

Effectiveness of over-the-counter tooth-whitening strips and toothbrushing for stain removal

Eficácia da utilização de tiras de clareamento dental e da escovação na remoção de manchas dentais

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Abstract

Objective: The present study compared the effectiveness of over-the-counter tooth-whitening strips and toothbrushing for stain removal. **Materials and method:** Forty bovine teeth were subjected to initial color readings and divided into two groups: 20 teeth were stained with grape juice for seven days and 20 did not receive any treatment (control). Each group was subdivided into two groups (n=10) according to treatment: whitening strips twice/day (30 minutes/7 days) and mechanical brushing with toothpaste (one year). After the treatments, final color readings were taken and color stability (ΔE_{ab}), coordinates (ΔL , Δa , Δb), and whitening index (WI_D) were calculated and analyzed statistically (two-way ANOVA, Bonferroni $\alpha=0.05$). **Results:** Statistical differences were found for ΔE_{ab} and all coordinates between the Control and Stained groups, with major changes in the Stained groups for both treatments. In the Control group, whitening strips produced greater changes in Δb ($p < 0.05$), indicating decrease of yellowness. For the Stained group, whitening strips produced greater changes in Δa ($p < 0.05$), indicating redness reduction. **Conclusion:** Both treatments were effective for removing stains, and whitening strips were more efficient and effective for changing the color of teeth without previous staining.

Keywords: Toothbrushing. Tooth bleaching. Hydrogen peroxide. Tooth discoloration.

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Introduction

Tooth discoloration/darkening is cause for great concern among patients, mainly due to the imposition of current aesthetic standards¹. Different factors may induce color change²: Intrinsic factors – when the pigments are incorporated into dentin or enamel; and Extrinsic factors – when the coloring agents are deposited on the surface of teeth; or a combination of both types of staining³.

Extrinsic stains on the tooth surface may be eliminated by professional dental prophylaxis and controlled by regular and effective toothbrushing with dentifrice⁴. Tooth bleaching is also a very common procedure⁵, which has proved to be an effective and conservative treatment for aesthetic purposes⁶.

There are different types of bleaching techniques for vital teeth, such as in-office and at-home bleaching. These two techniques differ in bleaching gel concentration and time of use. The technique choice is based on diagnosis, type and intensity of discoloration, and patient needs⁷.

For the in-office bleaching technique, high concentrations of hydrogen peroxide (35-40%) are used at short application times. For at-home bleaching, lower concentrations of hydrogen peroxide (4, 6, 7.5, and 10%) or, most frequently, carbamide peroxide (10-16%) are used for a few hours per day, from two to eight weeks^{8,9}. When controlled by a professional, both techniques are effective and safe for the patient, as various clinical studies have shown^{9,10}.

The high demand for bleaching treatments has led the industry to develop more affordable and over-the-counter products, which can be acquired freely without prescription¹¹. One of these products are whitening strips, which consist of flexible polyethylene strips containing hydrogen peroxide at lower concentrations (6-10%)¹². The strips adapt to the anterior teeth and are used for shorter periods when compared to supervised at-home treatments¹¹.

Although it has been shown that hydrogen peroxide gel is effective and safe for patients, scientific evidence is required, regardless of the effectiveness of readily accessible bleaching

products such as whitening strips. Scientific evidence provides reliable and scientific information to the population and dentists, considering the degree of whitening obtained may be lower than expected, similar to that obtained by toothbrushing, or lower than the expectation imposed commercially.

Thus, this study aimed to compare, *in vitro*, the effectiveness of over-the-counter tooth-whitening strips and toothbrushing for stain removal. The null hypothesis tested claimed there would be no difference in stain removal effectiveness, regardless of treatment type.

Materials and method

Forty bovine incisors were extracted, maintained at a temperature of 4°C, and cleaned with pumice stone and Robinson brushes. Stained teeth, cracks, or structural anomalies were excluded.

The teeth were cross-sectioned at 1 mm below the enamel/cement junction with a flexible diamond disc mounted in a precision cutter (SYJ 150 Digital Diamond Low Speed Saw 4, MTI Crystal, Richmond, CA, USA). The crown portion of each tooth was embedded in a PVC ring with acrylic resin (Vipi Flash, Vipi, Pirassununga, SP, Brazil) and color was measured in all teeth 24 hours later (Vita Easyshade, VITA Zahnfabrik, Bad Säckingen, Germany), according to the CIE L* a* b* system (The International Commission on Illumination). Then, the teeth were separated randomly into two groups: Stained – subjected to staining by immersion in grape juice (Sufresh, WOW ind. e com. Limitada, Caçapava, SP, Brazil) for seven days; and Control: maintained immersed in distilled water in a 37°C oven for seven days.

After seven days of immersion, new color measurements were taken from the Stained group (Table 1) and then Control and Stained groups were separated again (n=10) according to the treatment for stain removal – tooth bleaching and toothbrushing.

The bleaching treatment was performed with whitening strips (10% hydrogen peroxide, 3D White whitestrips, Oral B, Rockford, USA)

adhered to the buccal surface of each tooth for 30 minutes. After removing the strips, the teeth were washed and maintained immersed in distilled water in a 37°C oven. The protocol was repeated twice a day for seven days.

Toothbrushing was performed in a mechanical brushing machine (Pepsodent MAVTEC- Com. Peças, Acess. e Serv. Ltda. ME, Ribeirão Preto, SP, Brazil), with a toothbrush (Tek Macia, Johnson & Johnson, São José dos Campos, Brazil) and Close Up Peppermint Drops toothpaste (Unilever Brasil Industrial Ltda, Ipojuca, PE, Brazil), for 41 minutes, which is equivalent to one year of manual toothbrushing by a healthy individual¹³. The toothpaste was diluted in distilled water (ratio of 1:1), the static axial load of 200 g was used to stabilize the toothbrush, and the brushing speed was set to 5.9 moves per second.

After tooth whitening and brushing, all samples were washed with water spray for 20 seconds, final color readings were taken and color change was calculated according to the criteria of the NBS (National Bureau of Standards), as follows (Equation 1)¹⁴:

$$\text{Equation 1} - \Delta E_{ab} = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$$

Where:

$$\Delta L = L^*_F - L^*_I \text{ (final values - initial values)}$$

$$\Delta a = a^*_F - a^*_I \text{ (final values - initial values)}$$

$$\Delta b = b^*_F - b^*_I \text{ (final values - initial values)}$$

In addition, a modified CIELAB color space-based whitening index (WI_D) was proposed and calculated according to the following equation (Equation. 2)¹⁵:

$$\text{Equation 2} - WI_D = 0.511L^* - 2.324a^* - 1.100b^*$$

The data on color stability (ΔE_{ab}), luminosity (ΔL), delta a (Δa), delta b (Δb), and whitening index (WI_D) were subjected to statistical analysis (two-way ANOVA, Bonferroni, $\alpha=0.05$).

Results

Table 1 shows the initial and final values of coordinates L^* , a^* , and b^* , showing the effectiveness of staining before bleaching.

Table 1 – Means and standard deviation of the initial readings of color coordinates before and after tooth staining

	Before staining	After staining
*L	85.6 ± 5.3	24.8 ± 6.7
*a	0.91 ± 2.3	23.56 ± 1.9
*b	35.1 ± 11.1	18.73 ± 4.2

Font: data obtained from the study.

Table 2 presents the comparison of the mean values of ΔE , change in coordinates L^* , a^* , and b^* , and WI_D (two-way ANOVA, Bonferroni test, $\alpha=0.05$).

Table 2 – Comparison of means (standard deviation) of color change (ΔE_{ab}), luminosity axis (ΔL), chromaticity axes (Δa and Δb), and whitening index (WI_D)

		Whitening strips	Toothbrushing
ΔE_{ab}	Control	14.6 (3.0) aB	3.4 (±2.2) bB
	Stained	40.6 (7.3) aA	39.9 ±15.4 aA
ΔL	Control	5.9 ±2.4 aB	0.5 ±3.7 aB
	Stained	35.0 ±7.8 aA	34.6 ±15.4 aA
Δa	Control	-1.9 ±0.9 aB	0.3 ±0.5 aB
	Stained	-17.1 ±1.3 aA	-14.8 ±2.0 bA
Δb	Control	-13.0 ±2.5 bB	1.0 ±1.1 aB
	Stained	10.7 ±2.7 aA	11.7 ±6.3 aA
WI_D	Control	31.2 ±4.5 bB	8.3 ±8.0 aB
	Stained	-17.1 ±5.4 aA	-23.3 ±10.3 aA

Font: data obtained from the study.

Different letters (capital letters in the columns and lower-case letters in the rows) indicate statistically significant results (two-way ANOVA, Bonferroni, $\alpha=0.05$).

In the analysis of ΔE_{ab} , the greatest color changes occurred for the groups subjected to staining, without statistically significant difference between them ($p>0.05$). However, the Stained groups were significantly different ($p<0.05$) in comparison with the Control groups, which also presented significant difference among them ($p<0.05$), and the greatest color change occurred for the whitening method.

The analysis of ΔL showed that the Stained groups presented lower luminosity, without statistically significant differences among them ($p>0.05$), but with significant differences ($p<0.05$) from the control groups. When the bleached and brushed samples of the Control groups were compared, there was no statistically significant difference ($p>0.05$).

For the Stained groups, Δa represented the greatest change such as redness reduction, which was higher for bleached than for brushed teeth ($p<0.05$), and the control groups were similar

among them ($p > 0.05$). When comparing only the stain removal method, the Stained group presented greater changes than the Control group, with statistically significant difference for both treatments ($p < 0.05$).

When analyzing the treatments in coordinate b, no statistically significant difference ($p > 0.05$) was verified among the Stained groups. In the Control groups, the greatest change ($p < 0.05$) occurred for the whitening method, indicating a reduction in yellowness. When analyzing only the effect of whitening strips and toothbrushing, there was greater change in the Stained group, with significant difference ($p < 0.05$) in comparison with the Control groups.

As for the WI_D , the greatest change ($p < 0.05$) occurred in the whitening method for Control groups, with statistically significant difference from the toothbrushing method. The Stained groups showed no statistically significant difference ($p > 0.05$) according to the method of stain removal. There was statistically significant difference ($p < 0.05$) among groups (Control and Stained) for both treatments.

Discussion

Stain removal promotes changes on tooth color saturation, resulting in tooth whitening. External tooth bleaching therapy is defined as the whitening of teeth via the topical application of pharmacological products on the enamel surface.

The action mechanism occurs by oxidation-reduction reaction, in which hydrogen peroxide works as an oxidizing agent, releasing free radicals that reduce the pigments impregnated in enamel and dentin¹⁶. This process occurs rapidly, and when a concentration of 3% is applied on the tooth structure, only 44% to 32% of the original concentration remains after 30 to 60 minutes¹⁷. This explains the better efficacy of whitening strips in the Control groups, because despite the low concentration of hydrogen peroxide (5.3%), it allowed penetrating the tooth structure and react chemically with the pigment, thus removing both extrinsic and intrinsic stains.

The simulated brushing method is suitable for simulating normal oral hygiene procedures¹⁸,

because the application force and the distance and frequency of the brush in the samples are standardized¹⁹. Toothbrushing by abrasion provides contact between the bristles and the toothpaste, imposing a superficial stain removal process. In the present study, brushing was simulated for up to one year, with color assessments. In normal clinical conditions, 40 brushing cycles per day are applied¹², thus 10,000 cycles would be sufficient to simulate one year of toothbrushing¹⁹. Some studies^{12,20} have proved that mechanical brushing is a suitable method for evaluating stain removal. This agrees with the results obtained in the present study, in which toothbrushing removed extrinsic staining, promoting tooth color change, but with a lower level of efficiency than bleaching for the Control group.

The Close Up Peppermint Drops toothpaste is composed by sorbitol, aqua, hydrated silica, peg-32, sodium lauryl sulfate, aroma, cellulose gum, sodium fluoride, sodium saccharin, zinc sulfate, mica, sodium hydroxide, ci 42090, ci 19140, and eugenol. Thus, it does not contain any whitening ingredient that could have increased its effectiveness for color change.

Visual color difference thresholds are used as a quality control tool to assess clinical performance and interpret visual and instrumental findings in clinical dentistry and dental research²¹. For this study, the color difference thresholds were as follows: one unit of ΔE is visually perceptible and 3.3 units are clinically acceptable^{9,22}. For the groups previously stained with grape juice, both treatments were effective for stain removal ($p > 0.05$) and produced color change (ΔE_{ab}) above the limits of clinical perception and acceptability. Color change occurred by redness reduction (major changes in Δa), meaning the removal of the pigmentation caused by grape juice. However, when analyzing the whitening index (WI_D), the results showed that the whitening perception was possible only in Control groups and, although the removal of pigmentation was efficient in Stained groups, there was no bleaching.

For the Control groups, whitening strips allowed an effective bleaching. Whitening strips produced more significant color change

than toothbrushing, and the greatest variation occurred in coordinate b (Δb), with significant reduction in yellowness added to increased luminosity, which corroborates the findings of other studies^{23,24}.

Previous studies^{16,25} have shown that dental tissues have a significant permeability degree and the higher the concentration of hydrogen peroxide applied the more such permeability increases²⁶. Therefore, it is generally accepted that the use of higher concentrations of hydrogen peroxide in bleaching agents (gels or strips) causes greater penetration of the active ingredients and enhances whitening¹¹. The tooth absorbs the hydrogen peroxide of whitening strips, and the remaining quantities (0.13 μg) may be found in the pulp chamber, indicating a penetration ability through the dental tissue, which would justify the removal of intrinsic staining^{11,16}.

Whitening strips were more efficient than toothbrushing, because they were able to bleach teeth without apparent extrinsic and intrinsic staining, as shown in the results of color change for the Control groups²⁷. Positive clinical outcomes using low concentrations of carbamide peroxide were also reported by Cardoso and colleagues⁹, whose study showed complete satisfaction of patients undergoing whitening treatment for short periods.

Despite the many advantages and positive outcomes of tooth whitening, if performed incorrectly and without control, it may offer risks to oral health²⁸. Therefore, there is criticism about the unrestricted and easy access to bleaching products²⁹. This does not occur with toothbrushing, which offers no health risks³⁰.

Conclusion

Despite the limitations of the study, it is possible to conclude that both treatments were effective for the stain removal of teeth, and whitening strips were more effective than toothbrushing when the teeth were not subjected to previous staining. The whitening perception was possible only in teeth without previous staining and subjected to whitening strips.

Resumo

Objetivo: o presente estudo comparou a eficácia das tiras de clareamento dentário e da escovação na remoção de manchas. **Materiais e método:** quarenta dentes bovinos foram submetidos à leitura inicial de cor e divididos em dois grupos: 20 manchados com suco de uva por 7 dias e 20 não receberam tratamento (controle). Cada grupo foi subdividido em 2 grupos (n=10) de acordo com o tratamento: tiras de clareamento 2 vezes/dia (30 minutos/7 dias) e escovação mecânica com creme dental (1 ano). Após os tratamentos, leituras finais de cor foram realizadas. Então, a estabilidade de cor (ΔE_{ab}), as coordenadas (ΔL , Δa , Δb) e o índice de clareamento (WI_D) foram calculados e analisados estatisticamente (two-way ANOVA, Bonferroni $\alpha=0,05$). **Resultados:** diferenças estatísticas foram encontradas em ΔE_{ab} e todas as coordenadas entre os grupos controle e manchados, com maior alteração no grupo manchado, independente do tratamento. No grupo controle, o clareamento produziu maior alteração em Δb ($p < 0,05$), indicando redução do croma amarelo. Nos dentes manchados, ocorreu maior alteração em Δa nos dentes clareados ($p < 0,05$), indicando diminuição do croma vermelho. **Conclusão:** ambos os tratamentos foram eficazes na remoção de manchas e o clareamento dentário mostrou-se um método mais eficiente e efetivo para alteração de cor de dentes que não haviam sido submetidos à pigmentação prévia.

Palavras-chave: Escovação. Clareamento dental. Peróxido de hidrogênio. Descoloração do dente.

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