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CASE REPORT

The Effect of At-Home Bleaching on the Increase of Enamel Microcracks

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Abstract

Background: Tooth bleaching materials have the potential to alter both the organic and mineral components of dental tissues, which may in turn affect enamel surface morphology. This study aimed to evaluate the effect of at-home bleaching on the increase of Enamel Microcracks.

Materials and Methods: In this in vitro experimental study, 40 extracted anterior teeth were randomly divided into two groups. Baseline stereomicroscopic images of the buccal surfaces were captured to record the initial number of enamel microcracks. Each tooth was measured at multiple regions before and after bleaching to allow repeated assessments. Group 1 was treated with 15% carbamide peroxide, and Group 2 with 20% carbamide peroxide, for ten consecutive days. Each day, teeth in Group 1 were exposed to the bleaching agent for 6 hours, and teeth in Group 2 for 4 hours. Stereomicroscopic images were taken after treatment, and the number of microcracks was recorded in all regions. Data were analyzed using a repeated-measures ANOVA ($\alpha = 0.05$).

Results: The mean number of enamel microcracks increased significantly in both groups after bleaching compared to baseline measurements ($p < 0.001$). No statistically significant difference was observed between the two concentrations in terms of microcrack formation ($p = 0.687$).

Conclusion: At-home bleaching with both 15% and 20% carbamide peroxide significantly increased the mean number of enamel microcracks. However, the extent of microcrack formation did not differ significantly between the two concentrations.

Keywords: Tooth Bleaching; Carbamide Peroxide; Dental Enamel

Introduction

Tooth bleaching is a cosmetic treatment considered the most convenient and least invasive method for managing discolored teeth (1). The most common technique for tooth whitening is the at-home bleaching method (2). This approach involves applying a mild bleaching agent (10–20% carbamide peroxide) to the teeth using a custom tray worn by the patient during the day or overnight. The use of carbamide peroxide gels can affect the calcium, phosphate, and fluoride content of dental tissues (3).

Peroxide-based bleaching products, even over extended periods, generally do not produce harmful effects on the teeth. However, non-peroxide-based whitening products (e.g., sodium chlorite-based agents such as Rapid White) can significantly affect enamel structure and chemistry, resulting in effects such as crack formation, surface abrasion, and demineralization of both surface and subsurface enamel layers, and thus are not recommended. Vital bleaching with 10% carbamide peroxide has been shown to reduce microhardness and fracture toughness (Ft) of dental tissues (3).

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Dental cracks encompass a spectrum of fractures, ranging from enamel-confined craze lines to complete root fractures (4). These cracks include both incomplete and complete types and are typically caused by stress forces applied to the tooth. Some of these stresses originate from occlusal forces experienced during normal mastication cycles (5). Other contributing factors include bruxism, aging, chewing hard substances (such as ice or nuts), traumatic injuries (e.g., accidents or sports-related trauma), thermal fluctuations, and certain dental procedures such as extensive restorations, orthodontic bracket removal, and finishing and polishing, all of which may potentially lead to enamel microcracks (4). These factors can contribute to the development of enamel microcracks, which may present clinically as pain during chewing, spontaneous intermittent pain, thermal sensitivity (especially to cold), and localized gingival inflammation. However, in many cases, cracked teeth remain asymptomatic (4, 5).

Enamel consists of tightly packed enamel rods or prisms, oriented generally toward the crown and supported by the underlying dentin. Bleaching agents may increase the spacing between enamel prisms and alter the enamel surface topography, potentially facilitating bacterial plaque accumulation (6). To minimize such adverse effects on hard dental tissues, it is essential to use materials that exert minimal damage. Among these, carbamide peroxide is commonly used and, based on several studies, appears to be less destructive to dental structures than 35% hydrogen peroxide (7).

In a study by Satti et al. (8), a 14-day application of carbamide peroxide effectively whitened teeth discolored by mineral trioxide aggregate (MTA). According to Burrows (9), among various bleaching protocols, 10% carbamide peroxide delivered optimal whitening results with minimal side effects. Bernardon et al. (10) compared the effects of at-home bleaching using 10% and 16% carbamide peroxide and found no significant differences in outcomes; 10% concentration was sufficient for most patients to achieve the desired results within 30 to 45 days.

Given that the most commonly used bleaching technique is the at-home method employing 10% carbamide peroxide in a custom tray, and considering the increasing use of such materials by dental professionals and the availability of locally manufactured formulations, it is essential to assess the impact of these agents on hard dental tissues. Furthermore, since dental procedures such as composite restorations, tooth preparation, ultrasonic instrumentation, and orthodontic treatment may also contribute to enamel microcrack formation, the present study aimed to evaluate the effect of at-home tooth bleaching on the frequency of enamel microcracks.

Materials and Methods

In this experimental in vitro study, 40 extracted anterior teeth free of caries, composite restorations, fractures, or visible cracks were collected and stored in 0.2% thymol solution at room temperature. The teeth were cleaned thoroughly using a slow-speed handpiece brush and water, then stored in distilled water at room temperature. Seven days before the experiment, all samples were immersed in artificial saliva and incubated at 37°C. The teeth were then randomly divided into two groups of 20 each. The apical foramina of the root canals were sealed with heated sticky wax to prevent penetration of bleaching agents.

Group 1: 15% Carbamide Peroxide

1. Teeth were maintained in artificial saliva at 37°C for seven days, with the saliva refreshed every two days.

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2. Baseline photographs of the buccal surfaces were taken using a stereomicroscope at 25.1× magnification under fixed lighting. An additional light source was placed beneath the samples to enhance crack visibility. All visible cracks and microcracks detectable by the naked eye were recorded. Cracks with a minimum depth of 5 μm were considered.
3. Teeth were bleached for 10 consecutive days, 6 hours per day, using a 1-mm-thick 15% carbamide peroxide gel applied to the buccal surfaces. The cervical region (CEJ) was sealed with nylon and copper wire to prevent gel penetration (11). After each session, teeth were rinsed with air-water spray for 5 seconds and stored in a humid environment until the next session.
4. Post-bleaching photographs were taken under the same conditions as baseline, including magnification, distance, angle, and lighting.

Group 2: 20% Carbamide Peroxide

The same protocol as in Group 1 was followed, except that teeth were bleached for 4 hours per day with 20% carbamide peroxide gel over 10 consecutive days. The exposure time difference was based on previous studies to assess the effects of gel concentration and bleaching duration separately. The exposure time for each concentration was determined according to the manufacturer's instructions (Opalescence PF, Ultradent Products Inc., South Jordan, UT, USA)

After the bleaching period, post-treatment images were taken using the same stereomicroscope equipped with a Moticam 480 digital camera (Motic Instruments Inc., CA, USA). Imaging conditions including angle, distance, magnification, and lighting were maintained consistent with those of the pre-bleaching phase. All visible cracks and microcracks were counted again (Figures 1 and 2).

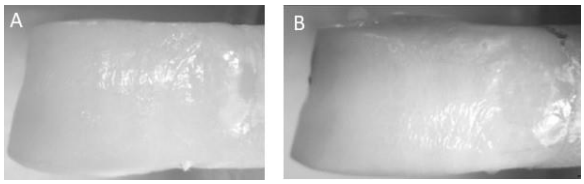

Figure 1. Images obtained using stereomicroscopy before (A) and after (B) at-home bleaching with 15% carbamide peroxide

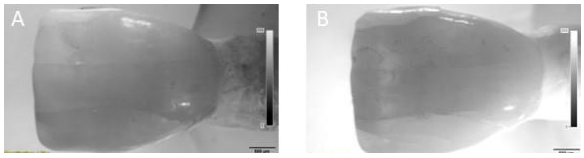

Figure 2. Images obtained using stereomicroscopy before (A) and after (B) at-home bleaching with 20% carbamide peroxide.

The normality of data distribution was first assessed using the Shapiro–Wilk test. Homogeneity of variances, an assumption of repeated-measures ANOVA, was evaluated using Levene's test. Changes over time within and between groups were analyzed using a repeated-measures ANOVA. Post-hoc within-group comparisons were performed to examine differences before and after bleaching. Data were analyzed using SPSS version 24 (IBM Corp., Armonk, NY, USA). A p-value of <0.05 was considered statistically significant.

Results

According to the results of repeated-measures ANOVA followed by within-group comparisons, the number of enamel microcracks significantly increased after bleaching in both groups ($p < 0.001$). The mean number of microcracks increased significantly after bleaching compared to before. However, there was no significant difference in the mean number of enamel microcracks between the two groups using 15% and 20% carbamide peroxide ($p = 0.754$). Additionally, the time × group interaction effect of the repeated-measures ANOVA was not statistically significant, indicating that the changes in the number of enamel microcracks before and after bleaching did not differ significantly between the two groups ($p = 0.290$) (Table 1)

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Table 1. Number of enamel microcracks before and after at-home bleaching with 15% and 20% carbamide peroxide

Group	Time of Measurement	N.	Min	Max	Mean	SE	P value*
Carbamide peroxide 15%	Before bleaching	20	0	12	4.20	3.33	<0.001
	After bleaching	20	0	12	4.50	3.50	
Carbamide peroxide 20%	Before bleaching	20	0	12	3.75	3.67	<0.001
	After bleaching	20	0	13	4.25	3.57	

*p-values refer to within-group comparisons (before vs. after bleaching) obtained from repeated-measures ANOVA

Post hoc Bonferroni tests showed a significant increase in the mean number of enamel microcracks after bleaching in both the 15% ($p = 0.029$) and 20% carbamide peroxide groups ($p < 0.001$) (Table 2, Figure 1).

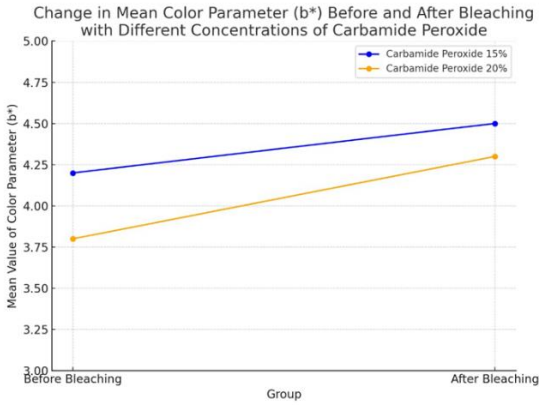

Figure 1. Mean number of enamel microcracks before and after at-home bleaching with 15% and 20% carbamide peroxide.

Table 2. Comparison of the mean number of enamel microcracks before and after at-home bleaching

Group	Mean (Before)	Mean (After)	Mean Difference	SE	*P* value
Carbamide peroxide 15%	4.200	4.500	0.300	0.132	0.029
Carbamide peroxide 20%	3.750	4.250	0.500	0.132	<0.001

Furthermore, the Bonferroni test indicated no significant difference in the mean number of microcracks between the 15% and 20% carbamide peroxide groups, either before ($p = 0.687$) or after bleaching ($p = 0.824$) (Table 3).

Table 3. Comparison of enamel microcrack means between 15% and 20% carbamide peroxide groups

Time of Measurement	Mean (15%)	Mean (20%)	Mean Difference	SE	P value
Before bleaching	4.20	3.75	0.450	1.11	0.687
After bleaching	4.50	4.25	0.250	1.12	0.82

Discussion

The results of the present study demonstrated that there was no statistically significant difference in the mean number of enamel microcracks between the 15% and 20% carbamide peroxide groups. Additionally, the changes in microcrack counts before and after bleaching were not significantly different between the two groups. However, at-home bleaching with both concentrations of carbamide peroxide significantly increased the number of enamel microcracks.

Although bleaching agents modify chromogenic molecules, they also penetrate the organic and inorganic structures of the tooth, leading to side effects such as hypersensitivity, decreased microhardness, and alterations in morphology and chemical composition (1, 12). Studies have shown that peroxide can cause morphological changes and alter the chemical and mechanical properties of enamel, including reductions in hardness and elastic modulus (1, 13, 14). In particular, high-concentration peroxide may induce erosion-like changes on the enamel

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surface due to hardness loss (13), which may result from demineralization and degradation of organic components (1). However, this reduction in enamel hardness may be reversible with post-bleaching remineralization phases (15).

Various factors, such as the acidity of bleaching gels and the temperature during application, can affect enamel surface characteristics during the whitening process (16). The effects of bleaching on enamel morphology have been inconsistently reported. Some studies have reported no significant impact on enamel hardness or mineral content (17–19), whereas others have observed irregular morphological changes and increased porosity (20, 21). In several studies, deeper grooves and surface roughening following bleaching have been reported (21–23). It has also been suggested that hydrogen peroxide may have more potent effects than carbamide peroxide. This is because carbamide peroxide products contain carbopol, a stabilizer, which reduces their impact compared to hydrogen peroxide, which can penetrate and damage both the enamel surface and subsurface layers (22).

However, in a study by Altınışık and Nezir (23), hydrogen peroxide at low, medium, and high concentrations showed no significant effect on final tooth color or hypersensitivity. Similarly, Fioresta et al. (24), in a review, concluded that although most studies support the general efficacy of bleaching gels, their long-term benefits for color stability are not well established in the literature, with most authors suggesting stability of about 1 to 2.5 years.

Bleaching agents are chemically active substances that may cause considerable structural changes in enamel, including increased surface porosity, demineralization, protein degradation, alterations in calcium/phosphate ratios, and calcium loss. Araujo et al. (25) reported morphological changes, including depressions, porosity, and increased groove depth, on bleached enamel surfaces, while Alqahtani (26) found minor morphological changes, including increased porosity and slight erosion.

Attin et al. (3) demonstrated that the use of carbamide peroxide gels may alter calcium, phosphate, and fluoride content. Vital bleaching with 10% carbamide peroxide significantly reduced enamel microhardness and fracture toughness, findings consistent with the present study.

Higher peroxide concentrations lead to faster whitening results. In-office products often contain 35% to 50% hydrogen peroxide and should be used carefully to protect soft tissues (27, 28). A 35% hydrogen peroxide concentration can significantly reduce enamel calcium and phosphorus content, while carbamide peroxide has fewer adverse effects (29, 30). The degree of whitening is directly related to the contact time between the bleaching agent and the tooth surface, but longer exposure also increases the risk of sensitivity (27, 28).

In the present study, the observed morphological changes in enamel may be attributed to pH reduction at the enamel surface following bleaching and to the action of oxygen radicals. A potential adverse effect of bleaching agents is the weakening of enamel and dentin due to oxidation of organic and inorganic components (31). Therefore, careful consideration is warranted when selecting and applying bleaching agents, given their surface and biological effects.

While some studies have reported no significant effect on enamel surface hardness and abrasion resistance after bleaching (32), others have indicated decreased hardness and fracture resistance (3). Wang et al. (33) found that non-peroxide-based at-home bleaching products (e.g., Rapid White) caused mineral loss in both superficial and deep enamel layers, along with microcracks and surface abrasion findings that align with the present study despite using a different bleaching agent.

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Dey et al. (34) found no significant differences in enamel microhardness when comparing 35% hydrogen peroxide, 25% hydrogen peroxide, and 10% carbamide peroxide. In contrast, Ameli et al. (35) reported significant reductions in microhardness one week after prolonged use of various bleaching agents. Gkavela et al. (36) concluded that carbamide peroxide bleaching did not cause clinically significant changes in the number of microorganisms or enamel ultrastructure. Melo et al. (37) observed a significant reduction in enamel microhardness after hydrogen peroxide application, which was largely recovered following the use of remineralizing agents. Among these, CPP-ACP and hydroxyapatite demonstrated greater surface deposition compared to arginine-based or fluoride products.

Morphological changes, including increased surface roughness, decreased surface hardness, unfavorable shifts in elastic modulus, surface corrosion, and protein matrix degradation, have been observed after bleaching with 10% carbamide peroxide (38). As a result, increased enamel roughness from bleaching procedures may make teeth more prone to discoloration and microcrack formation effects that can vary depending on the bleaching agent concentration and application duration.

Conclusion

The current study found that the occurrence of enamel microcracks increased after bleaching with both 15% and 20% carbamide peroxide. However, there was no statistically significant difference in the degree of microcrack formation between the two concentrations.

Conflict of Interests: The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial, or non-financial in this article

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