9} Recent technological progressions have yielded single-shade universal composite systems that dynamically adapt to surrounding tooth structures through smart structural coloration mechanisms.^{10–13} This shade-matching capability eliminates time-consuming color selection steps, which previously occupied 30 to 60 seconds of clinical time for over half of practicing clinicians.¹⁴ This “chameleon-like” optical phenomenon enables restorations to mimic adjacent dental tissues, facilitated by tailored resin chemistries and specialized filler particles engineered to optimize light scattering and spectral transmission.^{10–13,15}

Notwithstanding these merits, the inherent hydrophilic character of the resin matrix leaves single-shade universal composite prone to fluid uptake, which may impair long-term optical

fidelity and structural integrity.¹⁶ Color permanence is essential to the longevity of esthetic restorations, directly governing clinical success and patient satisfaction.^{17,18} Discoloration may arise through intrinsic pathways-such as matrix formulation, filler fraction, water absorption, and silane degradation¹⁷⁻¹⁹ or via extrinsic mechanisms, including habitual exposure to chromatic dietary substances like coffee, tea, juices, and soft drinks.^{20,21} Continuous contact with acidic solutions tends to elevate surface roughness and marginal microleakage, thereby accelerating colorant infiltration.^{22,23}

Surface microhardness represents another pivotal physical parameter, serving as an indicator of resistance against wear, abrasion, and chemical erosion.^{24,25} This property is mediated by monomer conversion, filler loading, and exposure to low-pH agents.^{24,26} Acidic challenges can induce matrix hydrolysis, compromise matrix-filler bonding, and generate micro-voids, ultimately weakening structural resistance.^{27,28} Furthermore, a decline in surface microhardness frequently correlates with an increased susceptibility to extrinsic staining.²⁹

Modern dietary shifts emphasizing healthy eating have substantially increased fruit consumption, including pineapple.³⁰ Frequently consumed across Indonesia, pineapple exhibits a distinct sweet-acidic flavor profile with a low pH ranging between 3.5 and 4.0, alongside high moisture content.³¹⁻³⁵ Rich in beta-carotene pigments responsible for its yellow-orange hue, pineapple also contains active biomolecules such as ascorbic acid and the proteolytic enzyme bromelain^{30,36}

While single-shade universal composites offer noticeable clinical efficiency and esthetic fidelity, empirical data evaluating their response to naturally acidic fruit juices-such as pineapple juice-remain scarce. Consequently, this investigation aimed to analyze the impact of pineapple juice immersion on the color stability and surface microhardness of two single-shade universal composite resins, offering valuable clinical insights relative to patient dietary habits.

RESEARCH FINDINGS

A total of 32 single-shade universal composite specimens were assigned across four experimental groups based on resin brand and immersion protocol. The mean pH of the freshly extracted pineapple juice was measured at 3.7, establishing an acidic condition. The evaluation encompassed color stability (ΔE) and microhardness dynamics post-exposure.

Color shifts were quantified via ΔE values. Zenchroma immersed in pineapple juice demonstrated the highest numerical mean color change, whereas Omnicroma stored in distilled water exhibited the lowest. Descriptively, specimens exposed to pineapple juice

consistently showed higher ΔE scores than their water-stored counterparts. Detailed color change parameters are summarized in Table 1.

Table 1. Mean Color Change (ΔE) of Single-shade Universal Composite Resin After Immersion

Resin Type	Immersion Medium	ΔE (Mean $\pm$ SD)
Zenchroma	Pineapple juice	0.40 ± 0.70^a
Zenchroma	Distilled water	0.04 ± 0.80^a
Omnichroma	Pineapple juice	0.18 ± 0.50^a
Omnichroma	Distilled water	0.01 ± 0.40^a

^a= no statistically significant difference ($p > 0.05$) for unpaired t-test between same resin type different immersion medium and different resin type same immersion medium

The Shapiro–Wilk normality testing confirmed normal distribution across all ΔE datasets ($p > 0.05$), whereas Levene's test revealed non-homogeneous variances ($p < 0.05$). Consequently, two-way ANOVA was conducted, as summarized in Table 2.

Table 2. Two Way ANOVA test Result ΔE Value

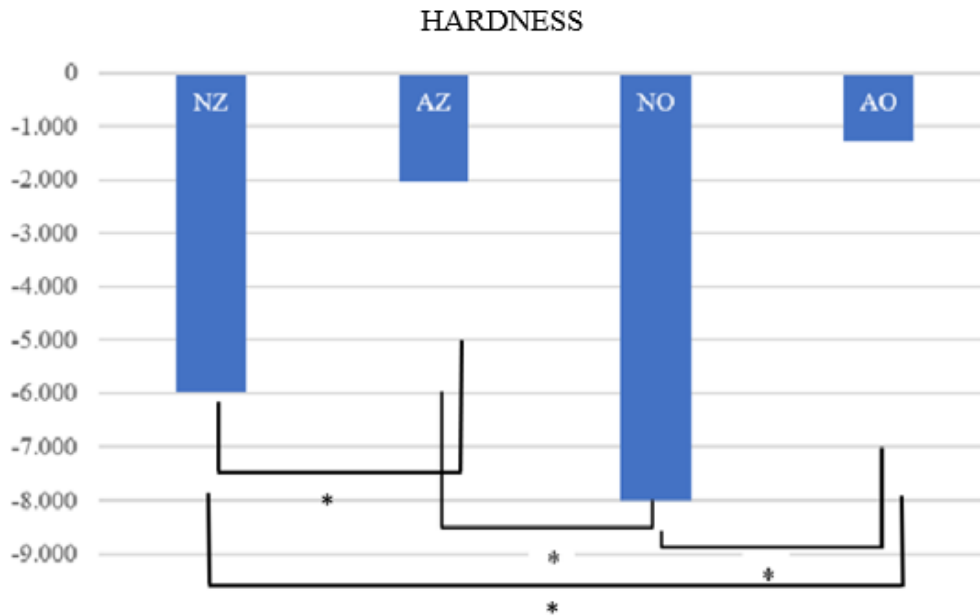
Variable	p Value
Resin Type	0.001*
Immersion Medium	0.010*
Resin Type and Immersion Medium	0.097

* $p < 0,05$ means there is significant difference

The results of a two-way ANOVA indicated that resin brand and immersion medium independently exerted significant effects on color change ($p < 0.05$), whereas the interactive term between resin brand and medium was non-significant ($p > 0.05$).

An unpaired t-test indicated no statistically significant intergroup differences in ΔE values when comparing immersion media within brands or across brands ($p > 0.05$). Likewise, Tukey's post hoc testing revealed no significant differences in color shift among the experimental cohorts.

Hardness evaluations demonstrated a post-immersion decline across all cohorts, with greater reductions noted in pineapple juice-treated groups. The most pronounced microhardness drop was recorded for Omnichroma exposed to pineapple juice, whereas Omnichroma in distilled water displayed the minimal reduction. Microhardness trends are depicted in Figure 1.



* = statistically significant difference ($p < 0.05$, Two-Way ANOVA and Post Hoc Tukey).

Figure 1. Mean Hardness Change Measurement of Single-shade Universal Composite Resin

The Shapiro–Wilk normality test confirmed normal distribution for microhardness data ($p > 0.05$), although variance homogeneity was not met ($p < 0.05$). Paired t-tests showed no significant difference between top and bottom surface hardness readings; therefore, values were combined as mean VHN. Unpaired t-tests revealed significant microhardness variations between resin brands following pineapple juice immersion, as well as between media within each brand ($p < 0.05$). Two-way ANOVA outcome data are displayed in Table 3.

Table 3. Two Way ANOVA test Result Hardness Change Value

Variable	p Value
Resin Type	0.642
Immersion Medium	0.000*
Resin Type and Immersion Medium	0.304

* $p < 0,05$ there is significant difference

A two-way ANOVA confirmed that the immersion medium was the predominant factor significantly influencing microhardness reduction ($p < 0.05$). Resin brand and the brand-medium interaction were not significant ($p > 0.05$).

Based on the mean hardness change values, the results showed that all groups experienced a decrease in hardness, with a greater negative mean value in the pineapple juice group compared to the distilled water group. The greatest decrease in hardness was found in the Omnicroma group immersed in pineapple juice. Based on the results of the Tukey post hoc

test, immersion in pineapple juice caused a significant decrease in the hardness of the composite resin, especially in the Omnicroma brand resin.

DISCUSSION

Increasing public awareness of dental aesthetics has led to the widespread use of composite resin due to its ability to mimic natural tooth color.^{1,3} Despite its popularity, composite resin has limitations, particularly regarding color stability and long-term mechanical properties when exposed to extrinsic factors such as acidic beverages.^{17,38} The hydrophilic nature of the resin matrix facilitates fluid absorption, which under acidic conditions can trigger hydrolysis and accelerate matrix degradation, potentially weakening the bond between matrix and filler and resulting in discoloration and reduced hardness.³⁹

In this study, all groups exhibited ΔE values <1 , indicating no clinically significant color change.⁴⁰ Although resin type and immersion medium independently affected color change statistically, the magnitude of change remained below the clinical threshold. Zenchroma resin showed higher ΔE values than Omnicroma after immersion in pineapple juice; however, this difference was not perceptible to the naked eye. These results suggest that single-shade universal composite resins maintain good color stability even under mild acidic conditions.

Variations in color change between resin brands may be related to differences in resin matrix composition. Zenchroma contains a Bis-GMA-based matrix, while Omnicroma is composed of UDMA and TEGDMA.²³ The hydroxyl groups in Bis-GMA increase hydrophilicity, potentially facilitating greater fluid absorption and pigment diffusion compared to UDMA and TEGDMA.^{6,10} However, pineapple juice lacks strong color pigments such as those found in coffee or tea; therefore, despite its acidity, it produces only minimal and clinically insignificant discoloration, consistent with previous studies.⁴¹⁻⁴³

Surface microhardness is another critical property that determines the resistance of restorations to abrasion and erosion.²⁴ In this study, all groups experienced a reduction in hardness after immersion, with the greatest decrease observed in the pineapple juice group. Two-way ANOVA revealed that immersion medium significantly influenced hardness changes, whereas resin type had no significant effect, indicating that the acidic environment primarily contributes to mechanical degradation.²

The higher hardness reduction in the pineapple juice group may be attributed to matrix hydrolysis and the cleavage of siloxane bonds in the coupling agent.^{5,28} The acidic environment, combined with bromelain enzyme activity in pineapple juice, may accelerate

matrix degradation and facilitate fluid penetration, increasing microporosity and reducing mechanical resistance.^{38,39} These findings are consistent with previous studies reporting hardness reduction in composite resins exposed to acidic beverages.^{5,25,28,38}

Differences in hardness reduction between resin brands may be related to monomer composition. Omnicroma, containing TEGDMA, showed greater hardness reduction than Zenchroma. The lower molecular weight of TEGDMA increases susceptibility to fluid penetration and chemical degradation, whereas Bis-GMA's rigid structure and strong hydrogen bonds provide greater mechanical stability despite its hydrophilicity.⁶

Clinically, these findings indicate that consumption of pineapple juice does not cause significant discoloration in single-shade universal composite resins but may reduce surface microhardness. Patients with composite resin restorations should be advised to limit acidic beverage intake, rinse the oral cavity with water after consumption, and undergo regular evaluations to monitor restoration integrity.

CONCLUSION

Based on the results of this study, single-shade composite resins immersed in pineapple juice maintained excellent color stability with clinically imperceptible shade alterations. However, acidic juice immersion induced a statistically significant reduction in surface microhardness, with Omnicroma displaying the highest susceptibility. These outcomes highlight that while single-shade composites demonstrate resilient optical properties, exposure to acidic fruit juices can impair their surface mechanical durability.

DECLARATION

Authors Contributions

[TKW]: Methodology, Writing – Original Draft; [RT]: Conceptualization, Investigation, Formal Analysis, Writing – Original Draft; [DLM]: Supervision, Validation, Writing – Review & Editing; [TPSP]: Supervision, Validation, Writing – Review & Editing; [MM]: Supervision, Validation, Writing – Review & Editing. All authors have read and approved the published version of the manuscript and agreed to be accountable for all aspects of the work.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Ethics Approval and Consent to Participate

Ethical approval was not required for this study because no involving of human subjects, human biological material, or vertebrate animals.

Consent for Publication

Not applicable.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Declaration of Generative AI In Scientific Writing

The authors declare that no generative AI or AI-assisted technologies were used in the writing or preparation of this manuscript.

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