

Vital tooth bleaching using different techniques: A clinical evaluation

Ana Rita Barcessat^{a,1}, Nalia Cecilia Gurgel-Juarez^{b,*}, Niklaus Ursus Wetter^a

^a Institute of Energy and Nuclear Research, University of São Paulo, Av. Professor Lineu Prestes, 2242, Vila Universitaria, São Paulo, SP, Brazil

^b Faculty of Health Sciences, University of Ottawa, Montpetit Hall 125 University, Ottawa, ON, K1N 6N5, Canada

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ABSTRACT

Objectives: This clinical trial aimed to evaluate dental color stabilization after different bleaching techniques. **Methods:** Four dental bleaching techniques were tested in 60 healthy volunteers aged from 25 to 35 years randomly assigned to four groups. Group 1 (G1): conventional in-office bleaching using 35% hydrogen peroxide. Group 2 (G2): in-office application of 3% hydrogen peroxide followed by in-office bleaching using 35% hydrogen peroxide. Group 3 (G3): in-office application of 3% hydrogen peroxide and activation with a light emitting diode (LED) lamp. Group 4 (G4): at-home bleaching using 10% carbamide peroxide. The color of canines and incisors was scored using a digital spectrophotometer to analyze lightness, chroma and hue. **Results:** All groups resulted in shade change. Lightness increased in all groups with no statistical difference among groups 60 days after finishing the treatment regardless of the technique used ($p > 0.05$). Differences were found in a short-term evaluation between some groups ($p < 0.05$). Chroma showed no statistical differences for central incisors after bleaching ($p > 0.05$). Analyzing canines, G4 showed higher chroma compared to G1 ($p < 0.05$) and G2 ($p < 0.05$). For hue, only G2 behaved differently for canines and incisors ($p < 0.05$). In other groups, hue scores decreased after bleaching. **Conclusions:** All techniques improved lightness. The addition of 3% hydrogen peroxide to conventional in-office whitening only increased appointment time, but no further benefits were noticed. **Clinical relevance:** This study is important to help clinicians deciding which is the most suitable dental bleaching for each patient in the current high aesthetic demanding world.

1. Introduction

Currently, tooth whitening is one of the most popular aesthetic procedures in dentistry. Dental market offers a variety of products, and literature shows different successful techniques. So much so that clinicians may have difficulty to decide, together with their patients, the most suitable treatment for each case.

Classical whitening techniques are at-home and in-office treatments. Some patients prefer at-home bleaching [1], and this technique has a relatively low-cost, with a reduced chair-time and less tooth sensitivity compared to in-office bleaching [2]. However, professional in-office whitening is becoming attractive due to its immediate whitening without the need for tray use at home [3]. Both treatments have similar short- and long-term results once concluded [4,5]. The type and concentration of the whitening gel, as well as application time vary according to the treatment: 25%–38% hydrogen peroxide in three sessions for in-office whitening; while at-home dental bleaching uses

10%–16% carbamide peroxide gel in custom-trays for two weeks.

Despite the gel, the bleaching active component is the same: hydrogen peroxide [6]. This chemical element can be either directly applied on tooth surface, or it is released from chemical reaction of carbamide peroxide [6]. As hydrogen peroxide diffuses through enamel and dentin, unstable free radicals are released. These radicals attack organic pigmented molecules, shifting the absorption spectrum of chromophore molecules, thereby promoting teeth whitening [7].

Hydrogen peroxide is known as a bleaching agent for vital teeth since the beginning of the 20th century [8]. But it was in the late 1960s that Dr Bill Klusmier accidentally established a home-bleaching technique. In order to promote gingival health among his patients, this orthodontist prescribed a carbamide peroxide-based mouthwash in a mouth tray for overnight use [9]. After follow-up appointments with the patients, Dr Klusmier noticed that their teeth were becoming whiter [9].

Nowadays, in-office and at-home bleaching are the most widespread

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* Corresponding author. 106 Strathaven Private, K1J1K7, Ottawa, ON, Canada.

E-mail addresses: ritabarcessat@gmail.com (A.R. Barcessat), ngurg011@uottawa.ca (N.C. Gurgel-Juarez), primareclinica@gmail.com (N.U. Wetter).

¹ Permanent address: Faculty of Nursing, Federal University of Amapa. Rod Juscelino Kubitschek - Universidade, Macapa-AP, Brazil. CEP 68900-000.

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evidence-based treatments presenting satisfactory clinical outcomes for vital teeth [10]. The gels used have high concentration of hydrogen peroxide. Otherwise, low concentrations of the bleaching agent are available in other products not necessarily used for teeth whitening. For instance, an oxidizing mouthwash containing 3% hydrogen peroxide is primarily prescribed for some types of gingival diseases; however, teeth whitening has been reported after its use [11].

A variety of over-the-counter products containing low levels of hydrogen peroxide has been marketed for teeth bleaching. Whitening strips, mouthwashes, paint-on brushes, and toothpastes are some of the goods easily available for consumers. Even though these products contain less than 3% hydrogen peroxide, their use result in teeth whitening [12].

Given the large variety of whitening products available, it can be challenging for clinicians and patients to choose the most adequate technique. Among various aspects to be considered, the long-term effect of bleaching is an important factor that might be decisive for treatment's choice [13]. Therefore, the aim of this paper is to evaluate the dental color stabilization after four different bleaching techniques. A priori, we hypothesize that the association of 3% hydrogen peroxide with classical in-office bleaching using 35% hydrogen peroxide (G2) would result in whiter teeth in comparison to other techniques used in this study.

2. Material and methods

Sixty people with an age range from 25 to 35 years old were randomly selected for this study. Each participant was informed about the risks and benefits of the treatment and had access to the Ethics Committee approval certificate from the Federal University of Amapá, AP, Brazil (which is in accordance with the Declaration of Helsinki). Before being enrolled in the study, all participants signed the informed consent form.

A clinical assessment was conducted in each participant to evaluate the group of teeth to be whiten (teeth which could be seen in the smile line for each patient), ensuring the upper arch had homogeneity of color. Participants with non-vital teeth discoloration or odd stains stressing a tooth or few teeth were excluded from the trial. Participants should be free of: periodontal diseases, dental prostheses, active caries, and failing restorations on upper central incisors (#11 or #21) and upper canines (#13 or #23). Periodontal assessment ensured the enrollment of participants with gingival scores up to 1 based on The Loe and Silness gingival index [14]. Exclusion criteria also involved no use of tobacco in the previous 30 days, no current or previous use of teeth whiteners, and women who were pregnant or lactating.

Participants meeting the criteria received dental prophylaxis and supragingival calculus removal 48 h before teeth whitening. They were randomly divided into four groups of different bleaching techniques, as described below:

2.1. Group 1: in-office, 3 sessions, 35% hydrogen peroxide

- 1 Initial dental prophylaxis and color measurement (1st color record);
- 2 Application of a light-cure rubber dam to protect and isolate soft tissue (Topdam, FGM, Joinville, SC, Brazil);
- 3 Application of the bleaching gel for 15 min according to manufacturers' instructions (Whiteness HP, 35% hydrogen peroxide, FGM, Joinville, SC, Brazil);
- 4 LED photoactivation (Twin Flex MM Optics, São Carlos, SP, Brazil) for 60 s continuously on each group of 3 teeth;
- 5 Rinsing off of the gel;
- 6 Repetition of steps 3 and 4 two more times, for a total of 45 min of bleaching in the same session, according to manufacturers' instructions (Whiteness HP, 35% hydrogen peroxide, FGM, Joinville, SC, Brazil);
- 7 Immediate color measurement (2nd color record);

- 8 Low level lasertherapy with diode laser (660 nm, 40 mW, 4 J/cm² - Twin Flex MM Optics LTDA, São Carlos, SP, Brazil);
- 9 Fluoride therapy (Flugel neutro incolor, sodium fluoride 2%, Nova DFL, Rio de Janeiro, RJ, Brazil);
- 10 Second bleaching session (1 week after 1st session), repetition steps 1–9 (3rd color record);
- 11 Third bleaching session (2 weeks after 1st session), repetition steps 1–9 (4th color record);
- 12 Follow up appointment (60 days after 3rd bleaching session) for dental prophylaxis and color measurement (5th color record).

2.2. Group 2: in-office, 3 sessions, 3% + 35% hydrogen peroxide

- 1 Initial dental prophylaxis and color measurement (1st color record);
- 2 Application of cotton soaked with 3% hydrogen peroxide (Água Oxigenada 10 vol, Farmax, Divinópolis, MG, Brazil) on frontal surfaces of the teeth for 5 min;
- 3 Rinsing off of the liquid;
- 4 Repetition of steps 2–12 from group 1.

2.3. Group 3: in-office, 3 sessions, 3% hydrogen peroxide

- 1 Initial dental prophylaxis and color measurement (1st color record);
- 2 Application of 5 layers of 3% hydrogen peroxide (Água Oxigenada 10 vol, Farmax, Divinópolis, MG, Brazil) on frontal surfaces of teeth with the aid of a microbrush;
- 3 LED photoactivation (Twin Flex MM Optics, São Carlos, SP, Brazil) for 60 s continuously on each group of 3 teeth;
- 4 Rinsing off of the product;
- 5 Repetition of steps 2–4 two more times, for a total of 45 min of bleaching in the same session;
- 6 Dental polishing and color measurement (2nd color record);
- 7 Low level lasertherapy with diode laser (660 nm, 40 mW, 4 J/cm² - Twin Flex MM Optics LTDA, São Carlos, SP, Brazil);
- 8 Fluoride therapy (Flugel neutro incolor, sodium fluoride 2%, Nova DFL, Rio de Janeiro, RJ, Brazil);
- 9 Second bleaching session (1 week after 1st session), repetition steps 1–8 (3rd color record);
- 10 Third bleaching session (2 weeks after 1st session), repetition steps 1–8 (4th color record);
- 11 Follow up appointment (60 days after 3rd bleaching session) for dental prophylaxis and color measurement (5th color record).

2.4. Group 4: at-home, 15 days, 10% hydrogen peroxide

- 1 Initial dental prophylaxis and color measurement (1st color record);
- 2 Alginate impression of upper and lower arches to produce stone models. Two scalloped whitening trays (Whiteness Plates for Custom Dental trays 1 mm, FGM, Joinville, SC, Brazil) extending out 1 mm for the cervical region were fabricated using a vacuum-forming machine. Appropriate reservoirs were made on the labial surfaces to receive the whitening gel;
- 3 Instructions and delivery of whitening gel (Whiteness Standard, 10% carbamide peroxide, FGM, Joinville, SC, Brazil) and trays for participants. All participants received a hands-on practical demonstration and written instructions concerning the proper use of the bleaching agent: 1-h daily application for 15 days (comprising 15 h of treatment);
- 4 Follow up appointment (7 days after bleaching treatment) for dental prophylaxis and color measurement (2nd color record) and anti-sensitivity therapy (steps 7 and 8 from group 3);
- 5 Follow up appointment (60 days after bleaching treatment) for dental prophylaxis and color measurement (3rd color record) and anti-sensitivity therapy (steps 7 and 8 from group 3);

This is a double-blind study, so neither the calibrated examiners nor

the assessors knew which whitening treatment each participant was receiving. Participants were oriented not to talk with the examiners about the treatment they were undertaking to prevent bias in research results.

Each participant had the color of their upper teeth (either #11 and #13, or #21 and #23) measured with a calibrated digital spectrophotometer (PS4 Color Reader, Imbotec, Brampton, ON, Canada). The equipment was positioned perpendicular and in contact with the tooth surface, centered on the facial middle-third of the tooth. All measurements were performed by the same examiner for more accurate data comparisons [15].

Dental color values were obtained in RGB scale with this spectrophotometer. The RGB scale considers red (R), green (G), and blue (B) color modes to measure chromatic changes in a scale from 0 (darkest) to 255 (lightest) [16]. Color information was first converted from RGB into CIE $L^*a^*b^*$ (Commission Internationale de l'Eclairage coordinates: L^* indicates lightness; a^* is a measure of red-green contrast; and b^* is a measure of yellow-blue contrast). Subsequently, CIE $L^*a^*b^*$ was converted into CIE $L^*C^*h^*$ (Commission Internationale de l'Eclairage coordinates: L^* indicates lightness; C^* indicates chroma; and h^* indicates hue). The $L^*C^*h^*$ color space is similar to $L^*a^*b^*$, but it describes color differently using cylindrical coordinates instead of rectangular coordinates.

Statistical analyses considered a significance level of 0.05 and were performed using the Sigmasat 4.0 computer software (Systat Software, Chicago, IL, USA). Firstly, the Shapiro-Wilk test for normal distribution values was performed. Then, groups showing a normal behavior, the variance analysis and the paired t -test were applied. Finally, groups without a normal behavior were analyzed using the non-parametric Friedman test and the non-parametric Wilcoxon test.

3. Results

Sixty participants were enrolled in this study. One upper central incisor and one upper canine were evaluated in each participant, comprising a total of 120 teeth. No tooth sensitivity was reported by participants and no gingival inflammation was detected during treatment. Intra-group analysis for canines and for incisors revealed no statistical differences in the baseline mean and median color measurements. All bleaching techniques resulted in change of lightness, chroma, and hue for canines and central incisors.

Lightness increased for both upper canines and central incisors regardless of the bleaching technique used (Fig. 1). Canines and central incisors data for lightness were first analyzed using Shapiro-Wilk test, resulting in a normal distribution data ($p > 0.05$, Fig. 2). Then, repeated measures analysis of variance (ANOVA) performed in each of the four groups ($p < 0.05$ intra-group) led to paired t -test. The results of t -test were statistically significant for comparisons of lightness at baseline and 60 days after bleaching in all groups ($p < 0.05$). Therefore, lightness increased significantly in a long-term fashion (60 days after bleaching) in groups 1 to 4.

Inter-group lightness comparisons showed no statistical differences

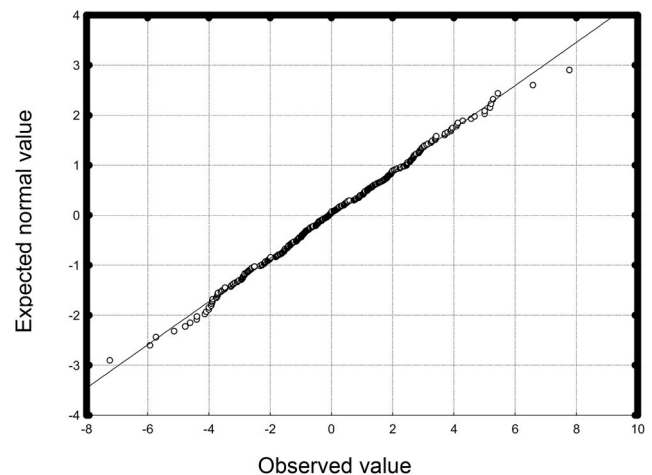


Fig. 2. Normal plot of residual for lightness in upper teeth.

60 days after treatment for both canines and central incisors ($p > 0.05$). However, when analyzing lightness in short-term evaluation (that is, after 3rd session for groups 1–3, and 7 days after at-home bleaching for G4), differences were found.

For canines, inter-group ANOVA test ($p < 0.05$) led analysis to another statistical test, the paired t -test, in which statistical difference was detected between G1 and G4 ($p < 0.05$). For central incisors analysis, ANOVA test ($p < 0.05$) led to statistical differences when paired t -test was performed between G2 and G3 ($p < 0.05$), G1 and G4 ($p < 0.05$), and G2 and G4 ($p < 0.05$).

Chroma resulted in a normal distribution of the values when Shapiro-Wilk test was performed for canines ($p > 0.05$) and for incisors ($p > 0.05$) (Fig. 3). No statistical differences were found according to repeated measures ANOVA ($p > 0.05$) for central incisors intra-groups in short- and long-term bleaching measurements (Fig. 4). However, ANOVA test indicated intra-group difference for canines ($p < 0.05$). When t -test was applied, bleaching led to a significant increase in canines' chroma in G4 ($p < 0.05$). Other groups showed no statistical differences for canines (Fig. 4).

The increase in canine's chroma found in G4 led to inter-group analysis statistical difference: chroma in G1 and in G2 was significantly lower than in G4 ($p < 0.05$). For central incisors analysis, no statistical difference in chroma was found in inter-groups comparisons ($p > 0.05$).

Hue analysis resulted in a not normal distribution of data using Shapiro-Wilk test ($p < 0.05$) (Fig. 5). Then, Friedman's analysis of variance was performed. Group 2 was the only one to present statistical differences for both canines and incisors ($p < 0.05$). Canines' hue in G2 changed significantly in long-term analysis according to paired-sample sign test ($p < 0.05$), which did not happen to incisors of the same group ($p > 0.05$). Statistical difference was observed for incisors of G4 according to Friedman's test ($p < 0.05$), however, this difference was

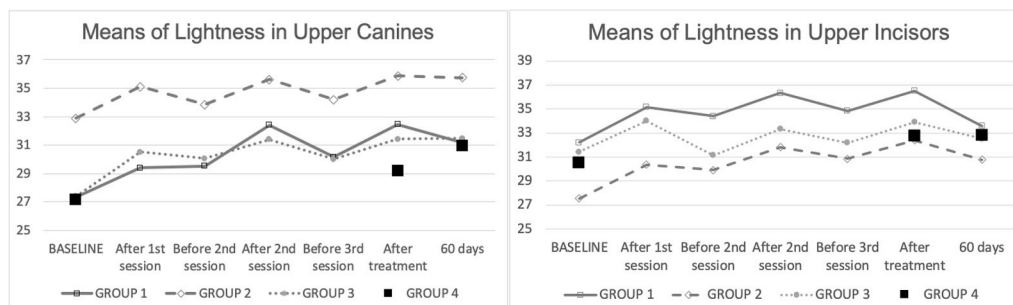


Fig. 1. Means of lightness in upper teeth.

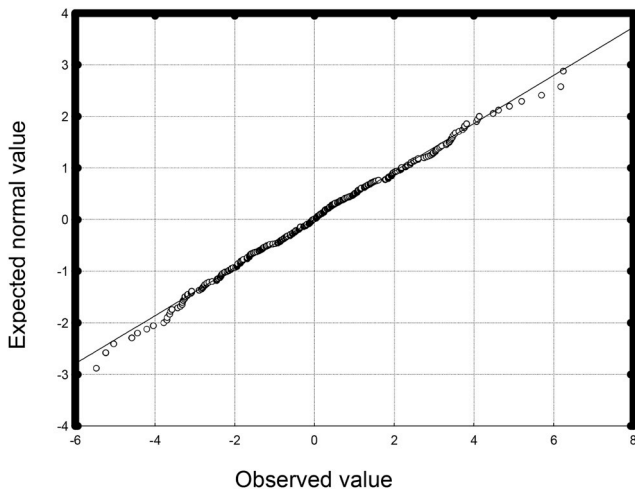


Fig. 3. Normal plot of residual for chroma in upper teeth.

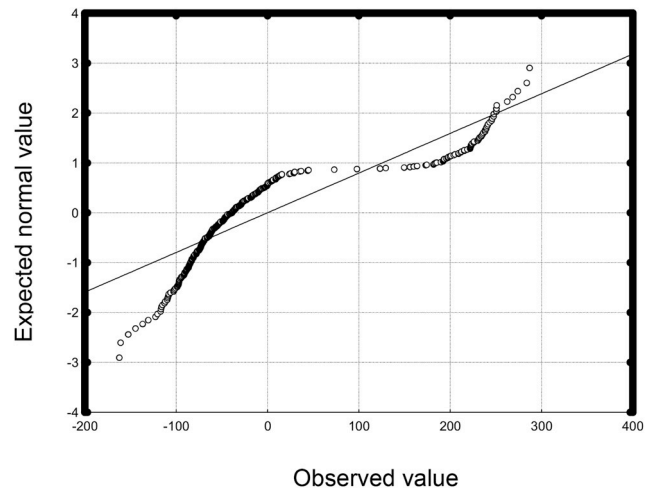


Fig. 5. Normal plot of residual for hue in upper teeth.

noticed during the bleaching process, and not for short- or long-term comparisons ($p > 0.05$).

Before bleaching, groups had no hue statistical difference ($p > 0.05$ for canines and central incisors). Long-term inter-groups data comparisons resulted in statistical differences according to Friedman's test ($p < 0.05$ for canines and central incisors). Then, Wilcoxon test revealed the highest canines' and central incisors' hue scores for G2 in comparison with other groups ($p < 0.05$). Means of hue are represented on Fig. 6.

4. Discussion

Since this study evaluated bleaching using different agents, it is important to consider dental sensitivity and gingival inflammation associated to whitening gels with increased concentrations [5,17]. In order to prevent teeth sensitivity, this study used a protocol in all participants based on the literature with laser therapy [18] and fluoride therapy [19] after bleaching. Both techniques were used since in-office whitening using a light source predisposes to tooth sensitivity [20]. All groups received the same anti-sensitivity procedures for homogeneity among groups and to avoid any interference in the results. The fact that no sensitivity was reported by participants may be explained by the use of combined anti-sensitivity therapies.

Gingival assessment, dental prophylaxis and supragingival calculus removal aimed at ensuring a non-inflammatory gingiva, which could have prevented some participants to be enrolled in this study. During whitening, strategies associated to each treatment were used to prevent gingival inflammation. In-office bleaching sessions were performed only after application of light-cure rubber dam, as instructed by manufacturers. At-home bleaching was performed with the gold-standard

treatment [21], that is, 10% carbamide peroxide gel. The association of hands-on practical demonstration and written instructions given to participants, coupled with the use of scalloped trays to minimize the contact between the gel and soft tissues [22] also might have contributed to prevent gingival inflammation.

The variety of bleaching products available on the market for professional and non-professional use [12], as well as effective whitening even when agents with low hydrogen peroxide concentration are used [12,23] called the attention of the authors to test a low-price non-conventional bleaching over-the-counter product.

The 3% hydrogen peroxide product tested was able to whiten participants' teeth. Bleaching was detected by spectrophotometer, chosen in this study for shade matching due to its accuracy regardless of ambient illumination [24]. However, whitening was also noticed visually, as reported by participants from all groups. Even though no visual analogue scales were used in this study, significant increase in lightness might have been responsible for this visual perception since it is the parameter better noticed by human eyes [22].

Analysis of lightness, chroma, and hue was conducted to evaluate whitening treatment in this study, as these are the three major color attributes [25]. Long-term lightness scores (60 days after treatment) were significantly higher after bleaching for all groups. That is, whitening treatments were effective regardless of the technique or concentration of the agent, which is in accordance with other studies [22,26].

Literature shows that effectiveness and longevity of bleaching treatments are not related to the increase of whitening agent concentration [5,10,23]. Therefore, statistical differences between G1 and G4 for canines, and between G2-G3, G1-G4, and G2-G4 for central incisors analysis do not impact the long-term stabilization of bleaching

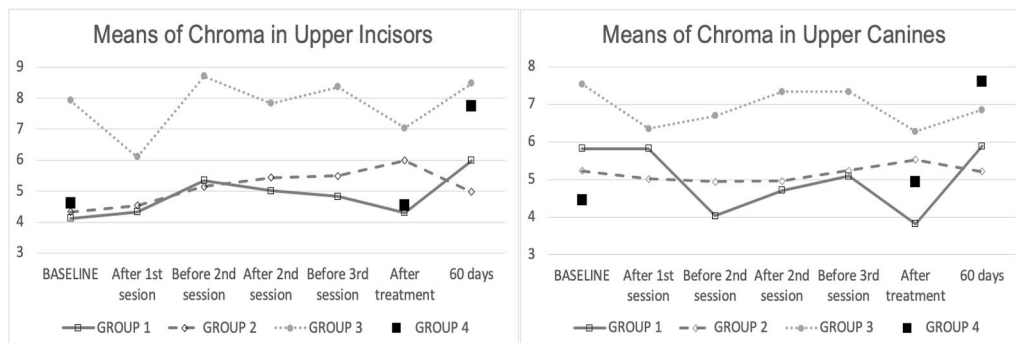


Fig. 4. Means of chroma in upper teeth.

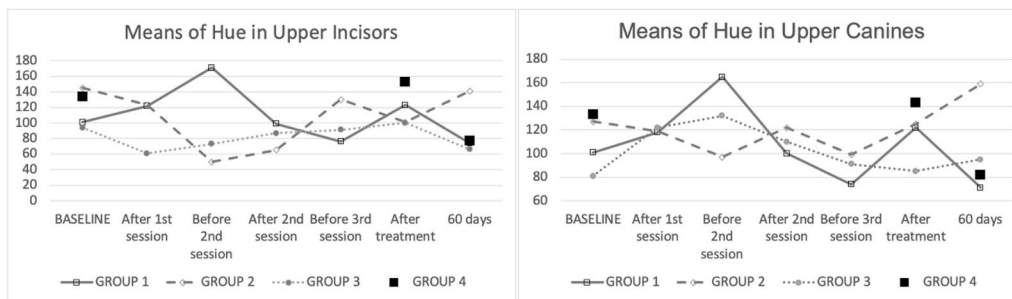


Fig. 6. Means of hue in upper teeth.

treatment, since these differences were obtained only in short-term analysis in this study. Such differences should not be considered relevant for choosing the whitening technique. Based on these analyses, the hypothesis initially posed was refuted.

Chroma, another color property investigated in this study, did not change statistically after central incisors' whitening neither in short-term, nor in long-term evaluations. However, canines from G4 had a significant increase in chroma, impacting groups comparisons in which lower scores for G1 and G2 were found. This may seem contradictory to whitening outcomes, since a reduce in yellowness (b^*) is expected [27,28], and chroma is directly proportional to b^* values mathematically [29]. However, the dentine chroma is more saturated [15], and canines have more dentin in comparison to incisors, leading to the difference found in this study. Even though, the present study is in agreement with other research that found different behaviours between canines and incisors regarding to chroma changes after whitening [15,23,30].

Hue changes were also different for incisors and canines in this study, which has been previously found [23,30]. Hue increased significantly in canines from G2 after whitening, but not for incisors. Although not statistically significant, hue also increased in G3. Studies show that hue is supposed to increase after teeth whitening [23]. However, hue is not a primary variable and should be seen in context with color saturation [15].

The results of this study might have been influenced by some limitations of the 3% hydrogen peroxide chosen. First, the product used had no gel consistency. Liquid-based hydrogen peroxide has been only used as mouthwashes in the literature [12,27]. Second, due to its flowability, the liquid might not have had a satisfactory contact with frontal surface of the teeth, which may have compromised the uniformity of the whitening. Finally, to the best of our knowledge, 3% hydrogen peroxide LED activation is not described in the literature and may have no influence on whitening.

5. Conclusion

Within the limitations of this study, it can be concluded that:

Considering lightness, dentists and patients can decide either the 3% or 35% hydrogen peroxide in-office products, or 10% carbamide peroxide at-home bleaching technique to target whitening.

The addition of 3% hydrogen peroxide to conventional in-office whitening only increased appointment time without improving whitening results.

Declarations of interest

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