Shade evaluation for clinical color change of discolored teeth treated by bleaching vs laminate veneers (Randomized Clinical Trial)

Hazim Abdalla Sharif
PhD fixed prosthodontics department, faculty of dentistry, Cairo University, Egypt
Corresponding Author email: hazim.sharif@dentistry.cu.edu.eg

Iman Salah El Din Hamdy
Professor of fixed prosthodontics department, faculty of dentistry, Cairo University, Egypt
Email: e.salah7@gmail.com

Omama Salah El Dein El Mahallaw
Professor of fixed prosthodontics department, faculty of dentistry, Cairo University, Egypt
Email: oelmahallawi@dentistry.cu.edu.eg

Abstract---Aim: Clinical evaluation for color change of discolored teeth treated by bleaching vs laminate veneers. Methodology: Patient with discolored anterior teeth were divided into two groups. Group1: treated by laminate veneers restoration (monolithic IPS e.max), while Group 2: treated by bleaching (hydrogen peroxide) in the same patient. Anterior teeth of one arch were prepared with butt joint design to receive laminate veneer restorations which constructed from IPS e.max and cemented by self-adhesive resin cement, while anterior teeth of the other arch was treated by 40% hydrogen peroxide bleaching agent material. Using spectrophotometer (Easy Shade) and digital photography with Photoshop software, the color change (ΔE) and color stability assessment were carried out and repeated four times (after one week, four weeks, two months and three months) respectively. The results were calculated and analyzed using Kolmogorov-Smirnov and Shapiro-Wilk tests. Results: Result obtained by spectrophotometer revealed that the first color change shown was after three months follow up, where, higher statistically significant difference in (ΔE) were displayed from data obtained from bleaching teeth. While first color change (ΔE) with higher statistically significant difference displayed from data obtained by digital photography was after 4 weeks follow up of bleaching teeth also. Conclusions: Both treatment modalities in this study, IPS e.max press laminate veneers...
restoration made in anterior teeth of one arch, and bleaching of the anterior teeth of the other arch, revealed acceptable clinical performance in terms of color stability.

**Keywords**—Monolithic IPS e-max; bleaching (hydrogen peroxide); color match; spectrophotometer (Easy Shade); digital photography; Randomized controlled trial.

**Introduction**

Dental esthetics, including tooth color, is of major importance for most of the people and any discoloration or staining can affect their quality of life negatively. Losing natural whiteness of permanent teeth that become darker over time is often due to the changes in enamel and dentin. Tooth discoloration is classified based on its etiology into intrinsic and extrinsic factors. Intrinsic factors can be congenital or acquired, and cause more complicated discoloration, for example, tetracycline stains, stains in dentinogenesis imperfecta, fluorosis, jaundice and dental trauma. While extrinsic discoloration is a consequence of accumulated stains on the tooth surface in addition to contact of teeth to outside influences, such as smoking, tea, pigments from food, bacterial byproducts, soda/carbonated drinks and cationic substances such as chlorhexidine.

There are different treatment modalities for discolored teeth such as bleaching, enamel micro-abrasion, porcelain veneers and crowns. These may be used individually or in combination depending on the etiology and severity of the staining. Superficial treatments like bleaching and microabrasion have been used in combination but controversy exists whether or not high concentration hydrogen peroxide causes morphological alterations in enamel.

Teeth bleaching become one of the best most popular esthetic dental treatment options for improving teeth color, since it is an effective, non-invasive procedure. As early as 1884 hydrogen peroxide \( \text{H}_2\text{O}_2 \) has been used to treat discolored teeth. Throughout the 1960s and 1970s, techniques were introduced using direct or indirect heat in attempts to accelerate the oxidation process.

Upgrading in bleaching products in the mid-1990s, such as light-and chemical application, and delivery systems such as light cured barrier materials, increased usage of in-office bleaching for multiple vital teeth. Although bleaching considered as non-invasive treatment approach, it is commonly associated with post-treatment tooth sensitivity, being significantly dependent on the pH of the agent. A significant relapse rate in tooth shade associated with bleaching procedure has been reported which necessities re-treatment.

Deeper stains resulting from enamel hypoplasia or intrinsic causes cannot be treated with conservative methods like micro-abrasion and bleaching need a restorative approach such as porcelain veneers and/or crowns. Porcelain laminate veneers have long been used as a minimally invasive restorative approach for improving tooth form and shade. Reports indicate a high success
rate and longevity of such restorations. Materials most commonly used are feldspathic porcelain and lithium disilicate. Several factors have been found to affect the exact color of porcelain restorations, such as tooth preparation and restoration of harmony, glazing and polishing, aging, and food consumption are external factors affecting coloration in addition to microleakage.

Although both porcelain laminate veneer and tooth bleaching has been studied in detail as methods of managing tooth discoloration, yet insufficient clinical attention has been paid to investigate the effectiveness of in-office bleaching and its color change stability compared to irreversible, more aggressive porcelain laminate veneer approach in cases of mild tooth discoloration. Consequently, this study aimed at evaluation of shade for clinical color change of discolored teeth treated by bleaching versus laminate veneers.

**Material And Methods**

This study was undertaken in the Prosthodontics Department of Cairo University, and participants were recruited from the out-patient clinic. Ethical approval was obtained from Ethics Committee of Scientific Research - Faculty of Dentistry – Cairo University. The present study was randomized clinical trial, single blinded study. Patients included in this clinical trial men and women between 18 and 40 years of age, had better general and oral health, the participants needed to have six sound maxillary and mandibular anterior teeth without caries lesions or restorations, the maxillary anterior teeth was shade A3 or darker as record by Spectrophotometer measurement. Participants were excluded from the study, if they presented with anterior restorations, had bruxism habits, pregnant/lactating, non-vital tooth discoloration.

This clinical trial was registered with the Clinical Trials.gov. The sample size was 22 tooth will be adequate to detect a mean difference between study groups of 2 points (SD=1.86) with a power of 90% and significance level of 5%. To compensate for 30% non-response rate, 14 teeth will be added; therefore the sample is increased to a total size of 36 teeth; with equal allocation to both treatment groups.

**Clinical procedures:**

The 36 teeth were divided into 6 blocks; these 6 blocks were divided into 2 groups (3 blocks per each): Group (1) control group: discolored teeth treated with monolithic laminate veneer(IPS e.max Press, Ivoclar Vivadent, Germany) with shade evaluation using spectrophotometer and digital photography with Photoshop software. Group (2) intervention group: discolored teeth treated with in-office bleaching agent (Opalescence Boost, ULTRADENT, south Jordan, UT, USA) with shade evaluation using spectrophotometer and digital photography with Photoshop software.

Tooth preparation for laminate veneer with putty silicon was used to obtain an index intraoral for each patient using condensation silicon impression material, were prepared labial surface 0.5, cervical finish line approximately 0.3 mm, 2 mm
incisal reduction (Butt joint preparation design), and proximal margins extended to the interproximal contact point without breaking it\(^6\). Final impression was taken using vinylpolysiloxane addition silicon (3M ESPE USA), two step impression technique was performed. The laminate veneers were supplied in the form of ingots (A1 shade) to fabricate tooth prepared shape by pressing technology\(^6\).

After scaling and polishing, the bleaching procedure was conducted according to the manufacturer’s instructions of Opalescence** Boost 40% HP. Retractor was set in place, the teeth were dried by air stream and the gingival soft tissues were isolated by protective Opaldam gel, which were illuminated by the polymerization unit Blue phase. Labial surfaces of the anterior teeth were then covered with whitening gel in about 1–2 mm thick layer using the original manufacturer brush\(^7\).

**Assessment of color change:**

After both treatments, shade re-evaluation was performed by both color selection methods;

Spectrophotometer and digital photograph as mentioned before. The shade evaluation was measured at before treatment (baseline for evaluation), after (immediately), one week, four weeks, two month and three months after the end of the procedure. At each tested time point, the spectrophotometer shade evaluation was done first and then the digital photograph. For each time point, the shade change for each tooth was compared with the baseline. Overall color change was calculated using the following equation: \(\Delta E = \sqrt{(L_1 - L_0)^2 + (a_1 - a_0)^2 + (b_1 - b_0)^2} \). \(L_0\) denotes the values of \(L^*\) recorded at the baseline (i.e. before bleaching treatment) and \(L_1\) the values recorded after the bleaching. The same coding applies to \(a^*\) and \(b^*\) values. The central region of the labial surface of each tooth was used for color measurement\(^8\).

**Data analysis:**

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). All data showed non-normal (non-parametric) distribution. Descriptive data included mean, standard deviation (SD), median, range and 95% Confidence Interval for the mean (95% CI) values. Wilcoxon signed-rank test was used to compare between the two groups. It was also used to compare between color change (\(\Delta E\)) as measured by spectrophotometric analysis and digital photo. Friedman’s test was used to compare between follow up times within each group. Dunn’s test was used for pair-wise comparisons when Friedman’s test is significant.

**Results:**

**A. Spectrophotometric analysis:**

1. Effect of follow up time intervals on the color change (\(\Delta E\)) with Spectrophotometric analysis:
As regard of follow up times on color change $\Delta E$ within each treatment modality, are presented in Table (1) and Figure (1). Spectrophotometric analysis of color change $\Delta E$ for laminate veneer showed no statistically significant differences through observation periods from after treatment, 1 week up to 4 weeks with Med $\Delta E$ reports 12.86, 12.65 and 12.11 respectively. The first statistically significant $\Delta E$ change occurs after 2 months (Med $\Delta E$ 9.94), and for vital tooth bleaching showed no statistically significant differences through observation periods from after treatment, up to 1 week with Med $\Delta E$ reports 12.63 and 11.09 respectively. The first statistically significant $\Delta E$ change occurs after 4 weeks (Med $\Delta E$ 9.01).

**Table (1). The median, range values and results of Friedman’s test for comparison between $\Delta E$ values using spectrophotometer analysis at different follow up times within each group.**

<table>
<thead>
<tr>
<th>Time</th>
<th>Laminate veneer (n = 12)</th>
<th>Bleaching (n = 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>Minimum</td>
</tr>
<tr>
<td>After treatment</td>
<td>12.86 $^A$</td>
<td>7.15</td>
</tr>
<tr>
<td>1 week</td>
<td>12.65 $^A$</td>
<td>6.71</td>
</tr>
<tr>
<td>4 weeks</td>
<td>12.11 $^A$</td>
<td>5.22</td>
</tr>
<tr>
<td>2 months</td>
<td>9.94 $^B$</td>
<td>5.35</td>
</tr>
<tr>
<td>3 months</td>
<td>9.17 $^B$</td>
<td>3.78</td>
</tr>
<tr>
<td>$P$-value</td>
<td>&lt;0.001*</td>
<td></td>
</tr>
<tr>
<td>Effect size($\omega$)</td>
<td>0.843</td>
<td></td>
</tr>
</tbody>
</table>

*: Significant at $P \leq 0.05$, Different superscripts in the same column indicate statistically difference
Figure (1): Box plot representing median and range values for ΔE with the two treatments using spectrophotometer analysis (Star represents outlier).

2. Effect of treatment modalities on the color change (ΔE) Spectrophotometric analysis:

As regard to the effect of treatment modality on color change ΔE, are presented in Table (2). Spectrophotometric analysis of color change ΔE showed that both laminate veneer and vital tooth bleaching results in comparable color change results up to 2 months. However, at this point, first significant difference in color change results between two treatments appears after 3 months observation period where laminate veneer showed statistically significantly higher median ΔE than bleaching (P-value = 0.001, Effect size = 1.873).

Table (2). The median, range values and results of Wilcoxon signed-rank test for comparison between ΔE values with the two treatments using spectrophotometer analysis.

<table>
<thead>
<tr>
<th>Time</th>
<th>Laminate veneer (n = 12)</th>
<th>Bleaching (n = 12)</th>
<th>P-value</th>
<th>Effect size (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Med</td>
<td>Min</td>
<td>Max</td>
<td>Med</td>
</tr>
<tr>
<td>After treatment</td>
<td>12.86</td>
<td>7.15</td>
<td>23.31</td>
<td>12.63</td>
</tr>
<tr>
<td>1 week</td>
<td>12.65</td>
<td>6.71</td>
<td>23.17</td>
<td>11.09</td>
</tr>
<tr>
<td>4 weeks</td>
<td>12.11</td>
<td>5.22</td>
<td>22.33</td>
<td>9.01</td>
</tr>
</tbody>
</table>
B. Digital Photoshop software analysis:

1. Effect of follow up time intervals on the color change (ΔE) with digital Photoshop software:

Results of the effect of follow up time on the shade change, measured by digital Photoshop software, of each treatment protocol are presented in Table (3) and Figure (2), for laminate veneer group show no statistically significant differences through observation periods from after treatment and after1 week with Med ΔE reports 13.66 and12.63 respectively. The median ΔE after 4 weeks Med 11.67 showed statistically significantly lower value than after treatment but no statistically significant difference from 1 week and 2 months values Med ΔE reports 12.63 and 10.89 . The median ΔE after 3 months Med ΔE 9.88 showed the lowest value with no statistically significant difference from 2 months value but a statistically significantly lower value than all other follow up times. For intra-oral bleaching group show no statistically significant differences through observation periods from after treatment, 1 week, 4 weeks and 2 months with Med ΔE reports 12.02, 9.94, 7.35 and 7.25 respectively. Color change showed further statistically significant color change after 3 months (Med ΔE 3).

Table (3). The median, range values and results of Friedman’s test for comparison between ΔE values using digital Photoshop software analysis at different follow up times within each group

<table>
<thead>
<tr>
<th>Time</th>
<th>Laminate veneer (n = 12)</th>
<th>Bleaching (n = 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>Minimum</td>
</tr>
<tr>
<td>After treatment</td>
<td>13.66</td>
<td>11.4</td>
</tr>
<tr>
<td>1 week</td>
<td>12.63</td>
<td>AB</td>
</tr>
<tr>
<td>4 weeks</td>
<td>11.67</td>
<td>B</td>
</tr>
<tr>
<td>2 months</td>
<td>10.89</td>
<td>BC</td>
</tr>
<tr>
<td>3 months</td>
<td>9.88</td>
<td>C</td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.001*</td>
<td></td>
</tr>
<tr>
<td>Effect size (w)</td>
<td>0.91</td>
<td></td>
</tr>
</tbody>
</table>

*: Significant at P ≤ 0.05, Different superscripts in the same column indicate statistically difference
Figure (2). Box plot representing median and range values for ΔE with the two treatments using digital Photoshop software analysis (Stars and circle represent outliers).

2. Effect of treatment modalities on the color change (ΔE) with digital Photoshop software:

Results of the comparison between the two groups are presented in Table (4), both laminate veneer and vital tooth bleaching show a statistically significant difference between median color change (ΔE) results immediately and throughout the readings after 1 week, 4 weeks and up to 2 and 3 months. Laminate veneer showed statistically significantly higher median ΔE than bleaching (P-value = 0.019, Effect size = 1.086), (P-value = 0.015, Effect size = 1.139), (P-value = 0.001, Effect size = 1.757), (P-value = 0.006, Effect size = 1.372) and (P-value < 0.001, Effect size = 3.207), respectively.

Table (4). The median, range values and results of Wilcoxon signed-rank test for comparison between ΔE values with the two treatments using digital Photoshop software analysis

<table>
<thead>
<tr>
<th>Time</th>
<th>Laminate veneer (n = 12)</th>
<th>Bleaching (n = 12)</th>
<th>P-value</th>
<th>Effect size (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Med</td>
<td>Min</td>
<td>Max</td>
<td>Med</td>
</tr>
<tr>
<td>After</td>
<td>13.66</td>
<td>11.4</td>
<td>16.55</td>
<td>12.02</td>
</tr>
</tbody>
</table>
Discussion:

The present results support acceptance of the null hypothesis of this research. As the results of follow up on color change ΔE within laminate veneer treatment group measured by Spectrophotometer analysis, showed no statistically significant differences through observation periods from after treatment and 1 week up to 4 weeks. The first statistically significant ΔE change occurs after 2 months which showed no further significant difference after 3 months observation period, which was in agreement with Ebeid et al. (2014) and Marchionatti et al. (2017) who conducted a study to evaluate the clinical outcome of color stability of lithium disilicate laminate veneers. They found high median ΔE values and no statistically significant differences through observation periods of 2 months.

While the results were not in agreement with Almeida et al. (2015) who conducted a study to evaluate the clinical outcome of color change coordinates between lithium-disilicate pressed glass and feldspathic ceramic, the results for the color difference (ΔE) showed that these changes were not significant different up to 12 months, this may be due to using opaque resin cement that affect color change in lithium-disilicate pressed glass ceramic.

The results of follow up in this study on color change ΔE within vital tooth bleaching group measured by Spectrophotometer analysis, showed no statistically significant differences through observation periods after treatment, up to 4 week. The first statistically significant ΔE change occurs after 4 weeks which showed significant difference till 3 months observation, which is in accordance with Bernardon et al (2015) and C Kose et al (2016) who conducted a study to evaluate the clinical outcome of color stability of vital tooth bleaching using spectrophotometer device. However, these findings contradict those of Dawson et al (2011) who reported that one session of in-office bleaching (38% hydrogen peroxide) produce little significant change in color. However, Dawson et al study showed a change in color after one session, possibly requiring additional bleaching sessions for this change to become more visually noticeable. This may be due to the 8 days gap between in-office bleaching sessions, as suggested by the manufacturer and advocated by some authors.

The results of color change ΔE within laminate veneer treatment group measured by digital Photoshop software were in agreement with Dhruv et al (2016) which revealed that the newly emerging digital photography technique was as accurate as the most commonly used method for shade selection and SLR camera with Adobe Photoshop used as an alternative to spectrophotometer in obtaining ‘L"
and ‘b’ values accurately. While the results were not in agreement with Pandey et al (2016)\textsuperscript{15} which may be due to change in Δa value when was measured by spectrophotometer and digital photograph in laminate veneer.

The results of follow up time on the color change ΔE within vital tooth bleaching group measured by digital Photoshop software showed no statistically significant differences through observation periods from after treatment, 1 week, 4 weeks and 2 months. While showed further statistically significant color change after 3 months, this were in agreement with Roberto et al. (2011)\textsuperscript{16}, and were not in agreement with Gurgan et al (2010)\textsuperscript{17} where the first statistically significant difference between median ΔE was after 6 months this may be due to using light activation in office bleaching in addition to home bleaching which lead to improve color stability.

The Tukey test showed a significant effect on the tooth color through the first month after the bleaching procedure. After this time point, the color remained stable up to three months after the bleaching Bernardon et al (2015)\textsuperscript{12}.

The color rebound in this study occur over time due to the continuous deposition of secondary dentin as well as the deposition of extrinsic stains from colored foods and drinks on the enamel surface Rezende M, et al (2016)\textsuperscript{18}.

In this study color change was evaluated by spectrophotometer and digital photograph software, the results of both devices is different but still significant statistically. The obtained values of ΔE’ above the reference value of 3.2, and strong correlations were obtained between L’, b’ values obtained with both methods. While weaker correlations were obtained for a’ component, when values were analyzed. Mean value differences were not statistically significant for L’ and b’, showing no systematic program tendencies to over or under evaluate light or green/blue axis. However, systematic deviations towards higher values (to red) were observed for the a’ axis represents red/green opponent colors, the measure of redness (positive value) or greenness (negative value).

The inconsistent results and weak correlations between spectrophotometric measurements and digital images may be attributed to the electronic flashes used in measurement mode, the influence of the surrounding light, automatic white balance of the camera and flash color temperature, this was in agreement with Takatsui, et al (2012)\textsuperscript{19}, and not in agreement with Farah RI, et al (2016)\textsuperscript{20} who conducted a study to found the percentage agreement between shades taken by digital photography and the Vita Easy Shade (spectrophotometer), which could be attributed to the standardized setup used for high quality photographs as well as the conversion of L’ a’ b’ values obtained from the Adobe Photoshop software to L’ a’ b’ values of the CIEL’ a’ b’ system using the conversion formulae mentioned. Similar findings were reported by O’Brien et al (2018)\textsuperscript{21}. In their study Jarad et al (2015)\textsuperscript{22} who stated that since a high percentage agreement existed between the L’, a’, b’ values of the spectrophotometric and digital photography methods, digital photography can be used as a shade selection method in the clinical setup.

The patients recorded their perception of teeth sensitivity (TS) during the bleaching sessions using a five point rating scale (0 = none, 1 = mild, 2 =
moderate, 3 = considerable, and 4 = severe). We asked subjects to indicate whether they experienced TS during the treatment and up to 48 hours post bleaching. As 3×15 bleaching sessions were performed, the higher score value obtained in both bleaching sessions was considered for statistical purposes. The values were arranged into two categories: overall percentage of patients who reported TS at least once during treatment (absolute risk of TS) and overall TS intensity in different periods (during treatment up to one hour; from one to 24 hours, and from 24 to 48 hours post bleaching). The patients were also instructed to record the painful tooth.

Using a higher hydrogen peroxide concentration may allow for the arrival of larger amounts of reactive species to the pulp, leading to a more intense inflammatory response and greater tooth sensitivity (TS). High hydrogen peroxide concentrations increase the enamel permeability and release more free radicals that reach the pulp. A previous in vitro study demonstrated that the cytotoxicity of hydrogen peroxide bleaching gels was dose dependent, with the highest concentration causing the most intense cytopathic effects to the cultured cells. This were in agreement with Kose et al 2016⁴, and were not in agreement with Bernardon et al. 2015¹².

Conclusions:

Based on the results and within the limitations of this clinical study, the following conclusions could be drawn:

1. Research design revealed successful clinical performance in terms of color stability up to 3-month clinical observation period, where laminate veneers restorations were constructed from IPS e.max press in one arch and bleaching were done in the other arch of the same patient.

2. Spectrophotometer, as an objective method, showed ability to capture the various tooth surface and recorded good results in cases of bleaching and laminate veneers.

3. The color outcome measurement of digital photograph software is comparative to that of spectrophotometer.

Recommendations:

Further researches may be conducted using different concentrations and techniques of bleaching agents as well as using different esthetic materials.

References

3. Aka B, Celik EU. Evaluation of the efficacy and color stability of two different at-home bleaching systems on teeth of different shades: a randomized


