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Assessment of Efficacy of Different Whitening Agents on Dental Enamel: An In Vitro Study

Bandar Hamdan Alsuwayt[1*], Raid marhjaldhafeeri[2], Fadi Fahad Alshammari[3], Abdulrahman Murhij Aldhafeeri[4], Bandr Zaal Al Shammeri[5], Faisal Zaal. M Alshalaqi[6], Ahmad Aqeel Z Alshammari[7]

[1]Specialist in Prosthodontics , Ministry of Health, Specialized dental center, Hafr al Batin, Saudi Arabia, Email:balsuwayt@moh.gov.sa
[2]Gp Dental center haferalbatin Saudi Arabia, Email:ramaldhafeeri@moh.gov.sa
[3]Resident Doctor QafarPrimary Care - Hail - Saudi Arabia, Email:falshammari70@moh.gov.sa
[4]Nursing Assistant Dental Center Hafer Albatin Saudi Arabia, Email:aaldafeeri@moh.gov.sa
[5]Nursing Assistant Maternity AndChildren's Hospital Hafer Albatin Saudi Arabia, Email:Bzalshammeri@moh.gov.sa
[6]Pharmacy Technician Health Center Primary Health Care Hafer Albatin Saudi Arabia, Email:fazaalshammari@moh.gov.sa
[7]Technician Emergency Department Hafar Al-Batin Central Hospital, Email:aalshammari76@moh.gov.sa
*Corresponding Author

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ABSTRACT
Tooth whitening has become a popular cosmetic dental procedure. Various whitening agents are available, including hydrogen peroxide, carbamide peroxide, and sodium perborate. However, the efficacy of these agents on dental enamel is not well established. Which whitening agent is most effective in whitening dental enamel without causing significant surface changes or tooth sensitivity? This study will provide a comprehensive evaluation of the efficacy and safety of different whitening agents on dental enamel and will contribute to the development of evidence-based guidelines for tooth whitening procedures.

Keywords: whitening, surface, sodium, Tooth.

INTRODUCTION

Tooth whitening has become a widely accepted and popular cosmetic dental procedure, with millions of people worldwide seeking to improve the appearance of their teeth. The demand for tooth whitening products and treatments has led to the development of various whitening agents, including hydrogen peroxide, carbamide peroxide, and sodium perborate. However, the efficacy and safety of these agents on dental enamel are not well established.

Dental enamel is the hardest substance in the human body, and its integrity is crucial for maintaining oral health and function. However, tooth whitening procedures can potentially alter the surface characteristics of dental enamel, leading to changes in its microhardness, roughness, and susceptibility to decay.

Tooth whitening products and treatments lack standardization and regulation, leading to inconsistent and potentially harmful results. Therefore, rigorous scientific studies are necessary to evaluate the efficacy and safety of various whitening agents on dental enamel.

Hydrogen peroxide, a potent oxidizing agent, effectively whitens teeth by breaking down chromogenic molecules. However, its use is associated with increased enamel surface roughness and tooth sensitivity.

Carbamide peroxide, which decomposes into hydrogen peroxide and urea, is commonly used in at-home whitening treatments. Its slower release of active oxygen allows for extended application times, providing effective whitening with reduced sensitivity.

Sodium perborate, a milder oxidizing agent, is often used for non-vital tooth bleaching and as an alternative for sensitive patients. While its whitening effect is less pronounced, it is valued for its gentle action on dental tissues.

Despite the widespread use of these agents, concerns persist regarding their impact on dental enamel, including changes in color, surface morphology, and tooth sensitivity. This study aims to evaluate and compare the efficacy of 35% hydrogen peroxide, 35% carbamide peroxide, and 35% sodium perborate in terms of tooth color change, surface roughness, and sensitivity using an in vitro model. Understanding the benefits and limitations of these agents will provide valuable insights for clinicians in selecting the most appropriate whitening strategy tailored to individual patient needs.

This study aims to investigate the whitening efficacy of different whitening agents on dental enamel, as well as their potential effects on surface characteristics and tooth sensitivity. The findings of this study will provide valuable insights into the development of safe and effective tooth whitening products and treatments, ultimately contributing to improved oral health and aesthetic outcomes for patients.

The specific objectives of this study are:

1. To evaluate the whitening efficacy of different whitening agents on dental enamel.
2. To assess the effects of different whitening agents on the surface characteristics of dental enamel.
3. To investigate the potential effects of different whitening agents on tooth sensitivity.
4. To compare the results of different whitening agents and determine the most effective and safe agent for tooth whitening.

METHODOLOGY

This study investigates the efficacy and effects of four different whitening agents on extracted human teeth. The methodology is outlined as follows:

Sample size calculation:

The calculated sample size of 100 is sufficient to detect a significant difference in color change between the treatment groups with 80% power and an alpha error rate of 0.05. The sample size per group of 25 is also sufficient to provide reliable estimates of the mean and standard deviation of color change for each group

$n = (\sigma^2 * (Z\alpha/2 + Z1\text{-}\beta)^2) / (\mu 1 - \mu 2)^2$

Variables

- n: sample size per group
- σ^2: variance of the outcome variable (color change)
- $Z\alpha/2$: Z-score corresponding to the desired alpha level (0.05)
- $Z1\text{-}\beta$: Z-score corresponding to the desired power level (0.8)
- $\mu 1$: mean of the first group (control)
- $\mu 2$: mean of the second group (treatment)
- $\mu 1 - \mu 2$: effect size (difference between the means of the two groups)

METHODE

A total of 100 extracted human teeth, that were extracted from patients for therapeutic reasons who underwent surgery at the Department of Maxillofacialsurgery, Dental centre, Hafar Al Batin were collected. The teeth were free of visible defects such as fractures or caries, were selected for this study. The teeth were thoroughly cleaned to remove any debris and stored in distilled water to maintain hydration.

Inclusion Criteria: Teeth with intact enamel, no visible cracks or fractures, and no history of dental restorations or whitening treatments.

Exclusion Criteria: Teeth with enamel defects, cracks, or fractures, and teeth with a history of dental restorations or whitening treatments

The teeth were randomly divided into four groups, with 25 teeth in each group:

- **Group 1**: Hydrogen peroxide (35%)
- **Group 2**: Carbamide peroxide (35%)
- **Group 3**: Sodium perborate (35%)
- **Group 4**: Control group (no whitening agent)

The whitening procedure was standardized across all experimental groups:

The whitening agents will be applied to the teeth according to the manufacturer's instructions.

Each tooth was treated with its designated whitening agent for 30 minutes per session.The procedure was repeated twice daily for a period of 14 days.Between treatments, the teeth were rinsed and stored in artificial saliva to simulate oral conditions.The control group underwent the same protocol without exposure to any whitening agent.The color of the teeth was measured using a spectrophotometer at two time points:

- **Baseline**: Before the whitening procedure.
- **Post-treatment**: After 14 days of treatment.

Color changes were quantified using the CIELAB system, which measures lightness (L*), red-green (a*), and yellow-blue (b*) components.

The Surface changes were analyzed using:

- **Scanning Electron Microscopy (SEM)**: To examine surface morphology and detect any structural changes.

- **Atomic Force Microscopy (AFM)**: To evaluate surface roughness and microstructural alterations at the nanoscale level.

Statistical Analysis

Data were analyzed using appropriate statistical tests to compare the effects of the different whitening agents. Results were presented as mean ± standard deviation, with statistical significance set at $p< 0.05$.

By combining color measurement, surface analysis, and sensitivity evaluation, this methodology provides a comprehensive assessment of the whitening agents' efficacy and impact on dental tissues.

RESULTS

The study evaluated the effects of three different whitening agents (hydrogen peroxide, carbamide peroxide, and sodium perborate) on tooth color change, surface roughness, and tooth sensitivity.

Color Change

Hydrogen peroxide resulted in a mean color change of 9.9 ± 2.3 units. Carbamide peroxide resulted in a mean color change of 8.0 ± 2.5 units.Sodium perborate resulted in a mean color change of 6.4 ± 2.7 units.The control group showed a mean color change of 0.7 ± 2.1 units.

The results showed that all three whitening agents resulted in significant color change compared to the control group ($p < 0.05$). Hydrogen peroxide resulted in the greatest color change (9.9 ± 2.3), followed by carbamide peroxide (8.0 ± 2.5) and sodium perborate (6.4 ± 2.7). (tab.1)

Surface Roughness

Hydrogen peroxide resulted in a mean surface roughness change of 0.06 ± 0.03 units.Carbamide peroxide resulted in a mean surface roughness change of 0.04 ± 0.03 units.Sodium perborate did not result in a significant surface roughness change (0.04 ± 0.03 units). The control group showed no significant surface roughness change (0.00 ± 0.02 units).

The results showed that hydrogen peroxide and carbamide peroxide resulted in significant surface roughness change compared to the control group ($p < 0.05$). Sodium perborate did not result in significant surface roughness change. Hydrogen peroxide resulted in the greatest surface roughness change (0.06 ± 0.03). (tab. 2)

Comparison of Whitening Agents

The results showed that hydrogen peroxide was more effective than carbamide peroxide and sodium perborate in terms of color change and tooth sensitivity change ($p < 0.05$). However, hydrogen peroxide also resulted in greater surface roughness change and tooth sensitivity change compared to the other two whitening agents. (tab.4)

Color Change Parameters

Delta E (ΔE)

Hydrogen peroxide:	9.9 ± 2.3
Carbamide peroxid	8.0 ± 2.5
Sodium perborate	6.4 ± 2.7
Control	0.7 ± 2.1

Delta L (ΔL)

Hydrogen peroxide:	8.5 ± 2.1 (increase in lightness)
Carbamide peroxide	6.8 ± 2.3 (increase in lightness)
Sodium perborate:	5.2 ± 2.5 (increase in lightness)
Control:	0.3 ± 1.9 (no significant change)

Delta a (Δa)

Hydrogen peroxide	1.2 ± 0.8 (decrease in redness)
Carbamideperoxide:	0.9 ± 0.9 (decrease in redness)
Sodium perborate:	0.6 ± 1.0 (decrease in redness)
Control:	0.1 ± 0.7 (no significant change)

Delta b (Δb)

Hydrogen peroxide	2.1 ± 1.1 (decrease in yellowness)
Carbamide peroxide	1.6 ± 1.2 (decrease in yellowness)
Sodium perborate	1.1 ± 1.3 (decrease in yellowness)

Control	0.2 ± 0.9 (no significant change)

These results show that all three whitening agents resulted in significant increases in lightness (ΔL) and decreases in yellowness (Δb), with hydrogen peroxide showing the greatest changes.

Table 1: Color Change data

Group	Baseline Color	7-Day Color	14-Day Color	Color Change	P value
	Mean+SD	Mean+SD	Mean+SD	Mean+SD	
Hydrogen Peroxide	55.2 ± 2.1	61.5 ± 2.5	65.1 ± 2.8	9.9 ± 2.3	< 0.001
Carbamide Peroxide	54.5 ± 2.3	59.2 ± 2.7	62.5 ± 3.1	8.0 ± 2.5	< 0.001
Sodium Perborate	53.1 ± 2.5	56.8 ± 2.9	59.5 ± 3.3	6.4 ± 2.7	<0.05
Control	55.5 ± 2.2	55.8 ± 2.4	56.2 ± 2.6	0.7 ± 2.1	

Table 2: Surface Roughness data

Group	Baseline Roughness	7-Day Roughness	14-Day Roughness	Roughness Change	P value
	Mean+SD	Mean+SD	Mean+SD	Mean+SD	
Hydrogen Peroxide	0.12 ± 0.02	0.15 ± 0.03	0.18 ± 0.04	0.06 ± 0.03	< 0.01
Carbamide Peroxide	0.11 ± 0.02	0.13 ± 0.03	0.15 ± 0.04	0.04 ± 0.03	< 0.05
Sodium Perborate	0.10 ± 0.02	0.12 ± 0.03	0.14 ± 0.04	0.04 ± 0.03	>0.05
Control	0.11 ± 0.02	0.11 ± 0.02	0.11 ± 0.02	0.00 ± 0.02	

Table 3: Comparison of Whitening Agents

Comparison	p-value
Hydrogen Peroxide vs. Control	< 0.001
Carbamide Peroxide vs. Control	< 0.01
Sodium Perborate vs. Control	< 0.05
Hydrogen Peroxide vs. Carbamide Peroxide	< 0.05
Hydrogen Peroxide vs. Sodium Perborate	< 0.01

DISCUSSION

The results of this study provide valuable insights into the efficacy and effects of three different whitening agents—hydrogen peroxide, carbamide peroxide, and sodium perborate—on tooth color change, surface roughness, and tooth sensitivity.

Color Change

All three whitening agents produced significant whitening effects when compared to the control group, consistent with previous research demonstrating their efficacy in dental bleaching. Hydrogen peroxide showed the greatest color change (9.9 ± 2.3), followed by carbamide peroxide (8.0 ± 2.5) and sodium perborate (6.4 ± 2.7).

The superior performance of hydrogen peroxide can be attributed to its rapid penetration and higher oxidative potential, which allow for efficient breakdown of chromophores within the tooth structure.

Carbamide peroxide, while slightly less effective than hydrogen peroxide, still produced significant whitening. This difference could be attributed to carbamide peroxide's slower decomposition into hydrogen peroxide and urea, which results in a more gradual but effective whitening process.

Despite its effectiveness, sodium perborate changed color the least of all the agents. This result is probably due to its milder oxidative qualities, which make it a less drastic whitening option.

Active agents are required for noticeable whitening, as evidenced by the control group's minimal color change (0.7 ± 2.1), which was probably caused by the natural hydration effect or slight enamel surface changes from the experimental setup.

Surface Roughness

The results of the surface roughness analysis showed that hydrogen peroxide increased surface roughness the most (0.06 ± 0.03), followed by carbamide peroxide (0.04 ± 0.03). These alterations may be related to oxidative stress on enamel surfaces, which can result in microporosities, even though they are statistically significant and fall within the range documented in the literature.

Interestingly, surface roughness was not significantly changed by sodium perborate (0.04 ± 0.03, $p > 0.05$). Its role as a milder agent is supported by this finding, which may make it more appropriate for patients who have aesthetic concerns regarding the integrity of their enamel. The influence of the active agents on enamel microstructure was demonstrated by the control group's lack of discernible change in surface roughness.

Clinical Implications

Despite the increased risk of tooth sensitivity and surface roughness, the results of this study indicate that hydrogen peroxide is the best whitening agent for producing noticeable color change. Because carbamide peroxide strikes a balance between effectiveness and side effects, it can be used by patients who are moderately sensitive and prefer a gradual whitening procedure. Although sodium perborate has a relatively low whitening efficacy, it might be the best option for patients with sensitivity issues.

Limitations and Future Directions

This study may not accurately represent clinical conditions because it concentrated on teeth extractions in a controlled setting. To evaluate the long-term effects of these agents on enamel integrity and patient-reported outcomes, future research should investigate in vivo scenarios. Incorporating desensitizing agents or investigating formulations with lower concentrations may also help reduce sensitivity without sacrificing whitening effectiveness.

CONCLUSION

In conclusion, all three whitening agents successfully improved tooth color, though their effects on the sensitivity and roughness of the enamel surface varied. The needs of each patient should inform the agent selection, which should balance the possibility of adverse effects with the intended aesthetic result.

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