Bleaching Stained Arrested Caries Lesions: *In vivo* Clinical Study

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Abstract

Objective Conservative approaches to esthetically treat stained arrested caries lesions (s-ACLs) have not been explored in clinical studies. This study aims to investigate the efficacy of in-office dental bleaching agent, as a conservative approach, to esthetically treat s-ACLs.

Materials and Methods Twelve patients ($n = 46$) presented with s-ACLs were treated with 40% hydrogen peroxide (in-office bleaching protocol; 20 minutes × 3). Color values were measured using a spectrophotometer (CIE $L^*a^*b^*$), aided with digital photography to assess visual color change clinically. Measurements were taken for each specimen at baseline and immediately after bleaching.

Statistical Analysis The color change calculated before and after bleaching for each dental substrate was analyzed using paired t-test ($\alpha = 0.05$).

Results The bleached s-ACLs had a significant increase in L^* values ($p < 0.001$), and a significant decrease in both a^* ($p = 0.001$) and b^* ($p = 0.007$) values, indicating lighter color improvement (bleaching efficacy). The baseline mean of L^*, a^*, and b^* values were 61.5, 2, and 15.4, respectively, and after bleaching were 67.7, 1.4, and 13.3, respectively, with a mean increase in ΔE of >7.9, which resulted in a visible clinical stain improvement as orange/light brown stains were removed completely, while gray/black stains improved to a lesser extent.

Conclusion Significant color improvement was observed when the in-office bleaching protocol (40% hydrogen peroxide) was used in orange/brown s-ACLs. However, it showed lesser improvement in gray/black s-ACLs.

Keywords
► arrested caries lesions
► bleaching
► color change
► esthetics
► hydrogen peroxide

Introduction

The evolution of dental materials and diagnostic tools particularly in the assessment of early caries lesions has directed modern dental practice into minimally invasive dentistry. It focuses on the detection of caries lesion in their early stages to successfully preserve the dental biological tissues and minimizes surgical intervention.[1] Based on this concept, incipient caries lesions have been approached by preventive measures that are considered simple, cost-effective options to halt or minimize the caries process.[2,3] Remineralization is one form of the minimum invasive approach that can either occur naturally from the surrounding environment (i.e., saliva, biofilm) or induced by therapeutic agents (i.e., antibiotics, fluoride, calcium, and phosphate-based materials) which precipitate into the dental structure resulting in an arrested caries lesion (ACL).[3]

ACLs are inactive, highly mineralized surfaces which are usually characterized by a dark unesthetic discoloration.[4] Discoloration is related to stain incorporation within the lesion during the remineralization process such as dietary pigments, metallic ions, amino acids from the proteolytic processes, organic debris, and chromogenic bacteria.[4,5] In such clinical scenario, some patients would psychologically refuse the dark discolorations and demand esthetic measures to mask the stains.[6] The common clinical esthetical approach to eliminate stains associated with the ACLs is surgical intervention,[7] this may improve the esthetic outcome but result in unnecessary removal of a highly mineralized tooth structure, for the sake of esthetics.[8] Furthermore, inadequate restorations are susceptible to plaque accumulation, secondary caries, sensitivity, and iatrogenic dentistry.[9,10]

We have introduced dental bleaching as a minimum invasive approach to eliminate or improve the stains of the ACLs as it is considered safe, effective, economical, and predictable.[11-13] Previous studies have shown promising esthetic results both in a clinical case report and in an *in vitro* study.[11-13] To the best of our knowledge, no clinical study has been done evaluating the effect of bleaching agents on stained ACLs (s-ACLs). This study aimed to investigate the efficacy of in-office dental bleaching agents (40% hydrogen peroxide) as a non-invasive esthetic treatment approach to treat s-ACLs.

Materials and Methods

Study Design
In this clinical study, 12 patients were recruited (n = 46 surfaces) with s-ACLs (pit and fissure surfaces) and subjected to an in-office bleaching protocol (40% hydrogen peroxide). The factor studied was dental bleaching, and the study outcome was color change (ΔE) measured at two time points, at baseline and after bleaching. Color measurements were taken by spectrophotometry ($L^*a^*b^*$ values) and digital photography.

Ethical Aspects and Criteria for Inclusion and Exclusion
The clinical study was conducted in full ethical accordance with the World Medical Association Declaration of Helsinki, 1964, and after the protocol was approved by the Institutional Review Board (IRB # E-18-3173). The study was conducted at the restorative department at King Saud University College of Dentistry.

Twenty-five subjects were informed about the study protocol along with the possible risks and benefits. After ensured understanding, a written consent form was obtained prior to the screening examination (soft and hard tissues) to determine their eligibility for the enrollment based on the inclusion and exclusion criteria. Twelve patients (age range: 20–45 years; mean age: 32 years) fitted within the inclusion criteria included adult (older than 18 years), medically fit, seeking regular dental bleaching of their vital teeth, and presented with s-ACL. The exclusion criteria included children (younger than 18 years), medically compromised, teeth with active caries, crowns or restorations, periodontal disease, previous bleaching treatment, and patients who did not have s-ACLs.

Dental Bleaching Efficacy Test
Prior to the bleaching procedure, three examiners were calibrated using patients from the dental clinic who were not enrolled in the present study,[14] their kappa score showed an interexaminer reliability of 0.97. All teeth surfaces received a thorough examination followed by complete isolation of all the targeted teeth along with the maxillary teeth (from the first right premolar to the first left premolar) using liquid dam to protect the gingival tissue and cleaned with pumice (Pumice Preppies, Whip Mix, Louisville, Kentucky, United States) and washed. The baseline color of the s-ACLs was measured spectrophotometrically (VITA Easyshade V, VITA Zahnfabrik Products, Bad Säckingen, Germany) along with digital photography (Canon EOS 550D, Canon, Tokyo, Japan). The bleaching procedure was performed using 40% hydrogen peroxide (pH 6.0–8.5) (Opalescence Boost, Ultradent Products, South Jordan, Utah, United States) and done in accordance with the manufacturer's instructions.

The bleaching gel was delivered on the labial surface of the maxillary teeth (from the right first premolar to the left first premolar) and the occlusal surfaces of the s-ACLs using a brush and left on the teeth for 20 minutes. Then, the bleaching agent was whipped off with a cotton roll and reapplied twice (20 minutes for each cycle) in the same session resulting in a total of 60 minutes of application time. After bleaching, the teeth surfaces were thoroughly washed, and the liquid dam was removed, and teeth were moist just before taking the final color values for each specimen.

Color Assessment
L^*, a^*, and b^* (Commision Internationale de l'Eclairage) values were taken for each specimen at baseline and immediately after the last bleaching cycle. All measurements have been repeated three times, the means of the L^*, a^*, and b^* values have been taken and the color difference (ΔE) has been calculated using the following equation, representing color changes after bleaching (ΔE bleaching= bleaching–baseline):

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

Where ΔE represents the amount of color difference, ΔL^* coordinate represents an increase (positive direction—white) or decrease (negative direction—black) in lightness, Δa^* coordinate represents redness (positive direction) or greenness (negative direction), and Δb^* coordinate represents yellowness (positive direction) or blueness (negative direction) of the surface.

Statistical Analysis
Shapiro–Wilk's statistical test was used to assess the normality of the values, which appeared to be normal, after which, the color change (ΔE) calculated before and after bleaching for each dental substrate was analyzed using paired t-test (α = 0.05). Statistical analysis was performed using SPSS version 25.0 (IBM SPSS Statistics; IBM, Armonk, New York, United States). Prior to the study, calculations performed using SPSS showed that with a planned sample size of 42, the study was designed to have 90% power, assuming a 5%

significance level and a standard deviation of 2.0 based on a previous study.[12]

Results

The results showed a significant mean change ($p \leq 0.007$) in all of the color coordinates values: ΔL^*, Δa^*, and Δb^* after bleaching. The mean change in the ΔL^*, Δa^*, and Δb^* coordinates were 6.3, −0.06, and −0.9, respectively. The increase in the L^* values (improve color lightness), along with the decrease in the a^* (greenness) and b^* (blueness) coordinates (leading to lighter shades) indicated the efficacy of the in-office treatment as it resulted in a perceptible improvement in the color lightness outcome in the s-ACLs. The L^*, a^*, and b^* numeric values at baseline and postbleaching and their mean values are shown in ►Table 1.

The bleached s-ACL had a ΔE value that ranged from 1.1 to 24.7 with a mean value of 7.9 and a standard deviation of 5.1, which is considered clinically noticeable as it exceeded the known clinically perceptible value of $\Delta E \geq 3.3$. The visual color change (ΔE) of some of the s-ACLs at baseline and post-bleaching is shown in ►Fig. 1.

Discussion

Introducing bleaching as a minimum invasive approach to treat s-ACLs has shown promising esthetic results in previous *in vitro* studies as they have either eliminated or minimized the discoloration.[11-13] However, their major limitation was the inability of laboratory settings to adequately simulate the complex biological processes involved in creating s-ACLs, therefore, recommending the importance of conducting clinical studies to carefully draw clinical conclusions. To our knowledge, this study is the first attempt to clinically investigate the efficacy of in-office bleaching protocol as a noninvasive approach to improving the color outcome of s-ACLs. It is considered clinically significant as it improves the color outcome, reduces the necessity of surgical intervention, and consequently iatrogenic dentistry.[11-13]

This study was conducted on 12 healthy subjects (who met the inclusion criteria) with a total of 46 teeth surfaces with s-ACLs. The color was evaluated objectively, to eliminate subjective errors, using the CIE $L^*a^*b^*$ color system, which is a standard method to characterize colors based on human perception.[6,15] The bleaching efficacy was verified based on the mean color change represented in the values of ΔE and the L^*, a^*, and b^* coordinates.

The ΔE represented the average color difference between baseline and after bleaching, which is of clinical significance when it equals or exceeds a value of ≥ 3.3.[6] Digital photography was used as an adjunct subjective measure to demonstrate the clinical color outcome.

To better represent a clinical condition of a patient seeking professional bleaching, an in-office bleaching agent was used (40% hydrogen peroxide) as dentists have more control over the bleaching procedure and would eliminate the factor of patient's compliance.[16] In-office bleaching protocol is time efficient, site specific, avoids accidental gel ingestion, and has immediate results.[17] Furthermore, the high concentrations of hydrogen peroxide would penetrate deeper into the histological structure of the dental tissue and increase the oxidative power which results in a fast bleaching outcome.[18]

This study has shown that s-ACLs subjected to in-office bleaching protocol (40% hydrogen peroxide) resulted in a significant mean color change in most of the teeth (ΔE 7.9) which exceeded the clinically perceptible color range of 3.3 indicating the effectiveness of our bleaching treatment. The color difference value (ΔE) is based on the changes in the L^*, a^*, and b^* color coordinates. Our study had a significant increase in the lightness values (L^*) and a decrease in the blueness (b^*) and greenness (a^*) values which directed the ΔE toward the lighter color scale indicating color improvement.[19]
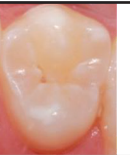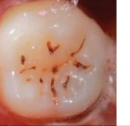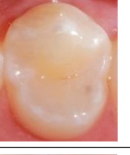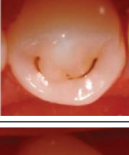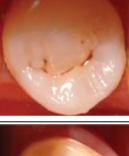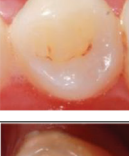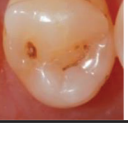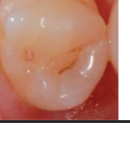
It is noteworthy to mention that although most of the stains (orange/brown) had a significant color improvement and were efficiently bleached, yet some stains (gray/black) bleached to a lesser extent. This variation in the color outcome (ΔE 1.1–24.7) can be explained by the different stain history of the ACLs (chemical composition, type, and depth), associated with the variety of patients enrolled in the study. Moreover, it is related to the bleaching mechanism of action. During the bleaching process, oxidative free radicals can easily breakdown the conjugation of the double bonds in organic stains (nonmetallic: orange/brown) as they have a small molecular weight and are more water soluble resulting in smaller molecular weight (single bond) with altered optical properties that reflect a lighter color.[17] However, nonorganic stains (metallic stains: gray/black) tend to have a larger molecular weight and are less water soluble making it difficult for the bleaching agent to penetrate deeper to oxidize the chromogenic stain molecule resulting in a less satisfactory bleaching result.[20,21]

The depth of the stains in the ACLs is an important factor as stains confined within the dentin (deep stains) have shown to be more difficult to bleach.[11,12] This is justified by the progression of caries lesions within the dental tissue, as it is faster in dentin structure compared with enamel, due to structural and compositional differences, which, in turn, results in more stain incorporation into dentin than enamel,

Table 1 The color coordinates (ΔL^*, Δa^*, and Δb^*) mean values (standard deviation) at baseline and after bleaching

Coordinate	Baseline	Bleaching	Change	p-Value
ΔL^*	61.5 (5.9)	67.7 (5.7)	6.3 (5.2)	< 0.001
Δa^*	2.0 (1.2)	1.4 (1.4)	−0.6 (1.1)	0.001
Δb^*	15.4 (4.6)	13.3 (4.3)	−2.0 (4.9)	0.007

Abbreviations: ΔL^*, lightness, value of 0 (black) to 100 (white); Δa^*, redness (positive direction) or greenness (negative direction); Δb^*, yellowness (positive direction) or blueness (negative direction).

#25	9.9			#15	3.4		
#36	7.4			#46	6.6		
#14	10.9			#14	24.7		
#44	21.1			#24	3.5		
#45	11.5			#26	2.4		
#46	10.3			#37	5.6		
#44	3.8			#35	10.6		
#45	5.9			#24	8.5		
#47	2.9			#44	3.7		

Fig. 1 Color improvement ($^*\Delta E$ bleaching= bleaching–baseline) of stained arrested caries lesions treated with 40% hydrogen peroxide bleaching agent at baseline and after bleaching.

making it easier to stain and harder to bleach.[22] Existing literature reports that the bleaching efficacy may increase with several bleaching attempts or when associated with longer bleaching time.[23-26] Thus, metallic and deep stains might need further in-office bleaching treatment (more than one visit) or at-home bleaching for longer periods to produce clinically satisfactory results. However, careful consideration must be exercised in view of the possible increased incidence of sensitivity.

Despite the advantages of the dental bleaching agents and its proven effect on the color improvement, it may cause morphological alteration within the dental tissue.[27-29] The oxidation–reduction reaction of the bleaching agent would cause a degradation of the organic and inorganic dental matrices resulting in areas of demineralization, depressions, reduced microhardness, and increased surface roughness.[30-33] These surface changes may lead to sensitivity, plaque accumulation, and the possibility of initiating

caries lesions.[29] Therefore, dental clinicians should consider using protective remineralizing agents such as fluoride, calcium, amorphous calcium phosphate, and hydroxyapatite immediately after the bleaching procedure. This study aimed to measure the color outcome objectively using the spectrophotometer along with taking clinical photographs to accurately quantify the results. Although the spectrophotometer tip diameter in some cases was relatively larger than the stains, yet, it is considered the best tool up to date to measure color and it was able to detect differences before and after bleaching, as numerical values of lighter stains were distinctly different from the value of dark stains. In our study, teeth were hydrated with saliva to remineralize the teeth after the end of the bleaching cycle as studies have reported that the exposure of saliva during the bleaching treatment would minimize enamel sensitivity and its susceptibility to further demineralization, reduce surface restaining, hence, preserve the bleaching result.[5,12,27,28,34]

In the clinical cases where the bleached ACLs did not achieve the optimum esthetic outcome, the surgical intervention would need to remove a less amount of dental tissue to mask the stains, resulting in a conservative restoration.[11-13,21] In such a clinical scenario, dentists should take into consideration the effect of immediate bonding of composite resin restorations to the bleached surface.[35-40] As the residual oxygen from the bleaching agent would interfere with the resin polymerization and weaken the shear bonding strength, it may affect the longevity of the restoration. Therefore, dentists should wait for a period of at least 2 weeks prior to bonding.[35-37]

Overall, in-office bleaching protocol can improve the esthetics of the s-ACLs in a fast, time-efficient, and simple approach; however, it depends on the type and depth of staining involved. Therefore, it is essential to understand the stain history (non-metallic and metallic) that contributes to the development of s-ACLs to reach an optimum bleaching outcome.

Conclusion

s-ACLs treated with in-office bleaching protocol (40% hydrogen peroxide) showed optimum clinically significant color improvement (ΔE >7.9) in organic stains (orange/brown) and lesser improvement in metallic stains (gray/black). Clinicians should consider bleaching as the first line as an effective, safe, and conservative approach to improve the color outcome of s-ACLs.

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