Comparative Evaluation of Bleaching Efficacy and Enamel Corrosion from Tooth Whitening Products with Varying Hydrogen Peroxide Concentrations

Chun Yao[1], Lei Wang[2], Hui Sun[3], Kaixin Chen[4], Lixin Xu[5]

[1]Department of Stomatology, The First People's Hospital of Zhenjiang, Jiangsu Province. Associate chief physician.

[2]Department of General Affairs, Second Outpatient Department, Peking University School and Hospital of Stomatology, Attending Physician

[3, 4]Xiling (Zhenjiang) Medical Technology Co., LTD.

[5]Beijing Zhongke Stomatology Department Associate Chief Physician.
Corresponding Author Email: *2818341465[at]qq.com*

Abstract: ***This study investigates the bleaching effectiveness and enamel corrosion potential of three commercially available tooth whitening agents with different hydrogen peroxide concentrations. Twenty extracted human teeth were divided into four groups, including one control group treated with saline and three experimental groups treated with whitening products containing 17%, 24%, and 40% hydrogen peroxide, respectively. Bleaching efficacy was evaluated using a standardized shade guide, and enamel surface changes were assessed via scanning electron microscopy. Results indicate that the 17% and 40% hydrogen peroxide products demonstrated superior whitening outcomes compared to the 24% product. However, the 40% agent caused more enamel erosion, while the 17% product exhibited minimal damage. These findings provide useful clinical insights for selecting safe and effective whitening products.***

Keywords: Hydrogen peroxide, Tooth whitening, Enamel erosion, Bleaching agents, Dental aesthetics

1. Introduction

With the development of the socio-economy, people's pursuit of beauty has continuously escalated. Since dental aesthetics can intuitively reflect a person's external appearance, tooth whitening technology has emerged in response to this trend. Moreover, with the continuous advancement of the medical industry, tooth whitening technology is also constantly being refined. Currently, using bleaching agents containing active whitening ingredients for tooth whitening has become a widely applied clinical method [1]. According to queries on the website of the National Medical Products Administration, a variety of related tooth whitening products have been launched domestically and internationally. After analyzing the bleaching active ingredients in existing imported and domestically marketed products, it has been found that the commonly used bleaching active ingredients are primarily carbamide peroxide and hydrogen peroxide. Furthermore, based on varying peroxide concentrations, these products can be categorized into two types: those for home use and those for in-office use. Although numerous scholars both domestically and internationally have conducted research on the whitening effects and enamel corrosion degrees associated with different peroxide concentrations, there has been relatively limited research on commercially available products. The purpose of this study is to evaluate and comparatively analyze the whitening effects and enamel corrosion degrees of commercially available tooth whitening products containing different concentrations of hydrogen peroxide, thereby providing theoretical references for clinicians when selecting products for tooth whitening treatments. This study aims to compare the bleaching efficacy and enamel corrosion effects of tooth whitening products with different hydrogen peroxide concentrations to guide clinical product selection. Understanding the balance between whitening effectiveness and enamel preservation is crucial for optimizing clinical outcomes and minimizing adverse effects in aesthetic dentistry.

2. Materials and Methods

2.1 Experimental Materials

2.1.1 Experimental Teeth

Twenty non-carious molars extracted for orthodontic treatment requirements were included in the study. The inclusion criteria for the teeth were as follows: they were not tetracycline-stained teeth or fluorosis-stained teeth; the crown portions were intact, free from caries, fillings, restorations, orthodontic treatments, or previous bleaching procedures; and the original tooth shade was A3 or D3. Immediately after extraction, the teeth were cleaned, the surrounding periodontal soft tissues were removed, and they were stored in 4°C physiological saline.

2.1.2 Experimental Reagents and Materials

0.9% physiological saline, Yirunbai®17% hydrogen peroxide tooth whitening agent (provided by Xiling (Zhenjiang) Medical Technology Co., Ltd.), iBrite® 24% hydrogen peroxide tooth whitening agent (provided by

Suzhou Pekton Technology Co., Ltd.), 40% hydrogen peroxide tooth whitening agent (from Ultradent Products, Inc., USA), and VITAPAN Classical shade guide.

2.2 Experimental Methods

2.2.1 Experimental Grouping

Twenty extracted premolars were randomly divided into four groups: Control Group A (0.9% physiological saline group, n=5), Experimental Group B (17% hydrogen peroxide tooth whitening agent group, n=5), Experimental Group C (24% hydrogen peroxide tooth whitening agent group, n=5), and Experimental Group D (40% hydrogen peroxide tooth whitening gel group, n=5). The five teeth in each group were labeled as A-1, A-2, A-3, A-4, A-5 for Group A; B-1, B-2, B-3, B-4, B-5 for Group B; C-1, C-2, C-3, C-4, C-5 for Group C; and D-1, D-2, D-3, D-4, D-5 for Group D, respectively.

2.2.2 Color Recording Before Bleaching

The four groups of teeth were removed from the physiological saline, rinsed with purified water, and then dried. They were placed under identical lighting and background conditions, and their colors were matched against the "VITAPAN Classical shade guide" to determine and record the shade that corresponded to each tooth in every group.

2.2.3 Tooth bleaching

The five teeth in Control Group A were coated with 0.9% physiological saline and left undisturbed for 30 minutes, after which they were rinsed with purified water. For the other groups, the whitening agents were applied and rinsed off according to the respective instructions provided in their manuals for the ex vivo teeth. After the whitening process, all teeth were placed under identical lighting and background conditions. Their colors were then matched against the "VITAPAN Classical shade guide" to determine and record the shade that corresponded to each tooth in every group. Whitening efficacy was determined by comparing shade values before and after treatment by comparing the shade before and after whitening (no whitening effect data was recorded for Control Group A as it did not undergo whitening).

2.2.4 Scanning Electron microscopy determination

After drying the ex vivo teeth from the four groups following the bleaching treatment, they were fixed onto specimen holders and subjected to a one-time gold coating under vacuum. Subsequently, the surface microstructure and enamel damage degree of the tooth specimens were scanned and observed under a scanning electron microscope at a magnification of 2000 times.

2.3 Statistical Methods

2.3.1 Statistical Method for Whitening Effect: The research data on whitening effect were recorded as raw data and mean values. Paired T-tests and one-way analysis of variance were employed for statistical analysis. The significance levels were set as follows: a p-value of 0.05 indicated a significant difference, while a p-value of 0.01 indicated a highly significant difference.

2.3.2 Statistical Approach for Corrosion Degree Evaluation: The corrosion degree of tooth surfaces was categorized into five grades based on the surface smoothness observed via scanning electron microscopy, with the ranking being Grade 0 < Grade 1 < Grade 2 < Grade 3 < Grade 4. The corrosion degree data were documented as both raw values and mean values. Statistical analyses were conducted using paired T-tests and one-way analysis of variance. The significance thresholds were set at 0.05 for significant differences and 0.01 for highly significant differences.

3. Results

3.1 Bleaching effect results

The data indicate that all three product groups exhibit a certain whitening effect on teeth. Among them, the group treated with the 40% hydrogen peroxide product achieved an average whitening shade change of 4, the group treated with the 17% hydrogen peroxide product had an average shade change of 3.6, and the group treated with the 24% hydrogen peroxide product showed an average shade change of 2.8. Statistical analysis reveals that the whitening effects of both the 40% and 17% hydrogen peroxide product groups are significantly superior to that of the 24% hydrogen peroxide group. Although the average shade improvement in the 40% hydrogen peroxide product group is slightly higher than that in the 17% hydrogen peroxide product group, statistical analysis indicates no significant difference between the two. For detailed information, please refer to Table 1 and Table 2.

Table 1: Comparison of Bleaching Conditions

Group	Product	Group	Tooth color gradation before bleaching	Shade level after bleaching	Shade Improvement	Does it have a bleaching effect
Experiment Group B	Yirunbai® Tooth Bleaching Agent	1-1	A3	A2	4	Yes
		1-2	A3	C1	3	Yes
		1-3	D3	C2	3	Yes
		1-4	A3	A2	4	Yes
		1-5	D3	C1	4	Yes
		Average value			3.6	/
Experiment Group C	iBrite® Teeth Whitening agent	2-1	A3	C2	2	Yes
		2-2	A3	C1	3	Yes
		2-3	D3	C2	3	Yes
		2-4	D3	C2	3	Yes
		2-5	A3	C1	3	Yes
		Average value			2.8	/
Experiment Group D	Ultradent Teeth Whitening Agent	3-1	A3	D2	3	Yes
		3-2	A3	A2	4	Yes
		3-3	A3	A2	4	Yes
		3-4	D3	A2	5	Yes
		3-5	D3	C1	4	Yes
		Average value			4	/

Table 2: Statistical Difference Analysis of Bleaching Effects among the experimental groups

Group	P value	Statistical difference
Group 1 and Group 2	0.0353	Yes
Group 1 and Group 3	0.3465	No
Group 2 and Group 3	0.0124	Yes

2.2 Tooth surface corrosion condition

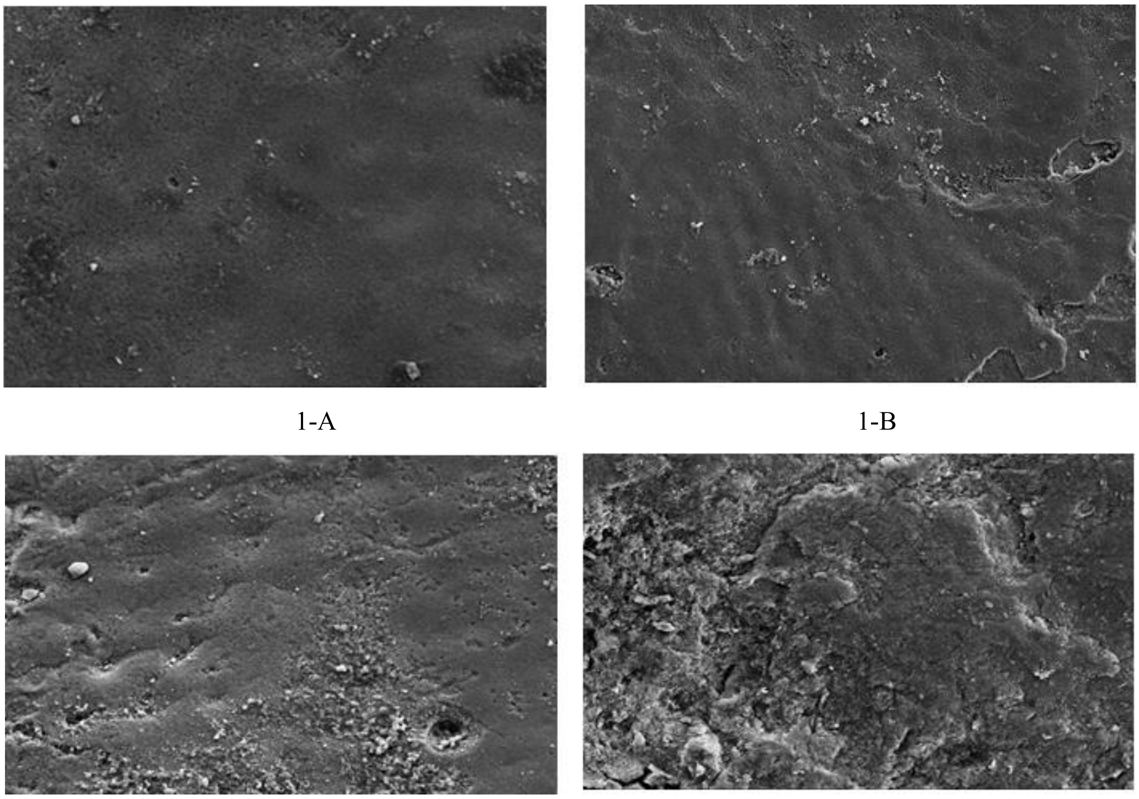
Compared with the control Group A, the three experimental groups all exhibited varying degrees of dental corrosion after bleaching treatment. Specifically, the tooth surfaces in experimental Group B showed slight irregularities and unevenness relative to Group A (as illustrated in Figures 1-A and 1-B), though no statistically significant difference was observed between the two groups ($P > 0.05$). In contrast, the tooth surfaces in experimental Groups C and D displayed severe irregularities and corrosion compared to Group A ($P < 0.01$), with Group D demonstrating the most pronounced and extensive corrosion (as shown in Figures 1-C and 1-D).

Table 3: Table of Tooth Corrosion Grades in Each Group

Group	Product	Group	Degree of corrosion
Compared with Group A	0.9% Normal Saline	A-1	0
		A-2	1
		A-3	0
		A-4	0
		A-5	0
	Average value		0.2
Compared with Group B	17% Hydrogen peroxide tooth bleaching agent group	B-1	1
		B-2	1
		B-3	1
		B-4	0
		B-5	1
	Average value		0.8
Compared with Group C	24% Hydrogen peroxide tooth bleaching agent group	C-1	2
		C-2	2
		C-3	3
		C-4	2
		C-5	2
	Average value		2.2
Compared with Group D	40% Hydrogen peroxide tooth bleaching agent group	D-1	3
		D-2	4
		D-3	4
		D-4	3
		D-5	3
	Average value		3.4

Table 4: Statistical Difference Analysis of Corrosion Grades in Each Group

Group	P value	Statistical difference
Control Group A - Experiment Group B	0.5447	No difference
Control Group A - Experiment Group C	0.0001	Extremely significant difference
Control Group A - Experiment Group D	0.0001	Extremely significant difference
Experiment Group B - Experiment Group C	0.0004	Extremely significant difference
Experiment Group B - Experiment Group D	0.00004	Extremely significant difference
Experiment Group C - Experiment Group D	0.0077	Extremely significant difference



1-A 1-B

1-C 1-D

Figure 1 shows the situation of tooth erosion

4. Discussion

Tooth staining is primarily caused by organic compounds in teeth that contain hydroxyl groups and benzene rings (chromophores). The strong oxidizing property of peroxides can disrupt these chromophores within the organic substances, thereby achieving a teeth-whitening effect [2]. The whitening process of hydrogen peroxide stems from its ability to freely penetrate both enamel and dentin, reaching all parts of the tooth. After decomposition into peroxide ions, hydrogen peroxide can break down chromogenic molecules responsible for tooth discoloration [3-4]. The factors influencing the whitening efficacy of hydrogen peroxide include the underlying causes of tooth staining in patients, the initial concentration of hydrogen peroxide in the bleaching product, the degree of hydrogen peroxide decomposition, the duration of application, the viscosity of the bleaching product, its pH value, and whether cold light illumination is used, among others. Moreover, the extent to which each factor affects the whitening outcome varies significantly. There is no consensus among scholars regarding the impact of hydrogen peroxide concentration in whitening products on bleaching efficacy. Studies by Lima et al. [5] demonstrated that 35% hydrogen peroxide was more effective than 15% hydrogen peroxide, but higher concentrations posed a greater risk of tooth sensitivity for patients. Grazioli et al.[6] suggested that H_2O_2 concentration above the 15% level does not increase bleaching effectiveness, and may increase the possibility for alteration of enamel hardness, surface morphology, and acidity of the medium. Bortolatto et al. [7] also supported that, in terms of tooth sensitivity, lower-concentration bleaching agents should be the preferred choice for in-office teeth whitening procedures. The results of this study demonstrate that the whitening efficacy of the 17% hydrogen peroxide bleaching agent from Yirunbai® and the 40% hydrogen peroxide teeth whitening agent from Ultradent significantly outperformed that of the 24% hydrogen peroxide bleaching agent from iBrite®. Additionally, no statistically significant difference in whitening efficacy was observed between the 17% hydrogen peroxide bleaching agent from Yirunbai® and the 40% hydrogen peroxide teeth whitening agent from Ultradent. These findings also confirm that the teeth whitening effect is not simply proportional to the concentration of hydrogen peroxide. Auxiliary ingredients in the product, as well as its viscosity and pH, may all influence the whitening efficacy of dental bleaching products, which aligns with the results of some previously published studies.

Other scholars have proposed that superoxide radicals generated by hydrogen peroxide during the teeth whitening process can decompose enamel matrix proteins and cause enamel dehydration, leading to porous structural changes on its surface[8]. The extent of these alterations becomes more pronounced with increasing hydrogen peroxide concentration[6,9]. This phenomenon may explain the post-bleaching tooth sensitivity issues observed in clinical practice. A 30% hydrogen peroxide solution can induce an acid-etched, porous structure on the enamel surface, with irregular decalcification and dissolution occurring in the enamel prisms and their surrounding areas. Additionally, densely packed crystals 30-40 micrometers beneath the surface are disrupted [10]. Some scholars have also demonstrated [11] that external bleaching using peroxides placed on the enamel surface can damage or denature protein components within the enamel, thereby compromising its mechanical properties. However, contrasting findings indicate that whitening agents do not reduce the surface hardness of enamel [12-13], nor do they significantly alter its surface roughness post-bleaching [14-15].Even researchers conducting studies on the bleaching of human dental enamel with hydrogen peroxide at different concentrations have found that specimens treated with 30% hydrogen peroxide exhibited the greatest reduction in microhardness, while those treated with 40% hydrogen peroxide showed the least decrease [16].The results of this study confirmed that both the 24% and 40% hydrogen peroxide groups exhibited significant surface irregularities on teeth after bleaching, demonstrating pronounced enamel erosion compared to Control Group A. In contrast, the 17% hydrogen peroxide group only showed mild surface irregularities post-treatment, with no statistically significant difference observed when compared to Control Group A. These findings suggest that the 17% hydrogen peroxide product did not induce noticeable enamel erosion during the teeth whitening process. However, these findings cannot directly conclude that higher hydrogen peroxide concentrations necessarily correlate with more pronounced enamel erosion, as the impact on enamel surface roughness during the bleaching process is influenced by multiple factors including the bleaching method, product formulation, active ingredient composition, and pH of the bleaching agent. Notably, the three whitening products used in this study differed not only in hydrogen peroxide concentration but also in other components and pH levels.

5. Summary

The study results demonstrate that, in terms of teeth whitening efficacy, the 17% hydrogen peroxide bleaching agent from Yirunbai® and the 40% hydrogen peroxide dental bleaching agent from Ultradent significantly outperformed the 24% hydrogen peroxide bleaching agent from iBrite®. No statistically significant difference in whitening efficacy was observed between the Yirunbai® 17% and Ultradent 40% hydrogen peroxide groups. Regarding enamel erosion during the bleaching process, both the iBrite® 24% hydrogen peroxide dental bleaching group and the Ultradent 40% group exhibited pronounced enamel erosion, whereas the Yirunbai® 17% hydrogen peroxide group showed no significant signs of tooth erosion. Both the whitening efficacy evaluation and enamel erosion assessment in this study were conducted using extracted teeth (ex vivo). However, actual clinical whitening procedures involve significantly more complex conditions. Notably, human saliva facilitates tooth remineralization by replenishing lost calcium and phosphate ions, thereby mitigating bleaching agent-induced damage to dental hardness. As an in vitro study, this research cannot fully replicate the intricate oral environment, particularly the impact of saliva and pH dynamics on tooth hardness during intracoronal bleaching. Consequently, the experimental findings may not entirely correspond to in vivo conditions. The primary objective of this study is to provide theoretical references for clinical practitioners.

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