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Clinical Research

Comparison of At-home and In-office Tooth Whitening Using a Novel Shade Guide

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Clinical Relevance

Five days of at-home whitening with 10% carbamide peroxide (eight hours/day) produces a similar tooth whitening result as one in-office treatment with 25% hydrogen peroxide (one hour).

SUMMARY

Objective: This study evaluated the time necessary for at-home whitening (HW) to match the results of an in-office (OW) treatment, side effects and patients' preferences/perceptions. Methods: The tooth color change of 20 subjects was measured using a shade guide (BSG) and spectrophotometer (ES). Color difference was calculated: $\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*ab)^2 + (\Delta b^*ab)^2]^{1/2}$. The whitening treatments were randomly applied to the right or left maxillary anterior teeth, in-office, with 25% hydrogen peroxide or at-home, overnight, with 10% carbamide peroxide. The tooth color was evaluated at baseline, one day after OW, six days (five days after HW) and at 20 days (14 days after HW and 19 days OW). Subjects rated their tooth and soft tissue sensitivity (1-10 scale). The results were analyzed by two-way RM ANOVA/Tukey's and Mann-Whitney ($p<0.05$). Results: At six days, the teeth that were treated with HW and OW presented $\Delta E^* = 5.2$ and 6.6, respectively, $\Delta BSG=3$, and at 20 days, they presented $\Delta E^* = 6.2$ and 6.6, respectively, $\Delta BSG = 3$. Less than 40% of the subjects experienced tooth sensitivity after OW and HW. No subjects experienced tooth and gingival sensitivity at 20 days.

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Seventy-four percent preferred HW over OW, 63% recommended OW and 100% recommended HW. Conclusion: While there was a subtle difference in ΔE* between HW and OW at six days, the measurement of ΔE* and ΔBSG agreed that five days of home whitening produced the same results as a single in-office treatment. The tissue and teeth sensitivity were mild and transient. Subjects preferred and would recommend HW over OW.

INTRODUCTION

Tooth discoloration results from varied and complex causes that are usually classified as being intrinsic and extrinsic.[1] Tooth whitening has been accepted as the least aggressive method for treating discolored teeth. The effectiveness of tooth whitening appears to be time- and concentration-dependent.[2] At-home tooth whitening is usually done overnight for several weeks, depending on the type of stain and the concentration of the whitening gel, which may vary from 5% to 35% carbamide peroxide (CP). The 10% CP used overnight in custom-fitted trays has been considered the "gold standard" for tooth whitening. This technique is the most common whitening procedure, and the literature heavily supports the efficacy of this method.[3-15] Despite the advantages of at-home whitening, some patients do not like wearing trays and desire to have teeth whiter faster. In-office whitening is an alternative for these patients. In-office whitening using hydrogen peroxide (HP), now often used in conjunction with a high intensity blue light, was first introduced in 1918 by Abbot;[16] nonetheless, this system has only gained popularity in recent years. Today, there are several in-office systems available with different gel concentrations, usually 15% to 38% HP. During the in-office procedure, whitening gel is placed on the tooth and may or may not be illuminated with a light source.

A frequently used in-office system is the Zoom system, wherein 25% hydrogen peroxide (HP) is applied onto the teeth. Ten percent CP corresponds to approximately 3% HP. Thus, the 25% HP used in Zoom is approximately eight times stronger than the 10% CP used most often for at-home whitening. Although the whitening concentration of this in-office system is higher, it is not yet known how much faster it whitens the teeth when compared to the lower concentration used at home to achieve similar whitening results.

At-home and in-office whitening techniques have advantages and disadvantages. A common clinical side effect of in-office whitening is thermal sensitivity.[13,17-18] This may occur during the whitening procedure and usually stops when treatment is suspended.[15,19] Gingival irritation caused by whitening agents has also been reported.[13-14,17-19] In order to avoid tissue irritation during at-home whitening, the whitening trays are scalloped to minimize contact of the gel with the gingiva. Moreover, the patients are instructed to wipe any excess gel off of the gingiva. For the in-office system, the soft tissue is protected with either a rubber dam or resin dam to minimize contact of the peroxide with the gingiva.

There have been only a couple of studies that have evaluated patients' satisfaction toward tooth whitening. According to the *CRA Newsletter* in 2001,[20] 10% of participants were very satisfied with in-office whitening, 32% were satisfied, 26% were unsatisfied and 6% were very unsatisfied. According to the same newsletter, 57% of the participants were very satisfied with at-home tooth whitening, 38% were satisfied, 1.2% were unsatisfied and 0.3% were very unsatisfied. Another study evaluated at-home, in-office and over-the-counter tooth whitening and reported that at-home whitening was significantly more accepted by patients compared to the in-office method.[15] There is a need for more research to assess not only patients' satisfaction and preference, but also their expectations and perceptions (comfort, recommendation) of both at-home and in-office whitening systems.

The objectives of the current study were to: a) compare the amount of time necessary for at-home whitening (HW) to match the results of a single one-hour session of in-office whitening (OW) using visual and instrumental shade matching methods, b) evaluate possible side effects, such as gingival irritation and tooth sensitivity and c) evaluate patient preferences for and perceptions of both systems.

METHODS AND MATERIALS

This was a randomized, single-blind, split-mouth design clinical study. One clinician performed the whitening and another evaluated the color change. Twenty patients were selected for this study, based on inclusion and exclusion criteria (Table 1).

During the screening appointment, the subjects signed the school's IRB authorization and consent form. The Loe and Silness gingival index was utilized to ensure that the included subjects did not have moderate-to-severe periodontal tissue inflammation. The subjects then received a dental prophylaxis to remove any extrinsic stains. One impression of the maxillary arch was made, and a stone model was produced to fabricate two whitening trays: one for the tooth whitening and the other was modified to make a positioning jig to ensure placement of the tip of the spectrophotometer in the same position at every color measurement. An impression of the tip of the probe of the spectrophotometer was made and a cast was fabricated. The spectrophotometer probe cast was used as a stamp guide to mark the whitening tray. The facial middle-third of the maxillary teeth was marked with the spectrophotometer tip cast using an ink pad. The facial marks were

Table 1: *Inclusion and Exclusion Criteria to Participate in the Study*

Inclusion Criteria	Exclusion Criteria
- Be at least 18 years old - Willing to sign a consent form - Willing to return for post-whitening evaluation - Presence of all six maxillary teeth equal or darker than 1M2 Vita Bleached guide in the value order - Have no maxillary anterior teeth with more than 1/6 of the facial surface covered with a restoration	- History of any medical disease that may interfere with the study or require special consideration - Presence of gross pathology - Use of tobacco products during previous 30 days - Current or previous use of whitening agent - Loe and Silness gingival score greater than 1.0 - Pregnant or lactating women - Tetracycline-stained teeth - Participant must not be taking these medications: Chlorthiazide, Hydrochlorothiazide, Chlorithalidone, Naprosyn, Oxaprozin, Nabumetone, Piroxicam, Doxycycline, Ciprofloxacin, Ofloxacin, Psoralens, Democlocyline, Norfloxacin, Sparfloxacin, Sulindac, Tetracycline, St John's Wort, Isotretinoin, Tretinoin

cut, leaving an opening for placement of the spectrophotometer probe. Prior to color measurement, the custom jig was positioned in the patient's mouth, and the spectrophotometer probe was positioned into the jig opening. At the same appointment, the subjects received a dental prophylaxis to remove any extrinsic stains. The subjects also received a non-whitening toothpaste (Crest Cavity Crotection, Procter & Gamble, Cincinnati, OH, USA) and a soft bristled manual toothbrush (Oral B, Iowa City, IA, USA). They were asked to brush at least twice a day in order to maintain a standardized home care regimen.

A pilot study was performed in order to assess how many days of at-home whitening treatment are necessary to achieve the same whitening effect of a single in-office whitening treatment. According to the pilot results, it took an average of five days. Thus, the authors of the current study measured tooth color five days after HW. The patients were asked to stop whitening their teeth and contact the authors of the current study if they could not see a difference between their right and left upper teeth after the five-day period. They were then asked to come to the clinic for tooth color evaluation. If the instrumental or visual evaluations showed similar color between the right and left teeth, the subjects were asked to stop whitening. Otherwise, they were asked to keep whitening and come back for evaluation on a daily basis.

Tooth color was measured at four intervals (Table 2). At the baseline appointment, an independent evaluator visually examined the patient's tooth color using the VITA Bleachedguide 3D Master (BSG, Vita Zahnfabrik, Bad Sackingen, Germany) and the same evaluator examined the patient's tooth color instrumentally using a spectrophotometer (ES-Easyshade, Vident, Brea, CA, USA). The evaluation was calibrated by using two BSG and matching pairs. The shade tab designation was covered with white tape, so that the evaluator could not see the shade tabs marks. ES measures the color of the teeth based on the CIELAB color notation system (CIE 2004), wherein L* denotes lightness (achromatic), while a* and b* denote green-red and blue-yellow coordinates, respectively. The total color difference or the distance between two colors was ΔE. The total color difference was calculated using the formula: $\Delta E^*ab = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$.[21]

The whitening treatments were randomly applied by flipping a coin to determine whether the right (teeth #6-8) or left (teeth #9-11) maxillary anterior teeth were to be treated. Liquidam (Discus Dental, Culver City, CA, USA), a light-cure resin, was applied on the soft tissue to isolate and protect it. Either the right or left anterior teeth were whitened in-office with Zoom AP (Discus Dental). The 25% hydrogen peroxide gel was applied according to the manufacturers' instructions as follows: the gel was allowed to remain on the teeth for a total of 15 minutes and illuminated by its proprietary light. The light was then turned off, the gel was rinsed off and the teeth dried. This procedure was repeated three more times, for a total of 60 minutes of whitening. The subjects were asked to return the next day so that the color measurements could be performed 24 hours (one day) after the whitening proce-

Table 2: *Data Collection Design*

Baseline	Day 1 (one day after OW)	Day 6 (five days after HW)	Day 20 (14 days after HW, 19 days after OW)
- Tooth-color measurement - OW treatment	- Tooth-color measurement after OW	- Tooth-color measurement after five days of HW	- Final tooth-color measurement

dure, allowing enough time for the teeth to rehydrate. Shade matching with the BSG was performed under a color-corrected light (Rite.light, Addent, Danbury, CT, USA), having a correlated color temperature of 5500˚K that simulates northern sky daylight.

The remaining anterior teeth were treated with NiteWhite Excel 3 (NWE 3-10% CP Discus Dental) using an at-home overnight tray method. The subjects received only the whitening tray side (half-arch tray), which was intended for at-home whitening, along with whitening gel and instructions. The patients were instructed to place the whitening gel in the half-arch tray and only whiten those teeth overnight for eight hours. In the morning, they were asked to remove the tray from their mouth and the remaining gel from their teeth with a cotton swab, then brush their teeth and the tray using cold water.

Most of the subjects were evaluated after five days, using visual and instrumental methods. Of the 20 subjects, two achieved the same whitening results with OW in three days of HW, three subjects achieved whitening results in seven days and one subject attained whitening results in eight days. The last tooth color measurement was taken at the same time, two weeks (14 days) after the HW procedure and 19 days after OW, in order to evaluate any color relapse. Tooth and gingival sensitivity was assessed at every visit. The patients were asked to rate their tooth and soft tissue sensitivity experience using a visual analog scale that had categories ranging from one to 10.

At the last appointment, the subjects were asked to complete a questionnaire (Table 3) and, if desired, they received upper whitening trays and NWE 3 10% CP gel to continue whitening their upper teeth at home. The subjects who wished to have their lower teeth whitened came back to have impressions of their lower teeth made and received trays for delivering the whitening gel. Subjects who experienced tooth sensitivity received desensitizing gel (Ultra EZ, Ultradent Products, Inc).

Statistical Analysis

The results were analyzed with computer software (Sigmastat 3.1, Systat Software, Chicago, IL, USA). A *t*-test ($p<0.05$) was used to compare the L* a* b* of the right and left teeth; it was obtained with the spectrophotometer at baseline and ΔE* between one day and baseline for the OW. The Mann-Whitney rank sum test was used to evaluate the BSG results of the right and left teeth at baseline, and the results between one day and baseline for the OW.

The individual ΔL*, Δa*, Δb* and ΔE* results were analyzed by two-way repeated measurements ANOVA/Tukey's test ($p<0.05$), and the shade guide rank results were analyzed by the Mann-Whitney rank sum test. Both parametric and non-parametric tests evaluated two factors: whitening system (HW and OW) and time (baseline versus six days, baseline versus 20 days).

Both the tooth and gingival sensitivity average scores of tooth whitening were compared using the Kruskal-Wallis one way analysis of variance on ranks/Tukey's test ($p<0.05$) for each whitening system and time. For the HW, the times evaluated were baseline, day six (five days after whitening treatment) and day 20 (14 days post-whitening). For the OW, the times evaluated were baseline, during treatment, one day after treatment and day 20 (19 days post-whitening).

The responses to the questionnaire are reported in percentages. A Chi square test ($p<0.05$) was done for responses to the patients' preferences and their recommendations.

RESULTS

Twenty subjects enrolled and completed the study. Eight participants were female and 12 were male, having an age range between 23 and 57 years. There were no statistically significance differences in the mean (ES) and median (BSG) baseline shade of the right and left teeth.

Spectrophotometer Data

After one OW treatment, the teeth became lighter, ΔL* ($p=0.02$) (Figure 1), less yellow, Δb* ($p<0.001$) (Figure 3), showing a significant difference in ΔE* ($p<0.001$) (Figure 4), but the change in the red-green axis, Δa* was not significant ($p=0.09$) (Figure 2).

When comparing time (baseline versus six days, baseline versus 20 days) and treatment (OW and HW), there was no significant ΔL* difference for time and treatment, Δa* treatment and ΔE* time. There was a Δa* difference for time, a Δb* difference for time and treatment and a ΔE* difference for treatment. There was only a significant interaction between time and treatment for Δb*.

Shade Guide Data

There was a significant color difference after one OW treatment (Figure 5). There was no significant difference for time and treatment; there was no difference in median results for both time (six days versus 20 days) and treatment (HW and OW) (Figure 5).

Tooth and Gingival Sensitivity

There was no statistically significant difference in tooth sensitivity at any time evaluated for both HW and OW. At baseline (prior to tooth whitening), none of the patients reported experiencing any tooth or gingival sensitivity. Seven out of 20 subjects reported mild-to-moderate tooth sensitivity (2-5 VAS) during OH. Three subjects reported mild tooth sensitivity (1-3 VAS) one day after OW. Five out of 20 subjects report-

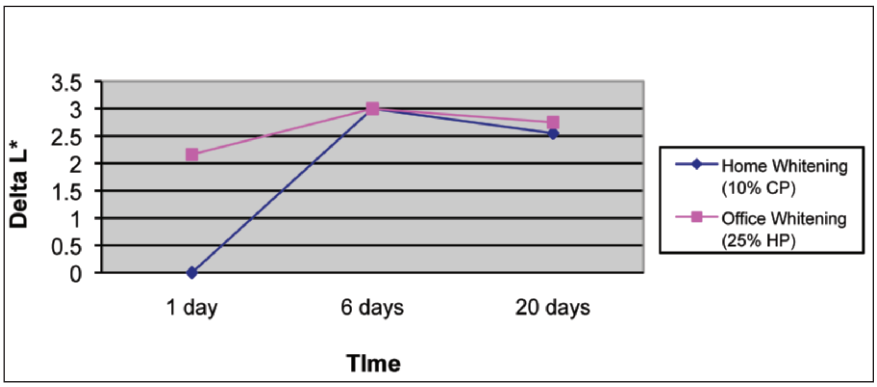

Figure 1. *Change in ΔL* for both whitening systems over a 20-day period.*

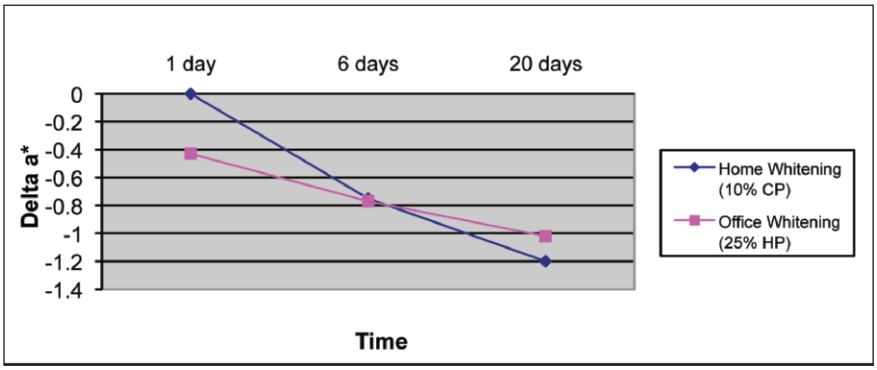

Figure 2. *Change in Δa* for both whitening systems over a 20-day period.*

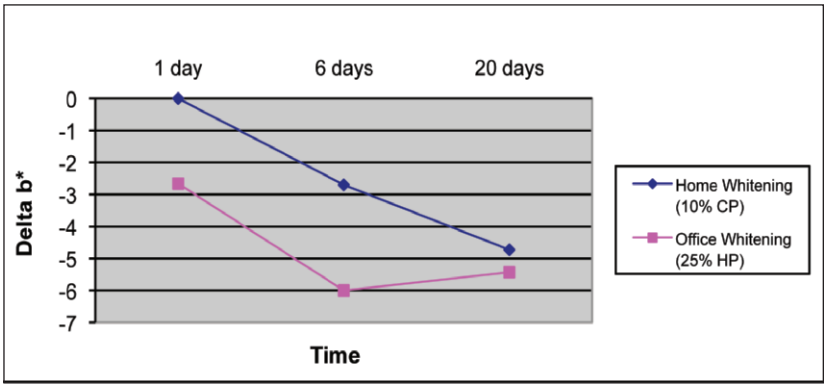

Figure 3. *Change in Δb* for both whitening systems over a 20-day period.*

ed mild tooth sensitivity (2-3 VAS) after five days of HW. None of the subjects reported sensitivity at day 20.

Two subjects reported mild gingival sensitivity (2 VAS) during OW, and one subject reported mild gingival sensitivity (2 VAS) after five days of HW.

Questionnaire

Nineteen surveys were returned and the responses are reported in percentages (Table 3). One subject did not turn in the questionnaire. The Chi-square test showed that there was a significant difference in terms of the patients' choice of method, with more than expected preferring at-home whitening, with a higher percentage recommending at-home whitening versus in-office treatment.

DISCUSSION

For objective measures of changes in the teeth during whitening, a spectrophotometer was used. The spectrophotometer measured and recorded the amount of visible radiant energy reflected from, or transmitted by, an object one wavelength at a time in the entire visible spectrum.[22-23] For visual tooth color measurement, a shade guide is usually used, with several being commercially available. Recently, a new VITA Bleachedguide 3D Master was launched on the market. This shade guide was designed primarily for visual evaluation of tooth whitening efficacy. The main difference between this shade guide and others is the inclusion of lighter shade tabs and more subtle color gradation.[24-25] This current study is one of a few done with the BSG, as previous studies have used the Vita Classical shade guide or Trubyte Bioform to evaluate tooth color change. It is possible to compare the BSG findings with the other two shade guides from previous studies by multiplying the values obtained from the current study by approximately 2.0.[24]

One of the purposes of the current study was to compare the amount of time necessary for at-home whitening (HW) to match the whitening results of a single one-hour session of in-office whitening (OW). While there was a subtle difference in ΔE* between OW (ΔE*=6.6) and HW (ΔE*=5.2) at six days, this 1.4 difference was slightly above the perceptibility threshold of ΔE*=1 obtained under controlled conditions and with trained evaluators[26] and well below the perceptibility threshold of ΔE*=2.6 recorded in less-controlled clinical settings.[27] In addition, a value of ΔE*ab of 3.3 was previously reported as 50:50% acceptability threshold in other studies.[28] The BSG showed no significant difference for both systems at six days. Moreover, there was no statistically significant difference in ΔE* and BSG between OW and HW at 20 days. ES and BSG findings demonstrated that five days of at-home whitening with 10% carbamide peroxide (eight hours/day) produced similar results as a single in-office treatment with 25% hydrogen peroxide (one hour). Another study showed that the teeth were lightened six shades with one in-office whitening treatment (45 minutes) using 38% HP

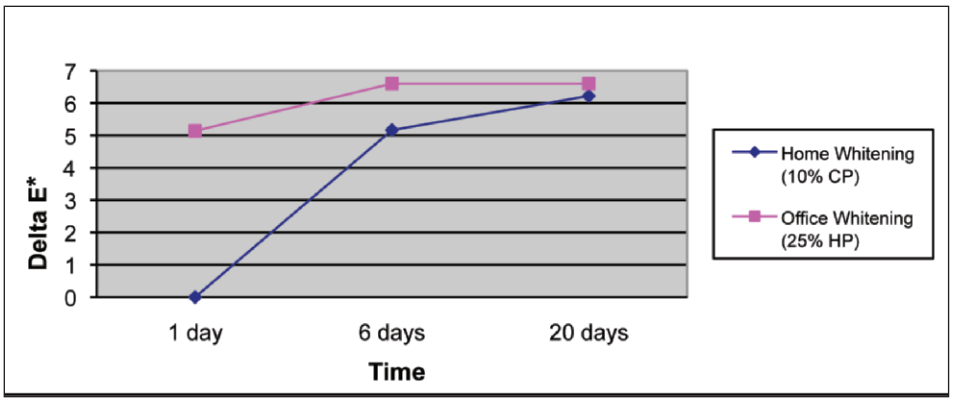

Figure 4. *Change in ΔE* for both whitening systems over a 20-day period.*

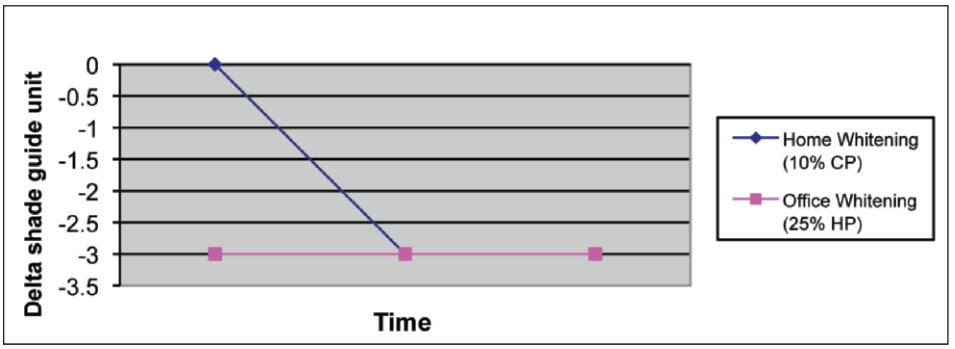

Figure 5. *Change in Δ shade Guide Tabs using BSG over a 20-day period.*

or seven days of at-home whitening using 10% CP.[15] The results of the two studies are similar and provide useful information to help patients make their decision when choosing to either have their teeth treated in-office or at home.

The two whitening systems proved to be effective for tooth whitening. The ADA[29-30] recommended that color change must be in the direction of higher L* and lower b* values. The two systems showed an increase in lightness (L*) and a decrease in yellowness (b*) at one day and five days after treatment for OW and HW, and these values were not different at day six for ΔL*, day 20 for ΔL* and Δb* for both systems. Furthermore, for OW, there was an increase in L* between one and six days (five days post-whitening), with no significant change thereafter.

The tooth color was evaluated at day 20, which is 19 days after OW and 14 days after HW. There was no significant color difference (ΔE*) immediately after whitening to day 20 for both systems. According to the visual findings, there was no color change for both treatments. Previous studies have evaluated tooth color after the whitening treatment was completed; nonetheless, it is hard to compare the results from different studies, because they differ in the concentration of bleaching, time of application, time and method of color evaluation and the type of color-measuring device. Matis and others[31] evaluated eight in-office whitening systems, including the one evaluated in the current study and showed tooth color relapse for every system. In their study, the tooth color was measured immediately after the in-office whitening treatment, and they commented that the initial color change may be due to dehydration.[32-33] Other studies with HW using 10% CP after two weeks

Table 3: *Questions and Answers (in percentage) Asked to the Study Subjects*

1) Was the in-office experience what you expected?
   - Yes (65%)
   - No (35%)
2) Was the at-home experience what you expected?
   - Yes (85%)
   - No (15%)
3) Were you expecting the in-office treatment to take
   - Less Time (15%)
   - More Time (30%)
   - About the time it took (55%)
4) Was the in-office experience comfortable?
   - Yes (70%)
   - No (30%)
5) Was the at-home experience comfortable?
   - Yes (80%)
   - No (20%)
6) Did the results meet your expectations?
   - Yes (80%)
   - No (20%)
7) If given a choice, which method do you prefer? (p=0.009)
   - In-office whitening (28%)
   - At- home whitening (74%)
8) Would you recommend the in-office procedure to a friend?
   - Yes (63%)
   - No (37%)
9) Would you recommend the at-home procedure to a friend? (p=0.012)
   - Yes (100%)
   - No

post-whitening have reported increased whitening,[14] no difference in whitening[9] and color relapse—a decrease in whitening.[11]

Both whitening systems yielded minimal side effects in the study subjects, with no differences between the methods. Less than 40% of the subjects reported transient mild-to-moderate tooth sensitivity during or after both whitening treatments and no symptoms at the last appointment. Less than 15% of the subjects reported mild gingival sensitivity during OW and after five days of HW. In contrast, one study reported that patients had slightly higher tooth sensitivity with HW compared to OW.[15]

Overall, the subjects were satisfied with the results of both the OW and HW treatments. A lower percentage of subjects reported their experience was as expected for the OW, compared to the HW. While the great majority of subjects found the OW a comfortable procedure, about three-quarters of the subjects preferred HW over OW. Additionally, a little more than half of the subjects would recommend OW to a friend, and all of the subjects would recommend HW. Although 80% of the subjects were satisfied with the results, all of them wanted to continue to whiten their teeth at home. Another important point is that in-office tooth whitening costs almost twice as much as at-home treatment and usually needs to be followed by at-home treatment to achieve the whitening effect expected by patients.

One of the limitations of the current study was that the post-whitening evaluation was done after a short period of time. Future studies should evaluate the tooth color change for months, instead of weeks. In addition, this study compared only one in-office system to the 10% CP at-home tray system. Future studies might evaluate other in-office systems with different HP concentrations to determine if similar results are achieved.

CONCLUSIONS

Within the limitations of the current study, the following conclusions can be drawn:

- While there was a subtle difference in ΔE* values between in-office and at-home whitening at six days, the visual and instrumental measurements agreed that five days of at-home whitening with 10% carbamide peroxide (eight hours/day) produced the same result as one in-office treatment with 25% hydrogen peroxide (one hour).
- Few subjects experienced tooth sensitivity during (35%) and one day after in-office whitening (15%) and after five days (25%) of at-home whitening. Very few subjects reported mild gingival sensitivity during in-office treatment (10%) and after five days of at-home treatment (5%). None of the subjects reported gingival or tooth sensitivity approximately two weeks after treatment for both systems.
- Subjects experiencing both at-home and in-office treatment reported overall satisfaction with both procedures in terms of comfort and whitening results; nonetheless, the subjects preferred and would recommend at-home whitening over the in-office procedure.

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