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ORIGINAL ARTICLE / ОРИГИНАЛНИ РАД

Clinical efficiency of a sodium perborate – hydrogen peroxide mixture for intracoronal non-vital teeth bleaching

Tatjana Savić-Stanković, Branislav Karadžić, Marina Latković, Vesna Miletić

University of Belgrade, School of Dental Medicine, Department of Restorative Dentistry and Endodontics, Belgrade, Serbia

SUMMARY

Introduction/Objective The aim was to evaluate initial efficiency of sodium perborate (tetrahydrate) and 30% hydrogen peroxide mixture for intracoronal non-vital teeth bleaching ("walking bleach" technique).

Methods Forty patients with discolored teeth were included in the study. Based on their history and clinical examination, causes of discoloration were classified as necrotic pulp, "endo-sealer" or unknown. The "walking bleach" technique was performed by applying sodium perborate (tetrahydrate) and 30% hydrogen peroxide mixture intracoronally to cavity dentin walls. The mixture was renewed in seven-day intervals. Tooth color was assessed visually before, during, and after the procedure using the Vita Classical shade guide (Vita Zahnfabrik, Bad Säckingen, Germany). Numerical values or shade guide units (SGU) were assigned to Vita shade tabs on a bright-dark scale. Analysis of variance, t-test, correlation and regression analysis were used to analyze the data ($p < 0.05$).

Results On average, 26 ± 9 days or 3–4 appointments were required for intracoronal bleaching to achieve the desired or best possible shade. Better clinical efficiency was found in the necrotic pulp group (17 ± 6 days; 8 ± 3 SGU) than in the "endo-sealer" group (42 ± 13 days; 4 ± 2 SGU) ($p < 0.05$). Age significantly influenced bleaching efficiency ($p < 0.05$). There was no significant correlation between bleaching efficiency and initial shade ($p > 0.05$).

Conclusion Intracoronal, non-vital teeth bleaching ("walking bleach" technique) using sodium perborate (tetrahydrate) and 30% hydrogen peroxide mixture showed satisfactory clinical efficiency. Discoloration caused by pulp necrosis was treated more efficiently than that caused by endodontic sealers. Younger age had a positive effect and discoloration intensity had no effect on bleaching efficiency.

Keywords: walking bleach; intracoronal bleaching; non-vital teeth bleaching; tooth discoloration; sodium perborate; hydrogen peroxide

INTRODUCTION

Tooth color affects smile esthetics, which is among the first facial characteristics observed in a social interaction. Even mild tooth discoloration may reduce individual's self-esteem and quality of life [1]. A recent study showed that a single discolored tooth adversely affects patient's dental self-confidence as well as social and psychological aspects of one's well-being [2].

Non-vital teeth are discolored mainly due to trauma and intracoronal hemorrhage, proteolytic degradation, root canal sealers and cements [3]. Increasingly popular calcium-silicate cements, such as mineral trioxide aggregate (MTA) and Biodentine®, have recently shown to have tooth discoloration potential [4]. Higher discoloration potential has been reported for calcium-silicate-based cements containing bismuth oxide as the radio-pacifying agent and lesser for cements with zirconium oxide [4, 5].

A non-vital tooth bleaching is clinically performed by placing a bleaching agent intracoronally and sealing the crown temporarily. This so-called "walking bleach" technique may be performed in one or more consecutive visits in intervals of three to seven days until the desired or maximum color change is achieved [3]. Regarding color assessment, it should be noted that visual shade matching using Vita shade guides is still most commonly used in daily practice [6].

Sodium perborate, hydrogen peroxide, and carbamide peroxide are commonly used bleaching agents for intracoronal bleaching using the "walking bleach" technique [7, 8]. The efficiency of the bleaching agent may be improved by additional activation with LED blue or laser infrared light or photon-initiated photoacoustic streaming [9, 10]. The mechanism of bleaching by all three agents is based on the release of nascent oxygen and hydrogen peroxide which forms free radicals in the alkaline solution, resulting in hydroperoxyl (HO_2) and hydroxyl (HO^-) ions capable of breaking longer-chained chromophores into shorter-chained colorless compounds [11].

In vitro studies of intracoronal bleaching focused on tooth fracture resistance, composition of calcium-silicate cements, their compressive strength, and bond strength to composite resin, adhesive bonding, orthodontic brackets

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Correspondence to:
Vesna MILETIĆ
School of Dental Medicine
Dept. of Restorative Dentistry and Endodontics
Rankeova 4, 11000 Belgrade
Serbia
vesna.miletic@stomf.bg.ac.rst

bonding to enamel and marginal integrity of temporary and permanent restorative materials following various intracoronal bleaching protocols [12–16].

A similar number of recent clinical studies were found in the literature for in-office bleaching of vital teeth and intracoronal "walking bleach" approach, illustrating the relevance of tooth bleaching in current dental practice and research [1, 2, 7, 8, 9, 17–20]. Hydrogen peroxide, carbamide peroxide and sodium perborate were all-efficient in intracoronal bleaching, with stable effects up to six months or one-year post-bleaching [7, 19, 20]. Even after 25 years post-bleaching 85% of the endodontically treated teeth bleached with 10% carbamide peroxide retained tooth color within two color shades [8]. Multiple studies have confirmed a strong positive effect of both in-office and "walking bleach" procedures on patients' quality of life, psychosocial interaction, and esthetic self-perception [2, 21]. Regarding the "walking bleach" technique, no difference was found between carbamide and hydrogen peroxide bleaching agents in the context of patient's esthetic perception, self-confidence, and psychological and social impact [2].

The aim of this clinical study was to evaluate initial efficiency of the sodium perborate - 30% hydrogen peroxide mixture for intracoronal non-vital teeth bleaching ("walking bleach" technique). The null hypotheses were:

1. There is no difference in clinical efficiency of intracoronal bleaching between different causes of discoloration;
2. there is no relationship between clinical efficiency of intracoronal bleaching and patients' age;
3. there is no relationship between clinical efficiency of intracoronal bleaching and initial shade.

METHODS

Patient selection, examination, and endodontic treatment

The study was approved by the University of Belgrade, School of Dental Medicine Ethics Committee. Inclusion criteria were visibly discolored crown, non-vital or endodontically treated upper central and lateral incisors, previous endodontic treatment performed two or more years earlier. Exclusion criteria were caries on upper central and lateral incisors, inadequate fillings, and progressive periodontal disease.

Forty patients (25 female and 15 male) aged 18–58 years participated in the study. Patients' history was taken and clinical examination performed, including pulp sensitivity tests. Retroalveolar X-rays were taken to check the periapical status and, in cases of previous endodontic treatments, to check the quality of root canal obturation, by assessing the length, conicity and homogeneity of the root canal obturation material. The overall success of previous endodontic treatment was based on patients' history and clinical exam confirming no signs and symptoms of periapical disease. Based on patients' history and examination, potential causes of tooth discoloration were classified into three groups:

1. "Necrotic pulp" (teeth with necrotic pulp with or without patients' recollection of trauma);
2. "endo-sealer" (previously endodontically treated teeth with traces of endo-sealer on pulp chamber walls, patients' recollection that discoloration occurred post-treatment);
3. "unknown" (previously endodontically treated teeth with no traces of "endo-sealer" on pulp chamber walls, patient could not confirm whether discoloration occurred before or after endodontic treatment).

Initial endodontic treatment was performed in the "necrotic pulp" group. A re-treatment was performed in previously endodontically treated teeth with inadequate root canal obturation whereas in endodontically treated teeth with adequate root canal obturation the intracoronal bleaching was performed without prior endodontic re-treatment.

Access cavity was prepared and the working length determined using an apex locator (Root ZX, Morita Corp., Osaka, Japan). Root canal instrumentation was performed with Gates-Glidden and K-Flex hand files (Kerr, Orange CA, USA) following the crown-down and step-back technique with 1% sodium hypochlorite irrigation (Patenting, Belgrade, Serbia) Depending on the initial apical size, the master apical files were K#25-35, mostly K#30. Canals were dried with sterile paper points and obturated with gutta-percha (Spident, Incheon, Korea) and AH-Plus sealer (Dentsply DeTrey GmbH, Konstanz, Germany) using cold lateral compaction technique. Each tooth was prepared for bleaching by removing 1–2 mm of the obturation material at the canal orifice and sealing it with roughly two mm thick glass-ionomer cement (Vitrebond, 3M Corp., St. Paul, MN, USA).

Intracoronal bleaching procedure

Tooth color assessment was performed by shade matching with color tabs on the Vita Classical shade guide (Vita Zahnfabrik, Bad Säckingen, Germany). The procedure was performed by three specialists at daytime in a dental office with no extra dental unit light. Color assessment was determined by consensus agreement of at least two specialists.

A mixture of sodium perborate (tetrahydrate) and 30% hydrogen peroxide was prepared in the 1:2 ratio by measuring the appropriate quantities of each component on an analytical balance (d = 0.1 mg, Acculab, Sartorius, Goettingen, Germany) and mixing them with a metal spatula on a glass slab until the mixture was homogeneous. A portion of the mixture was applied intracoronally as a thin layer and adapted to the entire cavity dentin using a dry, sterile cotton pellet. The cavity was then temporarily sealed with calcium-sulfate cement (Citodur, Dorident, Wien, Austria). At a follow-up after seven days, color assessment was repeated. Temporary filling and the sodium perborate-hydrogen peroxide mixture were removed using an excavator and the cavity was thoroughly rinsed with air-water spray. Freshly prepared mixture was then applied to the inner cavity walls and the tooth was again temporarily restored.

The treatment ended when the desired color was achieved *i.e.* visually acceptable shade in relation to the adjacent teeth

Table 1. Bright–dark scale for numerical expression of the Vita Classical shade tabs as shade guide units

Vita tab	B1	A1	B2	D2	A2	C1	C2	D4	A3	D3	B3	A3.5	B4	C3	A4	C4
Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

or when the color remained unchanged at two consecutive visits. The final achieved shade on the Vital Classical shade guide was recorded as well as the number of required visits.

Following the bleaching procedure, a calcium hydroxide paste was applied to the cavity dentin walls to neutralize the pH. The final restoration was done after two weeks using a two-step total-etch adhesive (Optibond Solo Plus, Kerr, Scafati, Italy) and a micro-hybrid composite (XRV Herculite, Kerr, Scafati, Italy). The adhesive was light-cured for 20 s and composite for 40 s using a conventional LED light-curing unit (LEdition, Ivoclar Vivadent, Schaan, Liechtenstein).

All 16 Vita Classical shade tabs were converted to a numerical 1–16 scale, #1 corresponding to the brightest shade (B1) and #16 corresponding to the darkest shade (C4) (Table 1). For each patient, the start and end point were identified on the numerical scale as shade guide units. Intracoronal bleaching efficiency (BE) was expressed as the percentage of the bleached shade relative to the initial shade on the bright-dark scale.

BE (%) = [(Initial shade - End shade) / Initial shade] × 100

Statistical analysis

Data were statistically analyzed using analysis of variance, Student's t test, correlation and regression analyses at the level of significance $\alpha = 0.05$. Statistical analysis was performed in Minitab 16 (Minitab Inc., State College, PA, USA).

RESULTS

The age structure *i.e.* mean (standard deviation) of 15 male and 25 female patients involved in this study was comparable: 37 (10.4) years of male and 32.6 (10.6) years of female patients. Necrotic pulp was diagnosed in 16 patients, 14 patients were allocated to the "endo-sealer" group, and in 10 patients, the cause of discoloration was unknown. All data taken together, 26 ± 9 days or 3–4 appointments were required for the intracoronal bleaching procedure to achieve the desired or best possible shade.

Table 2 presents information on the treatment duration relative to the cause of discoloration. Significantly shorter treatment was required in the "necrotic pulp" group than in the "endo-sealer" group ($p < 0.05$). In addition to longer mean treatment time, the "endo-sealer" group showed larger variation in terms of minimum and maximum duration spanning to almost 50 days compared to the "necrotic pulp" group with only 18 days between the minimum and maximum treatment duration. No significant differences were found between the previous two groups and the "unknown group" ($p > 0.05$). The number of patients in each group indicates that all patients returned for follow-ups *i.e.* the recall rate was 100%.

All data taken together, color change of 7 ± 2 shade guide units could be achieved. Table 3 presents data relative to the cause of discoloration. There was a statistically significant difference between the number of shade guide units achieved by bleaching in the "necrotic pulp" than in the "endo-sealer" group ($p < 0.05$). The "unknown" group was comparable to both previous groups ($p > 0.05$). In all three groups, the minimum number of shade guide units was the same (3), but the "necrotic pulp" group exceeded the other two groups in the number of maximum achievable shade guide units during bleaching (14).

Table 2. Treatment duration in different etiological groups

Duration in days	Necrotic pulp	Endo-sealer	Unknown
Mean	17	42	29
Standard deviation	6	13	11
Minimum	3	21	14
Maximum	21	70	42
Number of patients	16	14	10

Table 3. Changes in shade guide units following intracoronal bleaching

Changes in shade units	Necrotic pulp	Endo-sealer	Unknown
Mean	8	4	6
Standard deviation	3	2	2
Minimum	3	3	3
Maximum	14	11	10
Number of patients	16	14	10

Figure 1 shows a significant relationship between BE and patients' age. Pearson correlation analysis showed negative correlation between BE and patients' age ($r = -0.4708$; $p = 0.002$), indicating that better clinical efficiency could be accomplished in younger patients. Correlation and regression analyses showed no significant relationship between BE and initial shade ($r = -0.2826$; $p = 0.077$) (Figure 2).

Figures 3 and 4 show a case of intracoronal bleaching of an upper right central incisor discolored by trauma. Figures 5 and 6 show a case of intracoronal bleaching of an upper left central incisor discolored by "endo-sealer".

DISCUSSION

The first and second null hypotheses were rejected as different causes of tooth discoloration had a significant effect on intracoronal bleaching efficiency, which was more effective in younger patients. The third null hypothesis was upheld as no significant relationship was established between bleaching efficiency and initial shade.

This clinical study showed the potential of a sodium perborate (tetrahydrate) mixture with 30% of hydrogen peroxide to bleach discolored teeth. On average, the desired or maximum bleaching effect for this "walking bleach" technique required 3–4 appointments and 26 days. The

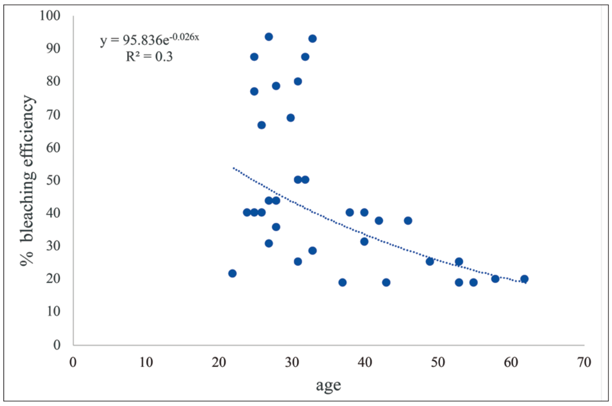

Figure 1. Regression analysis showing a significant relationship between bleaching efficiency and patients' age

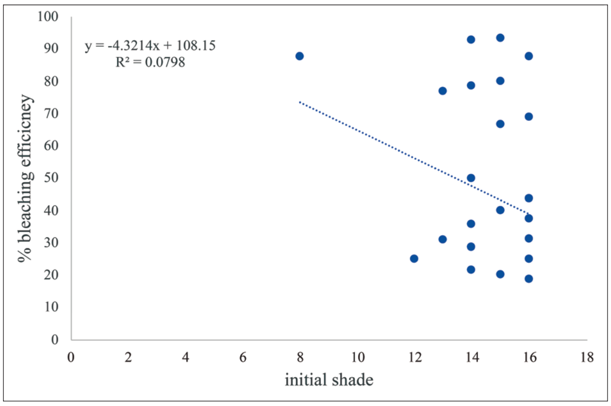

Figure 2. Regression analysis showing no significant relationship between bleaching efficiency and initial shade

Figure 3. An upper right central incisor discolored by trauma before intracoronal bleaching

Figure 4. The same upper right central incisors discolored by trauma after intracoronal bleaching

Figure 5. An upper left incisor discolored by endo-sealer before intracoronal bleaching

Figure 6. The same upper left incisor discolored by endo-sealer after intracoronal bleaching

present results are comparable to other recent clinical studies on the efficiency of the "walking bleach" technique. Pedrollo Lise et al. [7] used a mixture of sodium perborate (unspecified monohydrate, trihydrate, or tetrahydrate) and 20% hydrogen peroxide up to four weeks post-bleaching. Bersezio et al. [22] compared 35% hydrogen peroxide to 37% carbamide peroxide and Gupta et al. [20] used sodium perborate (tetrahydrate) alone for the same purpose. Both studies reported a similar number of required appointments for the most desirable outcome, 3–4 in Bersezio et al. [22] and three in Gupta et al. [20]. Given the fact that in all the studies, different mixtures were applied for intracoronal bleaching, it may be concluded that similar treatment longevity *i.e.* the number of appointments is expected irrespective of the bleaching agent/agents.

The desired or maximum achievable effect of intracoronal bleaching in the present study was seven shades on average. This was fewer than 12 shades reported by Gupta et al. [20] or 15 shades achieved by Bersezio et al. [22]. The differences could be explained by the greater number of teeth discolored by "endo-sealer" reducing the number of achieved shades in the present study. Gupta et al. [20] treated 41 patients with discolored teeth due to trauma, but without previous endodontic treatment, meaning that not a single “endo-sealer” case was included in their study. Nearly half of the 47 treated patients in Bersezio et al. [22] had discoloration due to trauma, whilst the other half of discolored teeth were previously endodontically treated but “endo-sealer” was not the stated cause of discoloration.

Generally, the “necrotic pulp” group showed a higher efficiency of intracoronal bleaching in the present study than the “endo-sealer” group both in terms of the required time/number of appointments and of the shade difference in bleached teeth. Despite the fact that the cause of discoloration was based on patients’ history and clinical examination and not confirmed by chemical testing, the necrotic pulp” and “endo-sealer” causes could be differentiated with high confidence. The same approach was followed in previously mentioned studies [7, 20, 22]. Furthermore, a distinct difference in the efficiency of bleaching confirms the correct diagnosis of the cause of discoloration. The “unknown” group showed the results between the other two groups indicating that it probably contained teeth with both causes of discoloration. The observed differences between the “necrotic pulp” and “endo-sealer” groups could be associated with the fact that pigments of natural origin (decomposition products of blood and pulp tissue components as well as pigments of microbial origin) are more susceptible to oxidation reactions that lead to chromophore cleavage and molecular conversion than endodontic sealers [23]. Endodontic sealers containing silver, bismuth, and resins cause not only discernible discoloration shortly after the placement but also show a significant degree of bleaching resistance [24]. Discoloration induced by endodontic sealers may be more bleaching-resistant than that induced by natural pigments due to the amount of excess sealer in the pulp chamber and complex interactions between sealer components and dentin tissue [25]. For example, it was recently explained that bismuth from MTA-based materials forms black precipitates upon interaction with dentin collagen in the presence of sodium hypochlorite, bismuth carbonate upon reaction with atmospheric carbon dioxide or breaks down to metallic bismuth and oxygen upon light irradiation in oxygen-free environment [26, 27].

Better treatment efficiency was associated with patients’ younger age and no direct relationship was found between bleaching efficiency and initial shade. These results are comparable to Gupta et al. [20] who also performed intracoronal non-vital teeth bleaching. Based on pooled data from 11 clinical trials, patients’ younger age was reported as a significant factor in clinical efficiency of vital teeth bleaching as well [28]. More efficient bleaching in younger patients and higher bleaching resistance in older patients may be associated with the diameter of dentinal tubules. In younger patients, wider dentinal tubules allow deeper penetration of hydroperoxyl (HO_2) and hydroxyl (HO^-) ions. Conversely, the results indicated that even a highly discolored tooth with necrotic pulp could be efficiently bleached, albeit taking more time and appointments, than a tooth mildly discolored by endodontic sealers. The cause was shown to have a more important effect on treatment efficiency than the intensity of initial discoloration.

It could be argued that in-office non-vital bleaching is faster than the “walking bleach” technique. Although this is true, the “walking bleach” technique is a more conservative approach that allows better control of the achieved result over a longer time. More aggressive in-office non-vital bleaching could lead to over-bleaching due to limited color control. Furthermore, studies indicate that the “walking bleach” technique results in a stable color over a period of months or even years [7, 8, 19]. The cost of commercial products for in-office bleaching often increases the cost of this treatment. Conversely, the low cost of sodium perborate powder and hydrogen peroxide used in the “walking bleach” technique makes this technique financially acceptable.

Despite advantages, biological risks of the “walking bleach” technique were recently investigated by Bersezio et al. [29]. They reported an increase in the production of IL-1β and RANKL biomarkers in periodontal tissues by analyzing gingival crevicular fluid up to six months after intracoronal bleaching with either 35% hydrogen peroxide or 37% carbamide peroxide over four sessions. Increased production of these biomarkers may be associated with osteoclastic activity with a potential for root resorption as an adverse consequence of intracoronal bleaching [30, 31].

A limitation of this study is that the efficiency of intracoronal bleaching was assessed visually using a Vita Classical shade guide. However, the same approach was followed in other studies [8, 20, 22]. Though digital shade matching has proven more accurate and reliable than visual shade matching, experience and training may positively affect the accuracy of visual shade matching [32, 33]. Colorimeters and spectrophotometers have not been widely accepted probably due to their high costs. The fact that visual shade matching was performed in the present study ensures clinically relevant results as most dentists would likely resort to the same technique when assessing bleaching efficiency. Furthermore, the 50:50 perceptibility and acceptability thresholds in color observation in dentistry were found to be significantly lower for dentists (mean ΔE_{00} 0.62 and 1.79, respectively) than laypersons (mean ΔE_{00} 1.00 and 2.04, respectively) who largely constitute the patient group [33]. This indicates that dentists observe color differences better than patients do, likely due to training, ensuring better treatment results and patient satisfaction.

CONCLUSION

Intracoronal, non-vital teeth bleaching or the “walking bleach” technique using a mixture of sodium perborate tetrahydrate and 30% hydrogen peroxide showed satisfactory clinical efficiency. On average, 3–4 appointments were required for a desired or maximum possible outcome. The cause of discoloration affected treatment longevity and efficiency, in that discoloration due to pulp necrosis was resolved more efficiently than discoloration due to endodontic sealers. Younger patients had better results and discoloration intensity had no effect on bleaching efficiency.

Conflict of interest: None declared.

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Клиничка ефикасност микстуре натријум-пербората и водоник-пероксида за интракоронарно избељивање депулписаних зуба

Татјана Савић-Станковић, Бранислав Караџић, Марина Латковић, Весна Милетић

Универзитет у Београду, Стоматолошки факултет, Клиника за болести зуба, Београд, Србија

САЖЕТАК

Циљ Циљ овог рада је да испита иницијалну клиничку ефикасност микстуре натријум-пербората (тетрахидрата) и 30% водоник-пероксида за интракоронарно избељивање депулписаних зуба („шетајућа“ техника).

Методе У студију је било укључено 40 пацијената са пребојеним зубима. На бази анамнезе и клиничког прегледа, узроци дисколорације су класификовани као „некротична пулпа“, „ендо-силер“ или „непознат“. У интервалима од седам дана микстура натријум-пербората и 30% водоник-пероксида апликована је интракоронарно на дентинске зидове кавитета. Боја зуба је процењивана визуелном методом пре, током и после третмана применом кључа боја *Vita Classic* (*Vita Zahnfabrik*, Немачка). Нумеричка вредност (јединица нијансе) додељена је свакој нијанси кључа *Vita* помоћу светло-тамне скале. Анализа варијансе, *t*-тест, корелациона и регресиона анализа су коришћене за статистичку обраду података ($p < 0,05$).

Резултати Просечно 26 ± 9 дана или 3–4 посете су биле неопходне да се интракоронарним избељивањем постигну жељена или најсветлија могућа нијанса. Боља клиничка ефикасност избељивања забележена је у групи „некротична пулпа“ (17 ± 6 дана; 8 ± 3 нијанси) него у групи „ендо-силер“ (42 ± 13 дана; 4 ± 2 нијансе) ($p < 0,05$). Узраст пацијента је значајно утицао на ефикасност избељивања ($p < 0,05$). Није утврђена значајна повезаност између ефикасности избељивања и почетне нијансе ($p > 0,05$).

Закључак Интракоронарно избељивање депулписаних зуба односно „шетајућа“ техника избељивања применом микстуре натријум-пербората (тетрахидрата) и 30% водоник-пероксида показала је задовољавајућу клиничку ефикасност. Дисколорација услед некрозе пулпе је успешније избељена него дисколорација изазвана ендодонтским пастама. Ефикасније избељивање је забележено код млађих пацијената, док интензитет почетне дисколорације није значајно утицао на ефикасност избељивања.

Кључне речи: шетајућа техника; интракоронарно избељивање зуба; избељивање депулписаних зуба; дисколорација зуба; натријум-перборат; водоник-пероксид