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Efficacy of Bleaching Agents on Color and Micro Hardness of SDF Treated Primary Teeth

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ABSTRACT
Bleaching agents affect color, microhardness, and esthetic balance in enamel.
Context: Dental caries remains a significant health issue. Silver Diamine Fluoride (SDF) is effective in arresting caries but causes tooth discoloration. Bleaching agents may mitigate discoloration but could impact enamel properties.
Aims: This study evaluates the effects of bleaching agents on the color and microhardness of SDF-treated demineralized primary tooth enamel.
Settings and Design: An in vitro study conducted on 40 extracted human primary anterior teeth
Methods and Material: Teeth were treated with SDF and divided into four groups: Potassium Iodide (KI), Hydrogen Peroxide (HP), Carbamide Peroxide (CP), and a combination of KI+CP. Color changes were measured using a spectrophotometer, and microhardness was tested using the Vickers Microhardness method.
Statistical analysis used: Data were analysed using ANOVA and Tukey's post hoc test with significance at $P \leq 0.05$.
Results: All agents improved lightness (L) and reduced discoloration. CP caused significant microhardness reduction, while KI+CP had minimal impact.
Conclusions: Bleaching agents are effective in reducing SDF-induced discoloration, but their effects on enamel microhardness vary

Keywords: Silver Diamine Fluoride, Bleaching Agents, Primary Teeth, Enamel Microhardness, Tooth Discoloration

INTRODUCTION

Dental caries remains a significant global health issue despite advancements in dental care. Effective prevention, such as fluoride varnish, is often costly, technique-sensitive, and associated with side effects like fluorosis. Silver diamine fluoride (SDF) has emerged as a promising alternative, effectively arresting caries but causing permanent tooth staining. Potassium iodide (KI) has been proposed to mitigate this discoloration. Limited options exist for addressing the aesthetic concerns of stained remineralizedcaries lesions (s-RCLs). This study aimed to assess the effects of fluoridated bleaching agents, including 10% carbamide peroxide, on the microhardness and color of s-RCLs to explore aesthetic enhancement solutions [1,2].

SUBJECTS AND METHODS

The materials used in this study are listed in Table 1.

Table 1: materials and compositions

Material	Compositions	Manufacturer/Company
38% Silver diamine fluoride (SDF)	Silver, Fluoride, and Ammonia	Kids-e-Dental India Company
Potassium iodide (KI)	Potassium iodide	Alpha Chemika India Company
10% Hydrogen Peroxide gel	Hydrogen peroxide gel	Nano Gate Egyptian Company
10% Carbamide	10% Carbamide Peroxide	Bleach Pro Whitening USA

Peroxide gel		Company
Nail Varnish	Nail varnish	Yolo Egyptian Company
Demineralizing Solution	Calcium nitrate tetrahydrate (2.0 mM), Monopotassium phosphate (2.0 mM), Acetic acid (75 mM)	Nano Gate Egyptian Company

Study Design

This in vitro study evaluated color changes and surface microhardness in 40 extracted human primary anterior teeth.

Sample Size Calculation

To evaluate the impact of application duration of fluoridated 10% carbamide peroxide (CP) and hydrogen peroxide (HP), with or without KI, on surface microhardness (SMH), enamel morphology, and color changes, an ANOVA test or non-parametric equivalent will be used. Based on Rafiee et al. (2022) [3], SMH increased from 230.8 ± 11 after demineralization to 337.19 ± 12.24 following SDF + KI with 8-hour daily CP for two weeks, and 327.66 ± 13.88 with 15-minute daily CP for three weeks. Using G*Power (version 3.1.9.4), 40 samples (10/group) ensure 95% power ($f = 0.99$, $\alpha = 5\%$).

Teeth Selection and Preparation: Forty extracted human primary anterior teeth were collected from paediatric patients at Al Azhar University. The inclusion criteria required primary anterior teeth without decay, restorations, or structural defects [4]. Teeth were anonymized and stored in deionized water at 37°C. The roots were removed, and the crowns were embedded in acrylic resin. A 2 × 4 mm window was prepared on each enamel surface, with the surrounding area coated in nail varnish [5].

Demineralization of Caries-Like Lesions: Teeth were exposed to a demineralizing solution (pH 4.5) at 37°C for 96 hours [5]. This solution was refreshed every 48 hours. After demineralization, 38% SDF was applied to exposed enamel surfaces using a micro-brush, followed by blotting excess solution after two minutes Figure (1).

Grouping and Treatment: Teeth were divided into four groups of 10, each treated with a different bleaching agent: Group I: Potassium iodide (KI) for 15 minutes. Group II: 10% Hydrogen Peroxide gel for 15 minutes. Group III: 10% Carbamide Peroxide gel for 15 minutes daily for three weeks. Group IV: KI followed by 10% Carbamide Peroxide gel daily for three weeks.

Evaluation Methods

1-Microhardness analysis:The Vickers microhardness test was conducted(Model HVS-50, Laizhou Huayin Testing Instrument Co., Ltd. China) at two stages: after SDF application and after bleaching. The percentage recovery of enamel microhardness was calculated after the creation of stained-remineralized caries-like lesions and following the final bleaching agent applied. Micro-hardness calculation;Micro-hardness was obtained using the following equation: $HV=1.854\ P/d^2$ where, HV is Vickers hardness in Kgf/mm2, P is the load in Kgf and d is the length of the diagonals in mm[6].

2-Color Assessment: The specimens' colors were measured using a Reflective spectrophotometer (X-Rite, model RM200QC, Neu-Isenburg, Germany). The aperture size was set to 4 mm and the specimens were exactly aligned with the device. A white background was selected and measurements were made according to the CIE L*a*b* color space relative to the CIE standard illuminant D65, also hue and chroma were recorded. The color changes (ΔE) of the specimens were evaluated using the following formula:$\Delta E_{CIELAB} = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{½}$ Where: L* = lightness (0-100), a* = (change the color of the axis red/green) and b* = (color variation axis yellow/blue) [7].

Statistical analysis

Statistical analysis was performed using a commercially available software program (SPSS, Chicago, IL, USA). Numerical data were described as mean and standard deviation or as median and range as appropriate according to the normality of the data. Data were compared using the Mann-Whitney test or independent t-test depending on normality. The level of significance was set at $P \leq 0.05$. All tests were two-tailed.

RESULTS

The results of this study are shown in Figures (2, 3, 4 and 5).

1. Color Parameters: The lightness parameter (L*) was significantly affected by all bleaching agents, with Potassium Iodide resulting in the highest change in lightness, while Carbamide Peroxide showed the least impact. Regarding the red-green axis (a*), which measures shifts towards red (positive values) or green (negative values), most groups exhibited no significant changes before and after bleaching treatment. However, the Carbamide Peroxide group demonstrated significant shifts towards red. For the blue-yellow axis (b*), which indicates shifts towards yellow (positive values) or blue (negative values), Carbamide Peroxide caused a significant increase in b*, highlighting a notable shift towards yellow. Results are summarized in Table2.

Table 2: Mean and Standard Deviation of L, a, and b* Showing the Effect of Material and Time on Color Parameters.

Group	L* Before	L* After	L* P-value	a* Before	a* After	a* P-value	b* Before	b* After	b* P-value
Potassium Iodide (KI)	75.37 ± 6.45	84.69 ± 12.73	0.045*	-0.92 ± 2.81	-0.28 ± 5.55	0.855	23.05 ± 8.35	32.76 ± 6.42	0.103
Hydrogen Peroxide (HP)	68.64 ± 10.06	79.45 ± 7.06	0.017*	-0.41 ± 2.61	-2.81 ± 3.30	0.113	13.28 ± 6.03	6.60 ± 3.35	0.076
Carbamide Peroxide (CP)	50.66 ± 2.27	59.55 ± 2.51	0.001*	5.99 ± 0.22	4.05 ± 2.53	0.148	2.55 ± 1.48	13.42 ± 0.96	0.0001*
KI + CP	58.57 ± 6.08	62.76 ± 1.19	0.033*	0.77 ± 2.06	1.97 ± 5.00	0.640	11.85 ± 2.90	17.75 ± 4.75	0.115

2- Color difference: Intergroup comparisons for the parameters ΔL, Δa, and Δb showed varying results. For ΔL, no statistically significant difference was observed between materials (P = 0.237), with Potassium Iodide (KI) showing a mean change of 9.32 ± 7.25, Hydrogen Peroxide (HP) 10.81 ± 6.11, Carbamide Peroxide (CP) 8.88 ± 2.55, and KI+CP 4.18 ± 2.93. Similarly, for Δa, representing the red-green axis, no significant difference was noted (P = 0.572), with values ranging from 0.64 ± 7.32 for KI to -2.40 ± 2.65 for HP. However, for Δb, representing the blue-yellow axis, a statistically significant difference was observed (P = 0.004), where CP showed the highest increase (10.86 ± 1.02), and HP demonstrated a negative shift (-6.68 ± 6.27). The results highlight notable differences in Δb, indicating material-specific impacts on the enamel color (Table 3).

Table 3: Mean and standard deviation of ΔL, Δaand Δb.

Parameter	KI Mean (SD)	HP Mean (SD)	CP Mean (SD)	KI+CP Mean (SD)	P Value
ΔL	9.32 (7.25)	10.81 (6.11)	8.88 (2.55)	4.18 (2.93)	0.237
Δa	0.64 (7.32)	-2.40 (2.65)	-1.94 (2.43)	1.20 (5.31)	0.572
Δb	9.71 (10.31)	-6.68 (6.27)	10.86 (1.02)	5.90 (6.57)	0.004*

ΔE (Overall Color Difference): The ΔE parameter represent thr overall color difference.Intergroup comparison between materials have shown no statistically significant difference (P = 0.094). The highest ΔE difference was within KI followed by HP then CP, the least ΔE was within KI+CP, but this was not statistically significant. (figure 6) (Table 4)

Table 4: Mean and standard deviation of ΔE showing effect of material on ΔE.

Group	Mean	SD	P-value
Potassium Iodide (KI)	21.41	4.07	0.094
Hydrogen Peroxide (HP)	17.17	3.10	0.094
Carbamide Peroxide (CP)	16.33	1.52	0.094
KI + CP	16.09	4.47	0.094

Microhardness: The application of bleaching agents resulted in changes to enamel microhardness. Potassium Iodide and Hydrogen Peroxide showed no significant change in microhardness, while Carbamide Peroxide and the combination of KI and CP led to significant reductions (Table5).

Table 5: Mean and standard deviation of hardness showing effect of material and time on hardness.

Group	Before	After	P-value
Potassium Iodide (KI)	227.00 ± 8.27	229.20 ± 5.66	0.462
Hydrogen Peroxide (HP)	232.62 ± 2.33	232.90 ± 4.32	0.841
Carbamide Peroxide (CP)	229.00 ± 3.19	224.82 ± 3.12	0.004*
KI + CP	228.66 ± 3.11	224.12 ± 5.52	0.007*

Figure 1: After application of SDF.

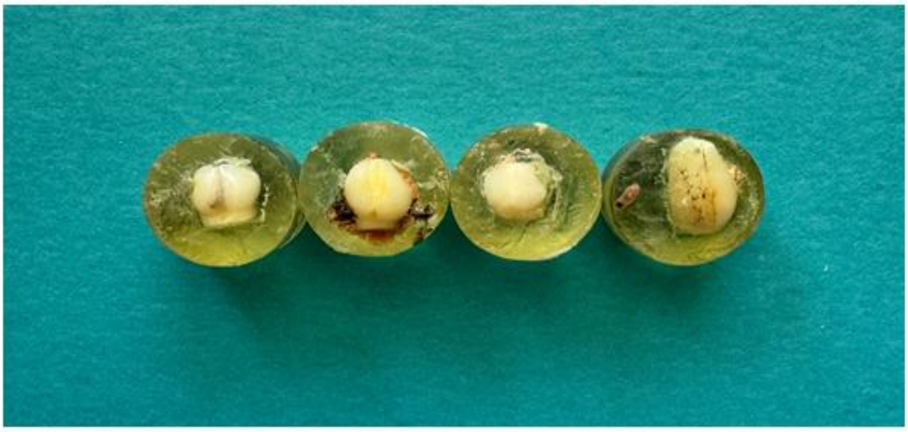

Figure 2: After application of KI.

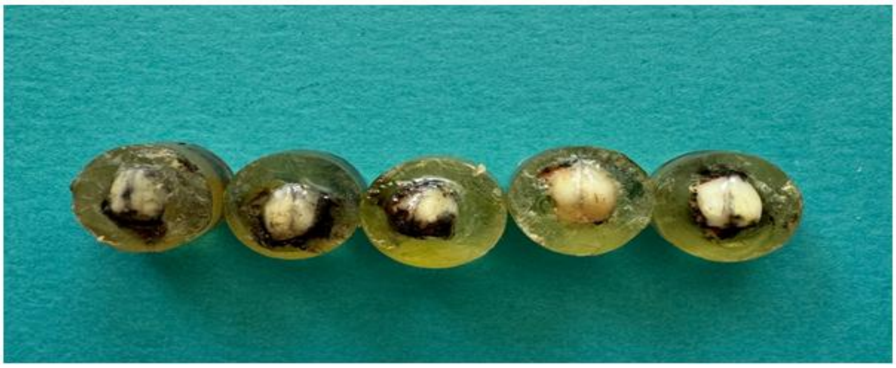

Figure 3: After application of Hydrogen peroxide gel.

Figure 4: After application of Carbmaide peroxide gel.

Figure 5: After application of KI and Carbmaide peroxide gel.

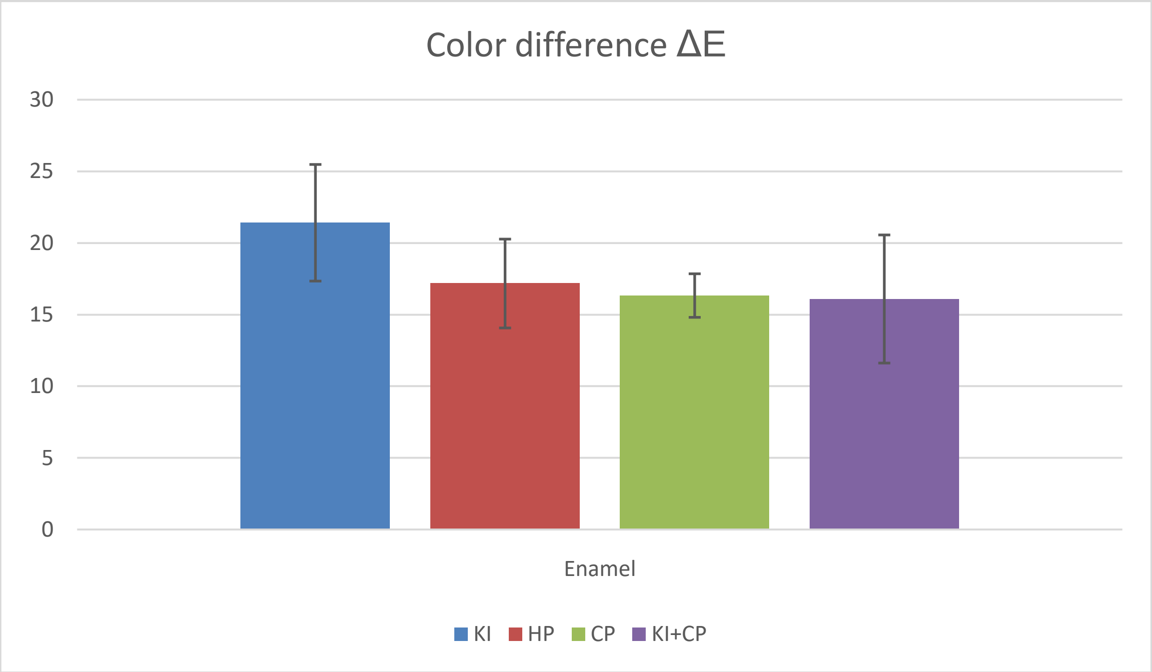

Figure 6: Bar chart showing ΔE within each material

DISCUSSION

Traditional restorative techniques for treating dental caries often necessitate extensive removal of tooth structure to eliminate bacteria, prepare for restorations, and remove demineralized dentin. However, advancements in adhesive and bioactive dental materials that bond micromechanically to teeth and provide structural support have reduced the need for extensive removal. These materials offer a strong peripheral seal, isolating carious lesions and facilitating their arrest without requiring complete decay removal [8]. This shift aligns with recent findings that structurally intact but demineralized dentin can be remineralized, leading to selective removal of infected dentin during cavity preparation. This approach minimizes pulp exposure risk, increases treatment success, and avoids the repetitive "death spiral of restoration" cycle [9].

Minimally invasive techniques prioritize preserving healthy tooth structure and have become the preferred initial treatment for carious lesions. Only when this fail should invasive methods be considered, underscoring the importance of these modern approaches in advancing dental care [8]. Silver diamine fluoride (SDF) therapy exemplifies non-restorative caries treatment. A 38% SDF solution containing antimicrobial silver ions and fluoride ions is widely recognized as an effective cariostatic agent. SDF inhibits biofilm growth, promotes remineralization, and prevents dentin collagen degradation through proteolytic peptidase inhibition [10].

SDF is noninvasive, painless, and cost-effective, making it suitable for children, older adults, and individuals with special needs who cannot undergo conventional restorative treatment [11]. However, its application causes permanent black staining on porous tooth structures. Dental bleaching has been proposed to address this discoloration, though some studies suggest acidic whitening products may affect enamel composition [12].

Potassium iodide (KI) applied immediately after SDF reduces silver ion availability, forming yellowish silver iodide deposits to mitigate staining [13]. Hydrogen peroxide (HP), a widely used bleaching agent, has demonstrated effective whitening in both primary and permanent dentition, even in the presence of mild caries [14]. Fluoridated bleaching agents like 10% carbamide peroxide (CP) have also shown promise for safe, effective whitening in children [15].

This study evaluated the effects of SDF treatment and subsequent bleaching with KI, HP, CP, and KI+CP on enamel microhardness (EMH), color change, and surface topography of artificially created stained-remineralized caries-like lesions (s-RCLs). Unlike studies focusing on sound enamel or resin composites, this research targeted vulnerable s-RCLs to better understand chromogen penetration and bleaching outcomes. Al-Angari et al. [16] emphasized surface roughness and color changes in sound enamel and composites, while Rafiee et al. [3] examined SDF-treated enamel without addressing surface topography. Similarly, Erçin and Güler [17] explored post-bleaching protective coatings, diverging from this study's focus on time-dependent bleaching effects on carious-like enamel.

The methodology included random allocation of 40 extracted primary anterior teeth into four groups to minimize selection bias and ensure objective treatment comparisons [18]. Teeth were demineralized to simulate early caries and treated with SDF, followed by bleaching. Standardized preparation involved embedding teeth in acrylic resin and polishing to create consistent enamel surfaces. The Vickers microhardness test was employed for its precision and non-destructive nature, making it ideal for dental research [19]. A spectrophotometer ensured accurate and objective color measurement, minimizing variability and providing reproducible data [20].

This study's findings align with Rafiee [3], demonstrating significant improvements in tooth lightness (L values) across all bleaching agents, with KI and HP showing the highest increases. Rafiee's study similarly observed lightness improvements in SDF-treated and SDF+KI-treated groups after two weeks of bleaching. However, while Rafiee focused on overall color changes, this study examined specific color parameters, revealing that CP caused significant shifts in the blue-yellow spectrum (b* value) ($P < 0.0001$), a detail Rafiee did not address.

Regarding ΔE (overall color difference), Rafiee found significant recovery from SDF discoloration with no differences between SDF-only and SDF+KI groups. This study observed the highest ΔE with KI (21.41), followed by HP (17.17), though differences among agents were not statistically significant ($P = 0.094$). Both studies confirm that bleaching agents effectively improve tooth color after SDF application, with minor variations in the degree of change.

Comparisons with Alqahtani [12] further highlight the role of bleaching agents in enhancing aesthetics. Alqahtani found higher concentrations of bleaching agents improved lightness but reduced enamel microhardness, indicating a trade-off between aesthetics and structural integrity. In contrast, this study showed HP maintained the highest post-treatment hardness, while CP significantly reduced enamel hardness, emphasizing the importance of selecting appropriate agents to balance aesthetic and structural outcomes.

The use of low-concentration bleaching agents like 10% HP and CP is considered safe for children. Studies, including one published in the *Journal of the American Dental Association*, confirm their efficacy in whitening without compromising enamel integrity [21]. The American Academy of Pediatric Dentistry supports the use of such agents under professional supervision [22].

In conclusion, this study supports the use of bleaching agents as effective tools for managing SDF-induced discoloration. Consistent with Rafiee [3], it highlights the superior performance of KI and HP in improving aesthetics while preserving enamel hardness. CP, although effective in whitening, should be used cautiously due to its potential to weaken enamel. These findings underscore the importance of selecting bleaching agents that achieve esthetic goals without compromising enamel integrity, particularly in pediatric and special care dentistry.

CONCLUSION

This study demonstrates that all four bleaching agents significantly improved tooth lightness (L values), with potassium iodide (KI) being the most effective (75.37 to 84.69), followed by hydrogen peroxide (HP) (68.64 to 79.45). Carbamide peroxide (CP) and KI+CP showed less pronounced but significant improvements (CP: 50.66 to 59.55; KI+CP: 58.57 to 62.76). CP significantly affected the yellow-blue spectrum (b), while no notable changes were observed in the red-green spectrum (a). KI and HP maintained enamel integrity, with HP preserving the highest microhardness (232.9). These findings confirm KI as the safest, most effective option, with caution advised for CP.

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