Effects of Pre-Operative Air-Powder Polishing and Rubber-Cup Prophylaxis on Tooth Bleaching Outcomes: Randomized Controlled Split-Mouth Clinical Study

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**Abstract**

**Background:** The aim of the study was to compare the effects of pre-operative air-powder polishing and rubber-cup prophylaxis on tooth bleaching outcomes.

**Methods:** 23 subjects suffering from discoloration were enrolled in a randomized controlled split mouth experimental study. Before bleaching, air powder polishing and rubber-cup polishing techniques were applied on either side of the mouth and the tooth bleaching effects assessed immediately after and 7 days.

**Results:** No statistically significant difference was found in DL, Da, Db, DE and DSGU values between air-powder polishing and rubber-cup groups at immediate and 1 week.

The difference between immediate and 1 week measurements is statistically significant in both air-powder polishing and rubber-cup groups, except DL for rubber-cup group, and Da, Db for air-powder polishing group.

**Conclusions:** Within the limitations of the study, it can be concluded that there was no lasting difference in tooth bleaching effects between rubber-cup and air-polishing techniques at immediately after and 1-week post treatment.

**Trial registration:** ClinicalTrials.gov ID: NCT04407910

**Background**

Dental esthetics has become an important issue in modern world. While the functional demands were the main consideration for dental treatment in the past, currently public spend considerable amounts of time and money in attempts to improve the appearance of discolored teeth. Discoloration of teeth can be classified as intrinsic and extrinsic. “Extrinsic discoloration” is associated with the outer enamel of the tooth is stained by tea, coffee, wine and smoking and “intrinsic discoloration” is a result of structural or compositional changes of the internal dentin layer of the tooth [1, 2]. Depending on the type, amount and extent of the discoloration, treatment protocols include removal of surface stain, bleaching or tooth whitening techniques and operative techniques to camouflage the underlying discoloration, such as veneers and crowns. Dental bleaching treatment is a more conservative approach compared to the other restorative treatments [3].

Vital bleaching treatment in dentistry are classified as office-bleaching and home-bleaching. Currently, office-bleaching gels are the most commonly used agents and contain high hydrogen peroxide concentrations (typically 15–40%) while home-bleaching products usually contain 3–10% of hydrogen peroxide. Office-bleaching has some advantages such as avoiding soft tissue irritation, preventing the use of excess material and producing immediate esthetic results [4, 5].

The agents used in bleaching treatment could penetrate enamel/dentin and oxidize the molecules of the substances that cause discoloration in the tissue. In the bleaching reaction, peroxides convert into peroxy radicals, which have singular and unpaired electrons with no electronic charge. These highly reactive radicals have a high affinity for double bonds. Peroxide radicals bond to and destroy the carbon-carbon double bonds of the chromophore and either convert them into single bonds or completely break down [6]. The resulting molecules are colorless and make teeth look whiter.

The superficial stains, plaque accumulation, and microorganisms formed on the outer surface of tooth enamel should be removed before starting bleaching treatment by polishing in order to make bleaching agent more effective. The most common method of polishing is rotary rubber-cup prophylaxis with various types of pastes. These polishing pastes include flour of pumice, glycerine and fluoride. Air-powder polishing devices (APDs) have emerged as a novel alternative to rubber-cup polishing. These devices use a slurry of water, abrasive powder and pressurized air to clean or polish tooth surface [7]. Sodium bicarbonate is the first air-polishing powder used with these devices. APDs require less time than traditional polishing methods and remove stains effectively [8].

The null hypothesis was that there would be no difference in the change in ΔL, Δa, Δb, ΔE and ΔSGU according to the type of prophylaxis on tooth-bleaching outcomes.
The aim of this study is to compare the effects of pre-operative air-powder polishing and rubber-cup prophylaxis on tooth bleaching outcomes.

**Methods**

This study used randomized, controlled split-mouth experimental design to compare the effects of pre-operative APD application (test side) and rubber-cup prophylaxis with paste (control side) on teeth bleaching. The flow chart of study design was given in Figure 1.

Among the patients who applied to the Cukurova University, Dental Faculty, Department of Oral Diagnosis for whitening treatment and volunteered to participate in the study and redirected to Department of Restorative Dentistry.

The inclusion criteria were:

- being at least 18 years of age
- having minimum of 20 natural teeth (including incisors, canines, and premolars in both arches)
- having good oral hygiene (Plaque index < 1, Gingival index < 1)

The exclusion criteria were:

- having restorations or active caries on the anterior teeth of either arch
- presence of tetracycline staining or fluorosis
- general hypersensitivity
- gingival recession or periodontal disease
- smokers
- pregnant or lactating women
- history of prior bleaching treatment

**Sample size calculation**

The sample size analysis for paired-sample t-test was done by G-Power package program. The sample size calculation was based on a previous study [9]. The expected mean difference of for the color change parameter between groups was 2.2 units with a standard deviation of 3.3 to 3.7 (the specified power of 80% and the Type I error rate of 5%). The calculated sample size was 21 patients while 23 patients (10% more) were included in the study to compensate possible dropouts.

**Study protocol**

**Clinical parameters**

Tooth color was measured using spectrophotometer VITA Easyshade V (Vita Zahnfabrik, Germany). The spectrophotometer was calibrated before use in each participant and the device tip was placed on middle thirds of the labial surface of teeth as suggested by the manufacturer’s manual.

The tooth color was measured before initial prophylaxis (baseline), immediately after bleaching and after one week. The digital spectrophotometer used in the current study measures the shade of teeth based on the CIE L*a*b* color space system [10]. This
system expresses color as three values: L* for the lightness from black (0) to white (100), a* from green (−) to red (+), and b* from blue (−) to yellow (+). The following values were recorded in the units of CIE L*a*b* color space.

-Data of lightness (L*) and a* and b*axis

-DE: calculated as: \[ DE = \sqrt{(DL*)^2 + (Da*)^2 + (Db*)^2} \]

While making Shade guide units (SGU) measurements, the bleached index is set according to the VITA Bleached guide 3D-MASTER at spectrophotometer for the measured shade. The measured bleached index after treatment was subtracted from the baseline value. The difference corresponded to the change of the SGU (DSGU) achieved immediately and 1 week after the bleaching treatment.

**Randomization**

The patients had bleaching treatment on the maxillary anterior area including right and left canines. The registration of the patients has been done by Department of Oral Diagnosis and randomly allocated by ZGBK. The right and left sides of the patients were randomized by toss of a coin to receive polishing with rubber cup prophylaxis or air powder polishing system before bleaching.

**Clinical procedures**

The rubber cup prophylaxis was applied with low-speed handpieces. A rubber cup was attached to the prophy-angle. The handpiece used at a steady slow pace of 2500–3000 rpm. The rubber cup contacted (Pro-Cup, Light Blue, Soft, KerrHawe S.A., Bioggio, Switzerland) each tooth surface for an average of 5 seconds together with polishing paste consisting of flour of pumice, glycerin and fluoride (Cleanic, KerrHawe S.A., Bioggio, Switzerland).

The air polishing treatment was performed by AIRFLOW® Master device (EMS, Nyon, Switzerland) with a six LED power setting (2.2 bars dynamic pressure inside powder chamber) and an 11 LED (35 mL/min) water setting for 30 seconds (powder consumption was 1.1 g). Sodium bicarbonate air-powder polishing powder (AIR-FLOW® Plus, EMS Electro Medical Systems, Nyon, Switzerland) was used. The nozzle was held 3–4 mm from the tooth surface and the tip was angulated diagonally. The spray was delivered for an average of 5 seconds using a constant circular motion for each tooth. The spray was directed towards the middle one-thirds of the exposed tooth [11].

The bleaching agent (Opalescence Xtra Boost/ Ultradent, South Jordan, UT, USA) was prepared and used following the manufacturer's instructions. Opal Dam (Ultradent, South Jordan, UT, USA) was used for protection of the gingiva. The bleaching gel was then applied to form 1–2 mm thickness on the buccal surfaces of the teeth of both arches. The gel remained on teeth for 15 minutes and was then suctioned from teeth using a surgical suction tip. This application was repeated a second time in the same session.

**Statistical Analysis**

The assumption of normal distribution of difference scores were examined prior to conducting the analysis. The assumption was considered satisfied for many differences of color scores, some of them not satisfied which were indicated with asterisk (*) in Table 1.

The proper reporting for non-normal distributed (skewed) data were summarized by using median (minimum and maximum) value instead of mean and standard deviation. Because of a consistent illustration in the Table 1 for parametric and non-parametric tests the both descriptive statistics mean ± SD, and Median (min, max) noted across all treatment levels.
The differences of color scores of the teeth were assessed for normality assumption by Shapiro-Wilks test (p>0.05) and homogeneity of variances were assessed by Levene's Test for Equality of variances (p>0.05).

The paired t-test were used if the normality assumptions were valid, otherwise the Wilcoxon-signed rank test were used to compare the rubber-cup and air-powder polishing treatments, and for the differences of 1 week and immediate values.

**Results**

All included patients completed the study protocol without any adverse events. The mean age of patients was 34.1±8.9. The results of the study are summarized in Table 1. The baseline measurements of teeth colors and the color changes (ΔL, Δa, Δb, ΔE, ΔSGU) immediately after bleaching and at week 1 are shown in Table 1.

The baseline measurements of teeth colors and the color changes (ΔL, Δa, Δb, Δe, ΔSGU) immediately after bleaching and at week 1 are shown in Table 1.
| Color Parameters | Immediate Mean±sd | Median (min,max) | Baseline - Immediate p value | 1-week Mean±sd | Median (min,max) | Baseline - 1 week p value | Change from Immediate to 1 week Mean±sd | Immediate-1 week p value |
|------------------|------------------|------------------|-------------------------------|----------------|------------------|--------------------------|---------------------------------|------------------------|
| ΔL               |                  |                  |                               |                |                  |                          |                                 |                        |
| APP              | 5,41±5.40 (4,2;14,7) | 5,2 (0,001) |                               | 8,54±5.99 (-1,4;20,5) | 7,9 (0,001) |                               | 3,13±3,60 (-3,9;9,2) | 0,001                     |
| RCP              | 4,9±4,39 (-3,7;11,6) | 5,4 (0,001) |                               | 5,95±4,80 (-2,0;12,6) | 7 (0,001) |                               | 1,05±5,08 (-10,9;9,0) | 0,354                    |
| p                | 0,667             | 0,153            |                               |                |                  |                          |                                 | 0,063                     |
| Δa               |                  |                  |                               |                |                  |                          |                                 |                        |
| APP              | -0,69±1,41 (-3,4;1,8) | -0,3 (0,003) |                               | -0,78±2,12 (-3,7;6,3) | -1 (0,003) |                               | -0,09±2,77 (-5,5;7,7) | 0,181*                   |
| RCP              | -0,15±1,26 (-2,5;4,0) | -0,3 (0,003) |                               | -1,45±0,87 (-3,4;0,2) | -1,6 (0,001) |                               | -1,3±1,62 (-6,2;2,0) | 0,002*                   |
| p                | 0,111             | 0,211*           |                               |                |                  |                          |                                 | 0,081                    |
| Δb               |                  |                  |                               |                |                  |                          |                                 |                        |
| APP              | -1,56±3,96 (-10,3;4,5) | -1,4 (0,001) |                               | -2,38±5,40 (-16,0;6,1) | -2,1 (0,001) |                               | -0,82±5,26 (-12,6;10,0) | 0,484                    |
| RCP              | -0,55±2,78 (-5,7;4,1) | -0,4 (0,001) |                               | -3,36±3,09 (-9,4;1,1) | -3 (0,001) |                               | -2,8±3,70 (-12,0;4,5) | 0,002                    |
| p                | 0,28              | 0,437            |                               |                |                  |                          |                                 | 0,119                    |
| ΔE               |                  |                  |                               |                |                  |                          |                                 |                        |
| APP              | 7,39±4,49 (2,2;15,0) | 7,2 (0,001) |                               | 10,94±4,91 (3,6;20,6) | 10,4 (0,001) |                               | 3,55±3,55 (-3,3;10,2) | <0,001                   |
| RCP              | 6,22±3,03 (1,5;11,7) | 5,94 (0,001) |                               | 9,08±2,84 (2,3;12,8) | 8,8 (0,001) |                               | 2,86±2,80 (-2,9;9,1) | <0,001                   |
| p                | 0,129             | 0,091            |                               |                |                  |                          |                                 | 0,359                    |
| ΔSGU             |                  |                  |                               |                |                  |                          |                                 |                        |
| APP              | 2,29±1,62 (0,0;6,0) | 2 (0,001) |                               | 5,09±2,23 (1,0;9,0) | 5 (0,001) |                               | 2,8±1,89 (-3,0;6,0) | <0,001*                  |
| RCP              | 1,48±1,99 (-4,0;6,0) | 1 (0,001) |                               | 4,62±2,67 (1,0;11,0) | 4 (0,001) |                               | 3,14±2,83 (0,0;10,0) | <0,001                   |
| p                | 0,148             | 0,484            |                               |                |                  |                          |                                 | 0,591                    |
There was no significant difference at the baseline CIE L*, a*, b* value between the groups (p > 0.05). At immediate and 1 week recall, both treatment groups remained significantly lighter than the baseline, as for the color parameters: lightness improvement (ΔL) (p < 0.001), reduction of redness (Δa) (p = 0.003), reduction of yellowness (Δb) (p < 0.001).

No statistically significant differences were found for ΔL, Δa, Δb, ΔE and ΔSGU values between air-powder polishing and rubber-cup groups at immediate and 1 week results.

The difference between immediate and 1-week measurements is statistically significant for both air-powder polishing and rubber-cup groups, except for ΔL (p = 0.354) for rubber-cup group, and for Δa (p = 0.181), Δb (p = 0.484) for air-powder polishing group.

ΔL value was significantly changed during immediate and 1-week treatment periods in air-powder polishing group (the mean change was 3.13 ± 3.60, p = 0.001) while no significant changes were noted in rubber-cup group (the mean change of ΔL = 1.05 ± 5.08, p = 0.354, increased brightness).

Δa value was not significantly changed during immediate and 1 week treatment period in air-powder polishing group the median change of Δa = -0.70 (-5.5, 7.7), p = 0.181, but in rubber-cup group the median change of Δa = -1.30 (-6.2, 2.2), p = 0.002 (reduction in red) was statistically significant.

Δb value was not significantly changed during immediate and 1 week treatment period in air-powder polishing group the mean change of Δb = -0.782 ± 5.26, p = 0.484, but in rubber-cup group the mean change of Δb = -2.80 ± 3.70, p = 0.002 (reduction in yellow) was statistically significant.

ΔE value was significantly changed during immediate and 1-week treatment period in air-powder polishing group the mean change of ΔE = 3.55 ± 3.55, p < 0.001, and also in rubber-cup group the mean change of ΔE = 2.86 ± 2.80, p < 0.001 was statistically significant.

ΔSGU value was significantly changed during immediate and 1-week treatment period in rubber-cup group the mean change of SGU = 3.14 ± 2.83, p < 0.001, and also in the air-powder polishing group the mean change of SGU = 2.80 ± 1.89, p < 0.001 was statistically significant.

**Discussion**

The null hypothesis was not rejected. The results of the study have shown that while effective bleaching was achieved [12] (as determined by a change in E of over 6 units immediately after and over 9 in first week), there were no significant changes between prior APD and rubber-cup prophylaxis.

Previous literatures have shown that whitening from bleaching agents is manifested mainly by an increase in lightness (higher L) and reduction in yellowness (lower b) and redness (lower a) [13, 14]. There were increase in the L value and decrease in a and b values immediately after the bleaching treatment. After 1 week, statistically different developments continued according to baseline measurements in all these three values. There are significant differences in a and b values in the rubber-cup group and L in flow group between immediate and 1-week measurements. Some studies found that the variance in b and L values had major influence on color change [15, 16]. In the judgement of whiteness of tooth none of a, b or L value distinctly evaluated, hence all off them equally valuable for the calculation of E value. Therefore, in this study, we also included SGU in the comparison.

To our knowledge, there are no studies comparing the effects of prior APD and rubber cup prophylaxis on the bleaching effectiveness which makes the interpretation of the results impossible. Results of previous studies comparing the effectiveness of air-polishing to the rubber cup polishing for bacterial plaque and stain removal demonstrate that both methods are equally effective with similar gingival trauma [17]. While some studies report APDs to be more effective for plaque and stain removal in
pits and fissures [18] and complete cleaning, down to the tooth microstructure [19]; others indicate that polishing with rubber cup was more effective for the crown and root surface smoothening and debris removal [20]. The main disadvantage of rubber-cup prophylaxis is that the polishing pastes abrade, flatten, and deposit debris into the microcavities voids on the enamel surface [19] which may theoretically decrease bleaching effectiveness. In addition, Nakamura et al. [21] reported that tooth polishing with a polishing agent and a brush caused a decrease in lightness and reduction of yellowness. The polishing with rubber cup and prophylaxis paste is highly operator-sensitive as rotation speed, abrasiveness of paste, pressure applied with hand piece and duration influence affect the efficacy of the procedure [22]. On the other hand, the aerosols generated by air polishing may present an infection control hazard hence, preprocedural rinse is always recommended along with aerosol reduction devices [23].

Up to date various studies have been performed to increase the effectiveness of the bleaching procedure in a shorter period of treatment time. Office-bleaching usually requires long application period and sometimes additional visits to obtain optimum results. Prolonging bleaching treatment may result in several side-effects such as tooth sensitivity, gingival irritation and alteration of enamel surface [24, 25]. Low molecular weight of HP diffuses through permeable enamel and dentin substrates, then reaches the pulp chamber via the dentinal tubules. Exposure to high HP concentrations, may cause inflammatory response in the pulp. Less application and sessions are recommended to minimize these side effects [26–28]. Researchers investigated whether reduced contact time of the bleaching gels could yield less-adverse effects while still being effective [27, 29, 30]. Several studies have shown that the substance released from bleaching gels is proportional to their contact time with enamel [31–34]. However, some authors have shown that exposure of pulp cells to low HP concentrations encourages the differentiation of odontoblasts and the formation of mineralization [35, 36]. On the other hand, shortening the bleaching time may prevent it from achieving satisfactory results. The gel used in the in-office technique is exposed to the environment and seemingly loses water faster. This is the argument used by manufacturers to recommend applications of 15 minutes. The shortest time of application (2 × 15 minutes) for one session as recommended by the manufacturer was performed in the current study.

The split-mouth design used in this study allows different experimental groups within the same patient. Thus, each patient served as his or her own control. This eliminates patient dependent variables on the results. In order to be more precise and objective, the spectrophotometer measurement was preferred over the visual evaluation [37]. Besides this, a positioning guide with orifices in the center of the middle third of teeth was fabricated [38]. This was because the middle area of teeth is generally flatter and provides a stable platform for the spectrophotometer sensor [39], and this area is the most representative tooth-color region as it reflects the light from the dentin with little influence from the enamel [38–40].

Conclusions

The results of the study show that both rubber cup prophylaxis and APD devices can be used before bleaching treatment as there were no statistical differences in color change.

Abbreviations

APD: Air-Powder polishing Devices, RCP: rubber-cup polishing, CIE: Commission Internationale de l’Eclairage (International Commission on Illumination), L*: Lightness, a*: Red/Green Value, b*: Blue/Yellow Value, E*: Degree of color variation, SGU: Shade Guide Units, HP: Hydrogen Peroxide, SD: Standard Deviation, LED: Light Emitting Diode, rpm: Revolution per minute, mm: millimeter

Declarations

Ethics approval and consent to participate

Informed consent forms were signed by all participants.

The protocol was reviewed and approved by Ethics Committee of Cukurova University (No: 1-6-18-78/78).
Consent for publication

Not applicable.

Availability of data and materials

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

ZGBK developed the study outlines and coordinated the protocol. Voluntary patients registered by MO and random allocations have been done by ZGBK. All prophylaxis procedures were performed by MO. All bleaching procedures were performed by ZGBK. ZGBK was involved in measuring data and writing the first draft of the manuscript, and MO contributed to revision of the final draft. All authors read and approved the final manuscript.

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**Figures**

![Sample size calculation diagram](image)

**Figure 1**
The flow chart of study design

**Supplementary Files**

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- [CONSORT2010checklistofinformationtoincludewhenreportingarandomisedtrial.docx](CONSORT2010checklistofinformationtoincludewhenreportingarandomisedtrial.docx)