The efficacy and complications of several bleaching techniques in patients after fixed orthodontic therapy

A randomized clinical trial

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SWISS DENTAL JOURNAL SSO 130: 493–501 (2020)
Accepted for publication: 23 October 2019

KEYWORDS
Randomized clinical trial
Home bleaching
Laser-assisted bleaching
Tooth sensitivity
Orthodontic treatment

SUMMARY

This study aimed to evaluate the efficacy and complications of several bleaching methods in patients with discolored teeth after orthodontic treatment. This randomized clinical trial involved 60 volunteers (31 women, 29 men) aged 14 to 30 years, who finished fixed orthodontic therapy at least three months before the study commencement and complained of discoloration on upper front teeth. The subjects were divided into four groups by treatment. The patients in group 1 received home bleaching, whereas those in groups 2 to 4 underwent in-office bleaching using a diode laser, a plasma arc and no light source, respectively. Tooth color was measured at baseline, one hour after the end of the bleaching procedure, and one week later, and the color alteration between different stages was compared among the groups. The severity of tooth sensitivity and the occurrence of other post-treatment complications were recorded. The color change between baseline and one week after treatment was greatest in the home-bleaching and the laser-assisted bleaching groups, and lowest in the plasma-arc bleaching group, although the difference between the groups was not significant ($p > 0.05$). Tooth sensitivity over 24 hours after bleaching was lowest in subjects who had undergone laser-assisted bleaching and highest in those who had received in-office bleaching without light ($p < 0.05$). All methods were effective in managing tooth discoloration after orthodontic treatment. Home bleaching produced favorable color alteration. Amongst the in-office approaches, laser-assisted bleaching should be considered as the best option, as it produced effective results with lowest tooth sensitivity and over a shorter period of time.

Introduction

Today, most people tend to have teeth that make them look younger, healthier and more attractive. Therefore, subjects with dental stains increasingly request for a treatment option. Although there are several ways to enhance tooth surface discolorations such as veneers and crowns, bleaching techniques are more conservative and cheaper than other approaches (Fornaini et al. 2013). There are two methods for professional tooth whitening, differing in the concentration of the bleaching agent and the period of treatment, including in-office (professionally administered) and home-applied (professionally dispensed) techniques. Home bleaching is performed with substances that liberate low levels of hydrogen peroxide (HP) over a long period of time. Generally, carbamide peroxide (5% to 22%) is employed during two weeks for home bleaching. Home bleaching is associated with some advantages such as lower concentration of the bleaching substance, low cost and saving chair side time and thus, it is usually considered as the first choice for tooth whitening. In contrast, in-office bleaching employs high concentrations of bleaching agents (up to 55% HP) and renders immediate and visible results, which increase patient satisfaction from the treatment (Luna et al. 2006; Ahrari et al. 2015; Geus et al. 2018). Therefore, the in-office technique is best suited for patients who request a fast whitening treatment or do not show enough cooperation in wearing the trays. Prevention of material ingestion or soft-tissue exposure is another advantage of the in-office procedure (Joiner 2006; Ahrari et al. 2015; Ghanbarzadeh et al. 2015).

Tooth discoloration is considered as a major side effect of orthodontic treatment. Discolorations are induced over the course of fixed orthodontic therapy, mainly in patients with inadequate oral hygiene (Greenwall 2009; Heymann & Grauer 2013; Poosti et al. 2014; Ahrari et al. 2017). The process of acid etching and priming makes the teeth susceptible to discoloration (Corekci et al. 2015). Occasionally, the corrosion of metal brackets occurs due to prolonged orthodontic treatment and low level of oral pH in some patients, leading to enamel discoloration (Shahabi et al. 2011; Ahrari et al. 2012). The colored food and acidic drinks such as cola and citrus drinks also cause a damaging effect on tooth color and should be consumed minimally over the course of orthodontic therapy (Shahabi et al. 2011). The process of adhesive removal is another factor that can lead to staining the tooth after debonding of orthodontic appliances. This is occasionally done by roughening the enamel surface during the adhesive removal procedure or by remaining some adhesive materials on the teeth, which are extremely susceptible to absorb stains (Ahrari et al. 2013; Boncuk et al. 2013).

The color producing materials called chromophores are typically organic compounds that contain extended chains of alternating single or double bonds and often include carbonyl and phenyl rings in their structure (Joiner 2006). Whitening of the chromophores can occur by destroying one or more of the double bonds or oxidation of other chemical moieties in the chain. Although the exact mechanism of bleaching by hydrogen peroxide is not well understood, but it is believed that decomposition of hydrogen peroxide into active oxygen species such as oxygen and per-hydroxyl radicals plays a great role in tooth whitening. These free radicals attack stain molecules and break their carbon chains into small particles and oxidize colored molecules, therefore making the tooth whiter (Joiner 2006). The in-office protocols can be accelerated by the use of heat or light to increase the decomposition rate of hydrogen peroxide and formation of hydroxyl and oxygen free radicals (Kashima-Tanaka et al. 2003; Ghanbarzadeh et al. 2015). This process is well known as power bleaching and enables the clinician to achieve results in a shorter time. Many devices such as halogen lamps, light emitting diodes (LEDs), plasma arc lamps and different types of lasers such as diode, argon, and KTP have been used for power bleaching (Fornaini et al. 2013).

There are numerous and controversial studies regarding the efficacy and complications of various bleaching systems. Some studies indicated that there was no considerable difference in whitening capacity between light-activated and non-activated bleaching systems (Papathanasiou et al. 2002; Hein et al. 2003). It has been reported that light sources do not have any clinical influence on bleaching results (De Almeida et al. 2012). On the other hand, Gurgan et al. (Gurgan et al. 2010) indicated that the activation of bleaching gel with diode laser leads to significantly better results compared to bleaching with a plasma arc lamp, a light emitting diode, or no light activation. Some authors have voiced concerns about potential complications of tooth whitening procedures such as tooth sensitivity, soft-tissue irritation, and alteration in enamel structure, degradation of enamel and dentin bonding, and material toxicity (Barghi & Morgan 1997; Sulieman 2008; Ghanbarzadeh et al. 2015; Moosavi et al. 2016). It has been reported that 70% of patients submitted to tooth whitening have complained about postoperative sensitivity (Buchalla & Attin 2007). Occasionally, patients report gastrointestinal mucosal irritation e.g., a burning palate and throat, and minor upset in stomach or intestines (Howard 1992). Nevertheless, the general evidence to date suggests that bleaching is a relatively safe procedure (Haywood 1992; Ferraz et al. 2019).

This single-blind, randomized clinical trial aimed to compare the efficacy and potential complications of a home-applied and three in-office bleaching systems in patients with discolored teeth after orthodontic treatment.

Material and methods

Study design and participants

This was a randomized single-blind clinical trial with an equal allocation ratio. The sample consisted of sixty volunteers who referred to the Department of Restorative and Cosmetic Dentistry of Mashhad Dental School, Mashhad University of Medical Sciences, Mashhad, Iran, with the chief complaint of tooth discoloration following orthodontic treatment. The inclusion criteria consisted of healthy subjects aged between 14 and 30 years and having undergone orthodontic treatment at least three months before the study commencement. All participants had discoloration on their maxillary anterior teeth with central incisors showing shade C2 or darker on a value-oriented shade guide (Vitapan Classical, VITA Zahnfabrik, Bad Säckingen, Germany). The exclusion criteria were patients who were pregnant or lactating, had moderate or severe discoloration resulting from pulpless teeth, tetracycline stains or fluorosis as well as patients having smoking habits or those taking analgesic and anti-inflammatory drugs. Patients showing restored anterior teeth, non-carious cervical lesions, dental caries, periodontal disease or gingival recession, and those with previous tooth whitening procedures were also excluded from the sample.
The research protocol was reviewed and approved by the Ethics Committee of Mashhad University of Medical Sciences and was registered in the Iranian Registry of Clinical Trials (IRCT) with the identification number IRCT20180912041012N1. The objec-

tives of the study were explained thoroughly and informed consent was taken from patients or their parents before beginning the treatment.

Considering the inclusion and exclusion criteria, 60 patients (31 women and 29 men) with an average age of 21.6 years (range 14–30 years) participated in this study. The study was contemplated between October 2018 and February 2019. Two weeks before the bleaching procedure, each patient received a professional dental prophylaxis with pumice and a soft prophy cup. The tooth surfaces were also observed in a dry environment and underwent tactile examination by a dental explorer to ensure that the adhesive remnants were completely removed and the enamel surface is felt smooth. Subsequently, the patients were instructed in a standardized tooth brushing technique. The participants were advised to brush their teeth twice per day with the same toothpaste containing 1450 ppm fluoride (Crest, Procter and Gamble Co., Cincinnati, OH, USA) and avoid smoking and eating dark and staining food (like foods containing soy sauce, tomato-based sauces, curry and balsamic vinegar) and beverages (like cola, citrus drinks, tea and coffee) over the study period.

Allocation concealment and blinding

The group allocation was achieved by a computer-generated table using a random block size of 4. The details of the allocated groups were written on cards and were kept in sequentially numbered, opaque, and sealed envelopes. These cards were prepared by an independent operator who was not involved in the research protocol. Once the participant completed the baseline assessments and was eligible for the bleaching procedure, the allocation assignment was revealed by opening the envelope by this independent person.

Bleaching was carried out by a single operator. Blinding of neither the participant nor the operator was possible as commercial products were used and they observed the treatment apparatus. However, the subject who contemplated the assessments was blinded to the group assignment.

The bleaching protocol

Bleaching was performed on maxillary anterior and premolar teeth. The participants were randomly assigned to one of the four bleaching protocols, as follows:

Group 1: The participants in this group received a home-bleaching treatment over a 14-day period, which was performed with 20% carbamide peroxide gel (Opalescence PF, Ultradent Products Inc., South Jordan, UT, USA). Special home-bleaching trays were made for the patients and they were asked to wear the trays filled with a sufficient amount of bleaching material for 2–4 hours in the evening after brushing the teeth.

Group 2: The patients in this group were treated with a laser-assisted in-office bleaching technique. In this method, a 46% hydrogen peroxide gel (LaserWhite 20, Biolase Technology Inc., San Clemente, CA, USA) was used in association with an 810 nm diode laser (Gigaa Optronics Technology Co., LTD, Wuhan, China). After inserting bite blocks and a cheek retractor to isolate the treatment area, and a suction device to remove the excess saliva and water, a continuous bead of a liquid dam (White 20, Biolase Technology Inc.) was applied along the gingival margin. The liquid dam was photo-polymerized with a standard curing light (Bluephase G2, Ivoclar Vivadent Inc., Schaan, Liechtenstein) for 20 seconds. Next, the bleaching agent was prepared by mixing the activator and base syringes, and the maxillary teeth were covered with a 1 mm thick layer of the bleaching agent. A total of eight or ten teeth between the first molars (depending on the extraction protocol) were bleached for each patient. The bleaching gel was activated using an 810 nm diode laser, applied at 3 W for 30 s per tooth from an approximate distance of 1 mm and with scanning movements. After completing laser radiation on the anterior teeth and premolars, a resting period of 10 minutes was allowed and then laser irradiation was repeated a second time. Finally, the bleaching substance was carefully removed by high volume suction, and the teeth were wiped off with gauze and thoroughly rinsed with an air and water spray to remove any residual gel. The liquid dam was removed at the completion of the procedure. The total period of bleaching was 20 minutes; the gel was applied once and remained over the period of treatment.

Group 3: The subjects in this group were treated with the Everbrite in-office bleaching system containing 35% hydrogen peroxide (Everbrite, Dentamerica, City of Industry, CA, USA) provided for use with a plasma arc device (400–490 nm, 2800 mV/cm^2; Remecure CL15, Remedent Inc., Deurle, Belgium). After placing bite blocks and a lip retractor, the gingival tissue was covered with a light cure dental dam (Sofdam, Dentamerica) and polymerized for 20 seconds. One of the vials of hydrogen peroxide was mixed with one of the jars of photoactivator, and the gel was applied on the maxillary anterior and premolar teeth with an approximate thickness of 1 mm using a curved syringe. The Remecure plasma arc light was employed for activating the bleaching agent, and the full-arch tip of the device was held 1 cm away from the teeth to be whitened. The Remecure had a 10-minute whitening program, consisting of 15 bleaching cycles. Each cycle involved a 30-second light activation period and a 10-second resting period. The whitening program was repeated three more times; therefore, the total bleaching period was 40 minutes. The bleaching agent was applied once through the procedure. Following the final whitening program, the bleaching gel was suctioned away and the teeth were rinsed thoroughly to remove any residual material.

Group 4: The participants in this group were treated with an in-office bleaching system (Opalescence Boost 40%, Ultradent Products Inc.) containing 40% hydrogen peroxide. A continuous bead of brush-on isolation material (Opaldam, Ultradent Products Inc.) was expressed along the gingival margin to isolate the gingival tissue and light cured with a standard curing light (Bluephase G2, Ivoclar Vivadent Inc.) for 20 seconds. The bleaching agent was prepared by mixing the activator and hydrogen peroxide syringes. A 1.0-mm thick layer of the mixture gel was expressed onto the labial surfaces of the maxillary incisors, canines, and premolars. The gel remained on the teeth for 20 minutes, and was periodically checked to reapply the areas that were thinned or needed replenishing. Afterwards, the gel was suctioned from the teeth using a surgical suction tip. The procedure was repeated a second time, so that the whole bleaching period was 40 minutes. Finally, the gel was removed by a surgical suction and the mouth was rinsed with abundant water. The bleaching agent was applied twice in this group.

Color evaluation

Tooth color was measured before treatment (T1), one hour after the end of the bleaching procedure (T2), and one week later (T3). The color evaluation was performed under standardized

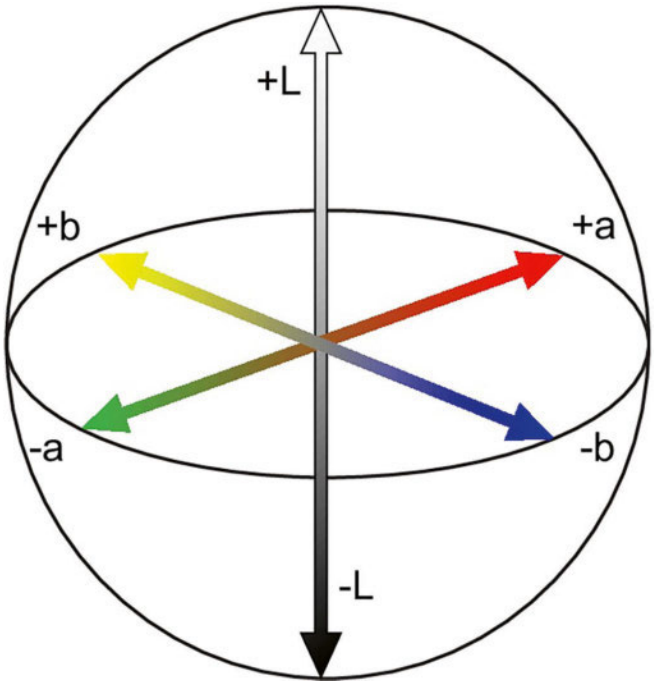

Fig. 1 The CIELAB color space system

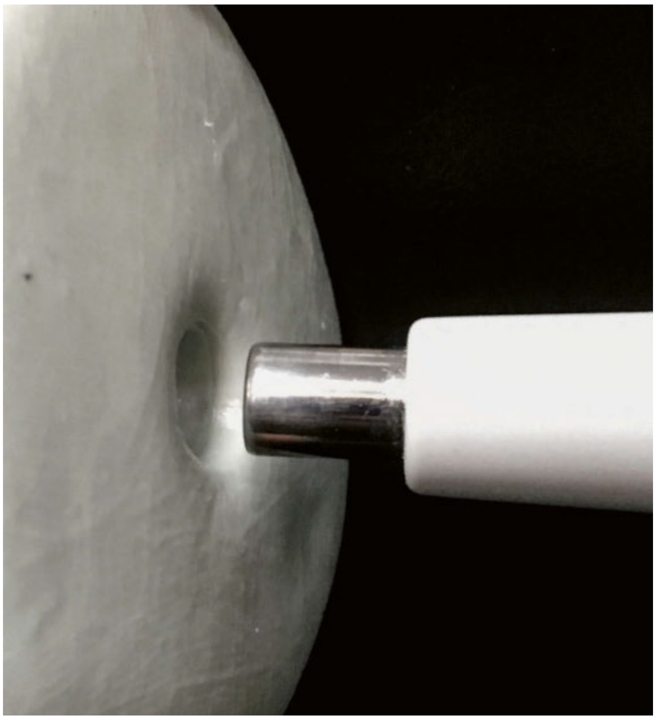

Fig. 2 The silicon guide used for accommodating the tip of the spectrophotometer during color evaluation.

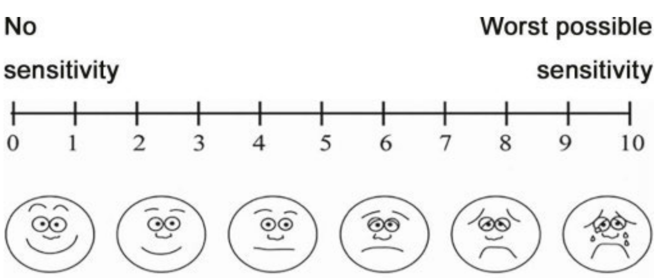

Fig. 3 The Visual Analogue Scale (VAS) used to determine the level of tooth sensitivity in this study.

conditions at the same place and lighting conditions by an experienced investigator who was blinded to the group allocation. A Vita Easyshade spectrophotometer (Vita Zahnfabrik, Bad Säckingen, Germany) was used for objective color evaluation in this study according to the CIELAB (Commission Internationale de l'Eclairage L*a* and b*) color space system. In this system, the "L" axis represents the degree of lightness within a tooth (the value from 0 [black] to 100 [white]), whereas the "a" and "b" degrees indicate the positions on red/green (+a = red, -a = green) and yellow/blue (+b = yellow, -b = blue) axes, respectively (Fig 1). The device calibration was performed by a white table supplied by the manufacturer before each assessment. To minimize measurement errors, the assessments were repeated three times and the mean values were considered in the statistical analysis.

The color evaluation was performed at the cervical one-third of the labial surface of the right central incisor. To standardize the evaluation, an impression of the maxillary canine to canine arch was taken with high-putty silicon (Speedex, Coltene, Altstätten, Switzerland). A window was created on the labial surface of the silicon guide corresponding to the cervical third of the right central incisor using a metal device with a well-formed border and 6 mm in diameter (Fig 2). This window allowed for accommodating the tip of the spectrophotometer for a standard color evaluation.

The color change (ΔE) between different treatment stages was calculated in each group using the following formula:

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

The color change (ΔE) values were defined as follows:

- ΔE_{T1-T2}: The color change before and one hour after the bleaching treatment
- ΔE_{T2-T3}: The color change between one hour after the bleaching treatment and one week later
- ΔE_{T1-T3}: The color change between before and one week after the bleaching treatment

Tooth sensitivity assessment

The intensity of tooth sensitivity (TS) was determined using a Visual Analogue Scale (VAS). This scale consisted of a 10-cm horizontal line, with the left side (0) showing no sensitivity and the right end (10) showing the worst possible sensitivity (Fig 3). The volunteers were asked to mark the degree of perceived sensitivity across the horizontal scale. The distance between the zero end and the vertical mark was then measured with a millimeter ruler. Tooth sensitivity was assessed over the first 24 hours and over the first week after completing the bleaching treatment. The subject who gathered the VAS questionnaires was blinded to the group allocation.

Other posttreatment complications

The patients were examined for the occurrence of gingival redness and were asked to record the presence of other symptoms like burning sensation in the throat as well as in the palate, and gastrointestinal sensitization of materials (such as heartburn and bloating) over the first day after the end of the bleaching treatment.

Patient satisfaction

Patient satisfaction was evaluated with a questionnaire completed by the patient one day after the end of the bleaching process using a Likert scale (I am very pleased [5], satisfied [4], indifferent [3], dissatisfied [2], very dissatisfied [1]).

Statistical analysis

The normal distribution of color change data was confirmed by the Kolmogorov-Smirnov test ($p > 0.05$). One-way analysis of variance (ANOVA) was run to compare the color change values (ΔE) among the study groups. When a significant difference was noted, pairwise comparisons were made with Tukey and Games-Howell tests. Due to the nonparametric distribution of tooth sensitivity data, the between-group comparison was made with the Kruskal-Wallis test and pairwise comparisons were performed with the Dunn test. The statistical calculation was performed using SPSS software (version 16.0; SPSS Inc., Chicago, Il, USA) and the significance level was determined at $p < 0.05$.

Results

All 60 participants continued until the end of the study period. The basic characteristics of the participants in different groups are presented in Table I. The study groups were comparable in age and sex at enrollment (Tab. I).

Color assessment

Table II indicates the descriptive statistics including mean and standard deviation (SD) of ΔE values between different treatment stages in the study groups. The color change between baseline and one hour after bleaching (ΔE_{T1-T2}) was greatest in the home-bleaching group (group 1), followed by the laser-assisted in-office bleaching group (group 2) and lowest in subjects who had undergone plasma-arc bleaching (group 3). One-way ANOVA indicated a significant difference in ΔE_{T1-T2} among the groups (p-value = 0.02, Tab. II). Pairwise comparisons by Tukey test revealed that ΔE_{T1-T2} was significantly greater in group 1 than group 3 ($p = 0.04$), whereas other comparisons were not statistically significant ($p > 0.05$).

The color change between one hour and one week after the bleaching procedure was lowest in laser-assisted in-office bleaching group (group 2). One-way ANOVA revealed a significant difference in ΔE_{T2-T3} among the four groups ($p < 0.001$, Tab. II). Pairwise comparisons by Games-Howell test exhibited significant differences in ΔE_{T2-T3} between group 2 and group 1 (p-value = 0.005), between group 2 and group 3 ($p < 0.001$), and between group 2 and group 4 (p-value = 0.004), whereas other comparisons were not statistically significant ($p > 0.05$).

When ΔE_{T1-T3} was compared among the groups, it was revealed that all techniques were effective for tooth whitening. The color alteration between baseline and one week after bleaching (ΔE_{T1-T3}) was 8.16 ± 4.31 in the home-bleaching group, 6.28 ± 6.11 in the laser-assisted in-office bleaching group, 5.06 ± 2.25 in the plasma-arc in-office bleaching group, and 5.96 ± 3.58 in the conventional in-office bleaching group. One-way ANOVA exhibited no significant difference in color alteration between baseline and end of the experiment (ΔE_{T1-T3}) among the study groups ($p = 0.25$, Tab. II).

Tooth Sensitivity evaluation

Table III indicates the descriptive statistics regarding tooth sensitivity scores perceived over the first day after the end of the bleaching procedure for the participants in the study groups. The Kruskal-Wallis test indicated a significant difference in VAS scores among the groups (p-value = 0.034, Tab. III). Pairwise comparisons revealed that tooth sensitivity was significantly greater in group 4 than in group 2 ($p = 0.039$), whereas other comparisons were not statistically significant ($p > 0.05$).

At one week after bleaching, the mean intensity of tooth sensitivity was zero in all groups and no significant difference was observed among the different bleaching techniques ($p > 0.05$).

No medication was required in the participants of this study to relieve the bleaching-induced sensitivity.

Other posttreatment complications

Posttreatment redness of the gums was not observed in any patient, and none of the patients reported any posttreatment complication.

Tab. I The sex (number and %) and age (mean ± standard deviation) of the participants in the study groups

		Home bleaching	Laser-assisted in-office bleaching	Plasma-arc in-office bleaching	Conventional in-office bleaching	Statistical significance
Sex	**Female**	8 (53.3%)	8 (53.3%)	7 (46.7%)	8 (53.3%)	
	Male	7 (46.7%)	7 (46.7%)	8 (53.3%)	7 (46.7%)	0.97
Age		21.53 ± 4.45	22.66 ± 4.71	20.66 ± 5.10	21.86 ± 4.59	0.71

Tab. II The mean ± standard deviation (SD) of ΔE values between different treatments stages in the study groups

Group	Definition	ΔE_{T1-T2}**	ΔE_{T2-T3}**	ΔE_{T1-T3}
1	**Home bleaching**	9.21 ± 4.07^{A}	5.20 ± 3.57^{A}	8.16 ± 4.31
2	**Laser-assisted in-office bleaching**	$7.52 \pm 6.45^{A,B}$	1.36 ± 0.78^{B}	6.28 ± 6.11
3	**Plasma-arc in-office bleaching**	$5.02 \pm 2.62^{A,B}$	4.27 ± 1.83^{A}	5.06 ± 2.25
4	**Conventional in-office bleaching**	5.20 ± 3.4^{B}	6.05 ± 4.24^{A}	5.96 ± 3.58
Statistical significance*		p-value = 0.02* F = 3.22	p-value < 0.001* F = 7.20	p-value = 0.25 F = 1.37

* Indicates statistically significant difference at $p < 0.05$.
** The groups indicated by different letters showed statistical difference at $p < 0.05$, whereas those with the same letters are statistically comparable.

Tab. III The descriptive data including mean, median ± interquartile range (IQR), minimum (Min), maximum (Max) and mean rank of tooth sensitivity within the first day after the end of the bleaching procedures

Group	Definition	Mean	Median ± IQR	Min	Max	Mean Rank
1	Home bleaching	1	0.0 ± 3.00	0	7	33.93
2	Laser-assisted in-office bleaching	0	0.0 ± 0.0	0	0	22.5
3	Plasma-arc in-office bleaching	0.4	0.0 ± 1.00	0	2	29.57
4	Conventional in-office bleaching	1.5	0.0 ± 2.00	0	4	36
Statistical significance		P-value = 0.034*				

* Indicates statistically significant difference at $p < 0.05$.

Patient satisfaction

The percentage of patients who were very satisfied from treatment was highest in subjects who had undergone laser-assisted in-office bleaching (66.7%) followed by those exposed to home bleaching (53.3%), plasma-arc bleaching (46.7%) and conventional in-office bleaching (33.3%). The statistical analysis revealed no significant difference in satisfaction scores between the four groups ($p = 0.53$).

Discussion

The present study evaluated the efficacy and complications of a home-applied and three in-office bleaching systems for lightening discolored teeth in patients who had undergone a fixed orthodontic therapy. The spectrophotometry was employed in this study to evaluate tooth color changes after whitening procedures. This is a standard and objective technique for color evaluation and is associated with some advantages such as reproducibility and minimizing personal evaluation bias (Eslami et al. 2015; Ahrari et al. 2017). ΔE values were used as the indicator of the bleaching effectiveness to compare different strategies of tooth whitening.

When $\Delta E_{T1\text{-}T2}$ (color change before and one hour after bleaching) was considered, it was revealed that home bleaching was the most effective strategy in lightening tooth color, followed by laser-assisted in-office bleaching. The statistical difference in $\Delta E_{T1\text{-}T2}$ was only observed between subjects having received home bleaching and those who had undergone plasma-arc bleaching treatments.

Decomposition of hydrogen peroxide into free radicals such as oxygen and per-hydroxyl is the main mechanism of bleaching. It has been demonstrated that the overall bleaching efficacy is determined mainly by two factors which include the concentration of the active agent and the duration of exposure (Gurgan et al. 2010). It seems that one of the reasons for better efficacy of home bleaching in this study was the long duration of contact between the bleaching substance and tooth surface (2–4 hours per day for two weeks). On the other hand, the concentration of the bleaching agent in laser-assisted bleaching was higher than that of the other approaches (46% HP in laser-assisted bleaching versus 20% carbamide peroxide [= 6% hydrogen peroxide] in home bleaching, 35% HP in plasma-arc bleaching, and 40% HP in conventional in-office bleaching). The higher concentration of the active agent leads to the acceleration of the oxidation process and thus faster color alteration.

After one week, all groups showed some alteration in tooth color. The color change between one hour and one week after the whitening procedure ($\Delta E_{T2\text{-}T3}$) was significantly lower in the laser-assisted bleaching group than in the other groups. Since this criterion is generally regarded as the indicator of bleaching regression, it can be assumed that laser-assisted in-office bleaching exhibited the lowest relapse rate over one week after the whitening process.

In this study, all techniques were effective in tooth lightening. The color alteration between before and one week after bleaching ($\Delta E_{T1\text{-}T3}$) was highest in the home-bleaching group (8.16 units), followed by the laser-assisted in-office bleaching (6.28 units), the conventional in-office bleaching (5.96 unites) and the plasma-arc bleaching (5.06 units) groups. However, the difference in overall color alteration between the groups failed to achieve statistical significance, possibly due to the small sample size and the great variation in color parameters in the study groups.

The outcomes of this study confirm the results of Patel et al. (Patel et al. 2008) who showed that nightguard-based vital bleaching with 10% carbamide peroxide is an effective tooth whitening technique and there is no evidence to support laser application for obtaining better efficacy. In a clinical split-mouth design study, it was indicated that tooth whitening occurred in both the light-activated group and the control group, and the additional activation of the bleaching agent with Nd:YAG laser had no significant effect on the whitening efficacy (Strobl et al. 2010). De Almeida et al. (De Almeida et al. 2012) reported that the use of light sources to bleach teeth is unnecessary. Several studies reported that the in-office bleaching outcome was not improved by using the plasma arc light (Gomes et al. 2009; Gurgan et al. 2010). Basting et al. (Basting et al. 2012) compared the effectiveness of 10% and 20% carbamide peroxide (CP) in home use and 35% and 38% hydrogen peroxide (HP) in in-office bleaching agents, and found that all treatments were effective in tooth whitening.

In contrast to the outcomes of this study, Fekrazad et al. (Fekrazad et al. 2017) concluded that laser bleaching using LaserSmile gel and a diode laser lead to significantly superior whitening results than the conventional in-office technique with Opalescence Xtra Boost®. Calatayud et al. (Calatayud et al. 2010) concluded that using a diode light with a 35% hydrogen peroxide gel slightly improved the clinical efficacy of a dental bleaching system. A previous in vitro study on demineralized enamel revealed that in-office bleaching with an 810 nm diode laser lead to faster and better efficacy than home bleaching (Ahrari et al. 2015). Tavares et al. (Tavares et al. 2003) compared 15% hydrogen peroxide gel illuminated with a gas plasma light source, 15% hydrogen peroxide alone, and placebo gel plus light, all treatments lasting one hour. The change in vita shade from baseline for peroxide plus light, peroxide alone, and placebo plus light, were 8.35, 5.88 and 4.93, respectively, implying that peroxide gel illuminated with a gas plasma light source was significantly better than the other bleaching techniques. The controversies observed between the results of this study and those of previous authors may be related to the different bleaching substances, and various laser wavelengths or parameters.

In the current study, dental sensitivity over the first 24 hours after tooth whitening was lowest in the laser-assisted in-office bleaching group and highest in patients having received the conventional in-office bleaching procedure. The difference in tooth sensitivity between laser-assisted in-office bleaching and conventional in-office bleaching groups was statistically significant. The findings of this study indicate that laser application during the bleaching process is capable to minimize postbleaching hypersensitivity, which is a chief complaint of most patients after the whitening process. Tooth sensitivity over one week after bleaching reached a negligible level and was not a problem in any patient. There are some concerns that the use of any light source with in-office bleaching procedures can lead to heat generation and absorption in dental tissues and thus cause pulp damage (Roberts & Swift 2011). However, other studies proposed that the presence of bleaching gel itself reduces the amount of heat that the pulp tissue might receive and concluded that light-assisted bleaching does not generate sufficient heat to cause serious pulpal inflammation (Kabbach et al. 2008; Carrasco et al. 2008; Coutinho et al. 2009).

The outcomes of this study are consistent with the results of Gurgan et al. (Gurgan et al. 2010) who found that bleaching with a diode laser was associated with less tooth and gingival sensitivity, and so this method might be preferred among the in-office systems. In contrast, some studies found that laser-activated bleaching had no effect on or even increased postoperative dental sensitivity (Farhat et al. 2014; Giudice et al. 2016).

In this study, redness of the gums was not observed in any subject and none of the participants reported posttreatment complications including burning of the throat, burning sensation in the palate, and gastrointestinal sensitization to the bleaching substance. This finding confirms the outcomes of previous authors who concluded that bleaching is a relatively safe procedure (Haywood 1992; Suleiman 2008).

When comparing all treatment methods together, it can be concluded that home bleaching is an effective strategy for treatment of discolored teeth. However, it may not be applicable in patients who are reluctant to wear the trays or look for a quick whitening result. Among the in-office approaches, laser-assisted bleaching provided effective tooth whitening with less relapse over one week after treatment, although its overall bleaching efficacy was not significantly different from the other techniques. In addition, the patients treated with laser-assisted bleaching showed minimal tooth sensitivity over the first day after the procedure. Laser-assisted bleaching also took about half of the time of other in-office approaches. This minimized exposure to the bleaching substance could reduce the tisk of soft tissue burns during handling and provide greater patient comfort by providing a quick whitening result. The advantages of laser bleaching should be weighed against the disadvantages of the need for a special apparatus and the relatively high price of the laser device and the bleaching substance. Plasma arc bleaching did not show any advantage over other in-office approaches in terms of color alteration and tooth sensitivity and so this method could not be recommended as a preferred approach for whitening tooth color after orthodontic treatment. The conventional in-office bleaching without any light source was a relatively effective method in tooth whitening with the advantage of not requiring a special light source, but the degree of tooth sensitivity was highest in this group over 24 hours after treatment.

Further long-term studies with a larger sample size are warranted to find the ideal bleaching method with greater efficacy and fewer side effects using different devices and laser parameters.

Conclusion

Under the conditions used in this study

1. All methods were effective in brightening tooth color after orthodontic treatment. Home bleaching and laser-assisted in-office bleaching produced the greater color alteration followed by conventional in-office bleaching and plasma-arc bleaching methods.
2. Over the first day after treatment, tooth sensitivity was highest in subjects having received conventional in-office bleaching and lowest in those who had undergone laser-assisted bleaching procedure with a significant difference between them.
3. Among the in-office approaches, laser-assisted bleaching could be recommended for brightening discolored teeth after orthodontic treatment, as it reduced postoperative hypersensitivity and was an effective whitening strategy with shorter treatment duration and significantly lower color regression over one week after treatment.

Zusammenfassung

Einleitung

Das Ziel dieser Studie war es, sowohl die Wirksamkeit als auch die Komplikationen von verschiedenen Bleichmethoden in Patienten nach kieferorthopädischer Behandlung zu vergleichen.

Material und Methoden

Diese randomisierte klinische Studie wurde an 60 zwischen 14 und 30 Jahre alten Freiwilligen (davon 31 weiblich und 29 männlich), die eine kieferorthopädische Behandlung mit fixen Apparaturen vor mehr als drei Monaten abgeschlossen hatten und sich über verfärbte obere Frontzähne beklagten, durchgeführt. Die Teilnehmenden wurden nach dem Zufallsprinzip in vier Gruppen eingeteilt. Gruppe 1 wurde mit «home bleaching» behandelt, Gruppen 2 bis 4 mittels einer direkt am Behandlungsstuhl durchgeführten Bleichmethode («in-office bleaching»), unterstützt durch einen Diodenlaser, eine Plasmalampe oder ohne Lichtquelle. Die Zahnfarbe wurde initial, eine Stunde nach Ende des Bleichvorgangs und eine Woche später gemessen. Die Farbveränderungen wurden zwischen den Gruppen verglichen. Zusätzlich wurden das Auftreten und das Ausmass von Zahnhalsüberempfindlichkeiten notiert.

Resultate

Die Farbveränderung von initial zu einer Woche nach dem Bleichvorgang war tendenziell am stärksten in der Home-Bleaching- und in der laserunterstützten Gruppe und am schwächsten in der Gruppe mit der Plasmalampe. Die gemessenen Unterschiede waren aber nicht statistisch signifikant ($p > 0,05$).

Die Zahnhalsüberempfindlichkeit über 24 Stunden war am schwächsten in der Laser-Gruppe und am stärksten nach der direkten Bleichung ohne Lichtquelle (p < 0,05).

Diskussion

Alle untersuchten Methoden reduzierten Zahnverfärbungen nach kieferorthopädischer Behandlung. Das «home bleaching» zeigte besonders gute Resultate. Unter den direkt am Behandlungsstuhl durchgeführten Methoden war die Diodenlaser-unterstützte Methode die beste, da sie gute Bleichwirkung zeigte und wenig Zahnhalsüberempfindlichkeiten verursachte.

Résumé

Introduction

Le but de cette étude était de comparer l'efficacité et les complications de différentes méthodes de blanchiment dentaire chez des patients après un traitement orthodontique.

Matériel et méthodes

Cette étude clinique randomisée a été menée sur 60 volontaires âgés de 14 à 30 ans (31 femmes et 29 hommes) qui avaient terminé leur traitement orthodontique par des appareils fixes il y a plus de trois mois et se sont plaints de dyscolorations des dents antéro-supérieures. Les participants ont été randomisés en quatre groupes. Les patients du groupe 1 ont été traités par blanchiment à domicile, et les patients des groupes 2 à 4, par une méthode de blanchiment au fauteuil *(« in-office bleaching »)* avec appoint d'une diode laser, d'une lampe à plasma ou sans source lumineuse. La couleur des dents a été évaluée initialement, une heure après la fin du processus de blanchiment et une semaine plus tard. Les différents groupes ont été comparés en ce qui concerne les changements de couleur observés. De plus, l'occurrence et l'étendue des cas d'hypersensibilité du collet dentaire ont été notées.

Résultats

Le changement entre la couleur initiale et la couleur une semaine après le processus de blanchiment a montré une tendance à être le plus marqué dans le groupe de blanchiment à domicile et le groupe assisté par laser, et le plus faible dans le groupe avec les lampes à plasma. Cependant, les différences mesurées n'étaient pas statistiquement significatives (p > 0,05). L'hypersensibilité du collet dentaire sur une période de 24 heures a été la plus faible dans le groupe laser et la plus forte après le blanchiment direct sans source lumineuse (p < 0,05).

Discussion

Toutes les méthodes examinées ont permis d'atténuer les dyscolorations dentaires après un traitement orthodontique. Le blanchiment à domicile a montré des résultats particulièrement bons. Parmi les procédés effectués directement au cabinet médico-dentaire, la méthode assistée par diode laser à été la meilleure, car elle a permis d'obtenir de bons effets de blanchiment en provoquant peu d'hypersensibilités cervicales.

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