Evaluation of pH Levels and Surface Roughness After Bleaching and Abrasion Tests of Eight Commercial Products

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Abstract

Objective: This in vitro study evaluated the effect of different bleaching protocols and the variation of pH levels of bleaching gels regarding roughness and wear of bovine enamel, after in-office bleaching protocols and brushing. Materials and methods: Ninety fragments were randomly divided into nine groups: C, control; WHP15, 35% hydrogen peroxide (HP) (Whiteness HP, FGM) three gel applications of 15 min each, three sessions with 1 week intervals; WHP45, 35% HP (Whiteness HP) one application/45 min, three sessions with 1 week intervals; LPS, 35% HP (Lase Peroxide, DMC) plus hybrid light (HL) [light-emitting diode (LED)/diode laser], four applications/7 min 30 sec (6 min of HL activation), one session; LPSII, 25% HP (Lase Peroxide II, DMC) plus HL, four applications/7 min 30 sec (6 min of HL activation), one session; LPL, 15% HP (Lase Peroxide Light, DMC) four applications/7 min 30 sec (6 min of HL activation), one session; WO, 35% HP (Whitegold Office, Dentsply) three applications/15 min, three sessions with 1 week intervals; WBC40, 35% HP (Whiteness HP Blue Calcium, FGM) one application/40 min, three sessions with 1 week intervals; and WBC50, 20% HP (Whiteness HP Blue Calcium) one application/50 min, three sessions with 1 week intervals. The median pH values were determined utilizing a pH meter during the initial and final gel applications. A rugosimeter was utilized to evaluate the surface roughness (Ra) before and after bleaching and brushing (100,000 strokes), and the surface wear after brushing. Results: For the results of the pH values, there was a decrease in the pH levels from the initial to the final bleaching time, except for the WBC50. The WO and WBC40 groups exhibited higher pH values. For the results of roughness and wear, there was an increase in surface roughness and wear among the groups. Conclusions: The pH values tended to decrease from the initial to the final bleaching. After tooth brushing, bleaching procedures with lower pH products provided a significant increase in enamel wear and surface roughness.

Introduction

With the development of new bleaching techniques, agents, light sources, and methods of activation, a variety of bleaching agents have been available in concentrations of 10–38% hydrogen peroxide (HP) gels, at low and high concentrations, with different consistencies, activated by light sources or not, with specific characteristics and indications. These photosensitive agents can be activated by different light sources, such as halogen, plasma arc, light-emitting diode (LED), and laser equipment. Some authors have questioned whether light sources actually catalyze the oxidation reaction and contribute to produce better results than home bleaching.

Despite all the developments in bleaching materials, there is still concern over the effects on the enamel surface after the bleaching treatment. The effects usually noted when home bleaching agents are used in low concentrations include shallow depressions, increased porosity, and mild erosion, whereas higher concentrations of whitening agents may cause morphological alterations of the enamel surface.

However, when using high-concentration whitening agents, some authors did not notice morphological changes to the enamel surface but saw greater susceptibility of the enamel surface to wear, and coarsening of the teeth through abrasion. The pH levels of the bleaching gels are related to the changes in the surface morphology of the enamel.
Recent studies pointed out the relation to the time application of bleaching gels on the tooth surface roughness and wear. Matis and others\(^5\) demonstrated that three 15 min applications were more effective than a single 40 min application; on the other hand, Mondelli and others\(^6\) showed that roughness was greater for the at-home bleaching group than for the group that received in-office bleaching with a hybrid light source (that is, the group with reduced exposure to the bleaching gel, which produced less damage to the tooth surface).

As seen, the data relating to changes in the dental tissues are conflicting, depending upon the variety of methodologies used and the diversity of bleaching agents, time of applications, concentrations, light activations, pH levels of the bleaching agents, and trademarks used.\(^6\)

The morphological problems in the enamel surface after bleaching are still controversial; therefore, a large number of studies have investigated the source and maintenance of these changes.\(^7\) Nevertheless, there are few published articles regarding the effects of pH level values. The aim of this study was to investigate the wear, surface roughness of the enamel, and pH level of different concentrations of bleaching gels, activated physically by hybrid light sources or not (LED/diode laser). The first null hypothesis of the study found that the differences in pH values and bleaching gel concentrations did not influence the roughness, and the second found that the differences in pH values and bleaching gel concentrations did not influence the wear of the enamel.

Materials and Methods

Materials

The materials and equipment used for the present study are outlined in Table 1.

Specimen preparation

A total of 90 recently extracted bovine mandibular central incisors, stored at 4°C in a solution of 1% chloramine-T, were chosen for the study. They were cut into rectangular shapes, using a low-speed diamond saw under cooling water (South Bay Technology Inc., San Clemente, CA) and embedded in slow-setting composite resin (15×5×4 mm). A flat enamel surface was produced by wet-polishing with 320, 400, 600, and 1200 grit silicon carbide abrasive papers. To control the individual variation in the enamel surface characteristics among the tested teeth, each specimen was divided into two sides. One side was used for treatment and the other as a control.\(^4\) They were stored in deionized water at 37°C for 1 week prior to testing (Table 2).

### Bleaching protocols

The prepared teeth were randomly divided into the following nine groups (\(n = 10\)) to receive the bleaching procedures: Control group, only artificial saliva; WHP15 group (35% hydrogen peroxide (HP) (Whiteness HP, FGM)), three sessions with 1 week intervals (three gel applications×15 min = 45 min) 135 min gel application; WHP45 group (35% hydrogen peroxide (HP) (Whiteness HP, FGM)), three sessions with 1 week intervals (three gel applications×15 min = 45 min) 135 min gel application; LPS group (35% HP (Lase Peroxide II, DMC)), one session (four gel applications×7 min 3 sec) (30 sec interval+2 min hybrid light (HL)+30 sec interval+2 min HL+30 sec interval+2 min HL) 30 min gel application (24 min of light activation); LPSII group (25% HP (Lase Peroxide II, DMC)), one session (four gel applications×7 min 3 sec) (30 sec interval+2 min HL+30 sec interval+2 min HL+30 sec interval+2 min HL) 30 min gel application (24 min of light activation); LPL group (15% HP (Lase Peroxide Lite, Dentsply)), three sessions with 1 week intervals (one gel application×45 min = 45 min) 135 min gel application; WBC40 group (35% HP (Whiteness HP Blue Calcium, FGM)), three sessions with 1 week intervals (one gel application×45 min = 45 min) 135 min gel application; WBC50 group (20% HP (Whiteness HP Blue Calcium)), three sessions with 1 week intervals (one gel application×50 min = 50 min) 150 min gel application as shown in Table 2. The bleaching agents were manipulated and applied according to the manufacturer’s instructions. For the new bleaching gel applications, the specimens were cleaned with deionized...
The chosen parameters of roughness were: T minimum = 0.01 µm, T maximum = 8.00 µm (T = Tolerance [extreme values to be considered for readings], trail limit (Lt) (real extension travelled by the tip) = 5.0 mm, Measuring limit (Lm) (extension for readings) = 4.5 mm, cutoff (Lc) (filtering, minimizing the interference of surface ripple) = 0.25 mm.

**Brushing abrasion**

Half of each specimen’s top surface was subjected to a toothbrush abrasion test. The other half served as a reference surface and was covered with a polyethylene film to avoid contact with the toothbrush and abrasives. The test was performed on 10 specimens with a tooth-brushing machine at a controlled temperature of 37±2°C. A load of 300 g with soft nylon bristles (Oral B 35, Gillette do Brasil, Brazil) was applied to the samples. Slurry was prepared by mixing 2:1 of deionized water and Colgate MFP (Colgate Palmolive, SP, Brazil) dentifrice by weight, immediately before testing. One hundred thousand brushing strokes were performed for each specimen. After testing, they were rinsed under deionized water and cleaned in a sonic device in deionized water for 10 min, and then stored in deionized water (37°C).

**Final roughness and wear measurements**

The final measurements of the roughness after brushing were obtained with the same protocols utilized before.
Roughness and wear

Wear was measured (μm) utilizing the same roughness meter in the profilometer function. The average depth obtained after three readings was taken for each specimen from the reference surface (control side), across the abraded area. Wear measurements (μm) were obtained from the difference between the control and abraded sides utilizing the Turbo DataWin software (Hommel-Etamic, Schwenningen, Germany).

The parameters used were: T minimum = 8.0 μm, T maximum = 40.0 μm, Lt = 10.0 mm, Lm = 9.0 mm, Lc = 0.00 mm

Statistical analysis

The results were presented as the mean and standard deviation. One way ANOVA and Tukey’s test were used to compare the pH levels and changes among the control group and within the same experimental systems. In relation to wear and surface roughness, the Kruskal–Wallis and Dunn’s tests were later utilized for comparisons between the individual groups. In all tests, we used a 5% significance level (p < 0.05).

Results

pH values

The averages of the readings were recorded in the initial and final bleaching times of each group by a digital pH meter.

Within the results of the pH values, there was a tendency toward a decrease in the pH levels from the initial to the final bleaching time, with the exception of the WBC50 group, which showed no statistically significant differences. The WO and WBC40 groups exhibited higher values than in the initial mean and an increase in the pH level at the end of the bleaching procedure (Table 3).

Roughness and wear

The data found in the assessment of the surface roughness of the bovine enamel after bleaching and after brushing (Table 4), indicated that there was an increase in surface roughness with statistically significant differences among the groups (initial and after bleaching, F = 45.82, p < 0.05; between the bleaching and brushing F = 53.87, p < 0.05).

<table>
<thead>
<tr>
<th>Groups</th>
<th>Initial pH ± SD</th>
<th>Final pH ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>6.251 ± 0.060&lt;sup&gt;Ac&lt;/sup&gt;</td>
<td>5.781 ± 0.045&lt;sup&gt;Bf&lt;/sup&gt;</td>
</tr>
<tr>
<td>WHP15</td>
<td>6.090 ± 0.056&lt;sup&gt;Af&lt;/sup&gt;</td>
<td>5.630 ± 0.105&lt;sup&gt;Bf&lt;/sup&gt;</td>
</tr>
<tr>
<td>LPS</td>
<td>7.420 ± 0.131&lt;sup&gt;Ad&lt;/sup&gt;</td>
<td>6.580 ± 0.286&lt;sup&gt;Bb&lt;/sup&gt;</td>
</tr>
<tr>
<td>LPSII</td>
<td>7.540 ± 0.061&lt;sup&gt;Ad&lt;/sup&gt;</td>
<td>6.920 ± 0.147&lt;sup&gt;Be&lt;/sup&gt;</td>
</tr>
<tr>
<td>LPL</td>
<td>8.380 ± 0.122&lt;sup&gt;Ab&lt;/sup&gt;</td>
<td>7.990 ± 0.137&lt;sup&gt;Bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>WBC40</td>
<td>8.130 ± 0.125&lt;sup&gt;Ac&lt;/sup&gt;</td>
<td>8.400 ± 0.176&lt;sup&gt;Bb&lt;/sup&gt;</td>
</tr>
<tr>
<td>WBC50</td>
<td>8.920 ± 0.091&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>8.880 ± 0.103&lt;sup&gt;Ab&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Different capital letters indicate significant differences between initial and after-bleaching roughness (p < 0.05); and between the bleaching and brushing (F = 45.82, p < 0.05).

Different lower case letters indicate significant differences among the groups evaluated (p < 0.05).
With regard to the wear, an increase was seen after brushing for all groups evaluated, with statistically significant differences between them (F = 39.63, p < 0.05) (Table 4).

Discussion

Many bleaching products are formulated at lower pH values to ensure the stability of the HP. Therefore, the pH value of the bleaching agents is an important factor in the reactions of the bleaching process. Verifying the results obtained in this study through analyses of the pH level of bleaching agents, it was observed that there was a trend toward a decrease in pH levels from the initial times to the end. These results are in accordance with the study of Price et al., who claimed that HP products can display a low pH value. These findings are in accordance with the results of the present study with the exception of the WBC50 group, which did not provide statistical differences proving that the pH levels were not affected. In the WO and WBC40 groups, the initial averages exhibited higher values than the initial values, with an increase from the initial pH levels to the end.

It has been reported that the greater the HP concentration, the more acidic the pH level of the bleaching product. Cadenaro et al., and Alexandrino et al., reported that the use of an HP-based gel capable of 7.0 pH maintenance did not cause morphological changes over the specimen’s surface. Unfortunately, there are no studies that relate the change in the pH level in direct contact with the substrate. According to Cadenaro and others, the results found in this study are associated with the pH level of HP, which generally displays values of 7.0–7.5. However, the WHP15 and WHP45 groups had the lowest pH values from start to end compared with the other groups studied. According to Sun and others, 30% neutral HP (pH ~ 7.0) resulted in less deleterious effects than acidic HP (pH ~ 3.6), and also had the same efficiency of tooth bleaching.

When comparing the surface roughness of different groups after the bleaching process, it was noted that groups bleached with 35% HP (WHP15 and WHP45) showed statistically larger roughness values when compared with the other groups studied, because of the low pH values found in 35% HP. These results were found by Mondelli and others, who related greater changes to the enamel surface treated with the bleaching agent at 35%.

The LPS, LPSII, and LPL groups, bleached with 35%, 25%, and 15% HP, respectively, did not show significant changes after the bleaching procedure. This fact is explained by the LED/laser-based systems that heat up the whitening agent and not the tooth structure, thereby avoiding deleterious effects on the enamel surface. In addition, there was reduced contact with the enamel with hybrid light activation, for a total of 30 min, against the 135 min application in groups WHP15 and WHP45. This observation is in agreement with the results of Mondelli et al., who claimed that the hybrid light-assisted photoactivation bleaching provided a procedure with reduced clinical time and lower sensitivity levels. A light source is useful to activate the bleaching procedure for low-HP bleaching gels, because the increase in the formation of hydroxyl radicals compensates for the low concentration of the gel. Other studies also observed that some whitening protocols are safe in the clinical situation with regard to pulpal temperature, as well as being efficient with LEDs, diode lasers, and halogen lamps as irradiation sources. There was no evidence of deleterious effects of a light source on the integrity of the enamel after the bleaching process. Thus, a low concentration of hydrogen peroxide solution containing titanium dioxide nanoparticles proves to be safe and has a strong bleaching effect. Light activation with bleaching procedures have also been studied, with positive results. The first null hypothesis was rejected because the differences in pH values and bleaching gel concentrations did not influence the superficial roughness.

During bleaching, enamel demineralization is associated with the mechanism of oxidation, the pH of the peroxides, and some components of the whitening agents. The formation of free radicals occurs during the oxidation of peroxide. These free radicals act nonspecifically and are able to degrade both the organic and inorganic matrix of the substrate, causing enamel loss and affecting the ionic balance that would enable the deposition of calcium on the enamel surface. A limitation of most of the commercial bleaching agents is that they are manufactured in gel form, which may contain some added ingredients such as carbomer, glycerin, fluoride, metal salts, and flavors to aid in the manipulation of the gel, and it is necessary to involve these factors in future studies to investigate the effects of HP bleaching agents on the superficial enamel. Therefore, the association between bleaching and acid exposure and abrasive challenges should be further studied in order to better understand the mechanisms involved. However, in a clinical situation, in addition to the bleaching procedure, other challenges might be presented in the oral cavity, such as erosion, abrasion, and cariogenesis, which might play an important role together with the bleaching procedure, leading to enamel surface alterations.

Conclusions

Within the limitations of this in vitro study, the following conclusions can be drawn:

- Bleaching gels have a tendency to decrease the pH values from the initial time to the final treatment time, except for the groups treated with 35% Whiteness HP Blue Calcium (WBC40).
- Bleaching gels that exhibited acidic pH values lead to changes in roughness and surface wear of the bovine enamel, especially in groups treated with Whiteness HP Maxx (WHP15 and WHP45) after a toothbrush abrasion test.
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Author Disclosure Statement

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