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Review Article

Methods for Reversing the Bond Strength to Bleached Enamel: A Literature Review

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Abstract

The residual oxygen can negatively interfere with the adhesive polymerization, and reduce the bond strength to bleached enamel. The aim of this study was to review the literature on methods for reversing the bond strength to bleached enamel, efficacy and clinical feasibility. A waiting period, the use of dental adhesives containing organic solvents and application of organic solutions or antioxidant agents are the most used methods in an attempt to reverse bond strength to bleached enamel. Delaying bonding for 1 week after bleaching is sufficient to remove any residual oxygen and reverse the bond strength to enamel, regardless the bleaching agent used. Alcohol and acetone used as organic solutions or solvents in dental adhesives are able to increase the enamel bond strength, but not reestablish it completely. Enzymatic agents such as catalase and, peroxidase; and non-enzymatic agents such as sodium ascorbate, flavonoids and vitamin E have antioxidant properties. However, the high cost and proven efficacy only in prolonged use hamper the clinical application of antioxidant agents. The most established method for reversing the decreased bond strength to bleached enamel is the waiting period of at least one week. Further studies should be conducted to evaluate the application of alcohol, acetone, and antioxidant agents in different concentrations and for a short period of time to be clinically feasible and efficient in a short and long term.

INTRODUCTION

Bleaching is a conservative esthetic treatment to remove intrinsic and extrinsic stains on dental surface. Hydrogen and carbamide peroxides are the agents most commonly used for home and in-office whitening. Although both of agents promote a satisfactory esthetic result, they can decrease immediately the bond strength to bleached enamel [1-3].

The reduced bond strength is the result of the presence of residual oxygen that can adversely affect the adhesive polymerization [2,4-9]. This fact is enough to compromise the quality of the restoration adhered to bleached enamel and affect its clinical performance.

It has been recommended a waiting period from 24 hours to 3 weeks after bleaching to perform adhesive restorative procedures [10,11]. This period is important to eliminate the residual oxygen from dental structure and reestablish the enamel bond strength [10,11]. However, not always this waiting time is possible, because the search for immediate results and urgency for aesthetic rehabilitation.

Other methods have been proposed for the restorative procedure can be done immediately after bleaching, as the application of adhesives containing organic solvents, [6,12] organic compounds [12] and antioxidants agents [1,2,8,13]. Alcohol and acetone are able to eliminate water excess from the dental structure and increase the bond strength [14]. Antioxidant agents present in foods such as flavonoids and vitamins A, C and E can accelerate the complete release of the residual oxygen and restore the bond strength depending of their application time [14].

Based on that, dentists should be provided with scientific basis on the feasibility of each method for reversing the bond strength to enamel and choose the most effective treatment for their patients.

The aim of this study was to review the literature on methods for reversing the bond strength to bleached enamel, efficacy and clinical feasibility.

REVIEW

Dental bleaching is a conservative treatment that promotes color change through a redox reaction caused by the presence of hydrogen peroxide in the composition of bleaching agents. Ions resulting from the degradation of hydrogen peroxide as free radicals and reactive oxygen penetrate the enamel to reach dentin by diffusion and the complex molecules of pigments are transformed into smaller molecules and colorless [15,16].

Although the hydrogen and carbamide peroxides promote excellent aesthetic results, adverse effects can be observed as reduced bond strength of composite resin restorations to enamel immediately after bleaching. The decrease in adhesion is due to persistence of oxygen ions in the dental structure even after removal of the bleaching gel. This residual oxygen is responsible for inhibiting adhesive polymerization [2,5-9,17] over the resin-enamel junction near the base of hybrid layer [4].

The reduced enamel bond strength becomes a problem for patients requiring aesthetic restorations after bleaching. A waiting period, the use of dental adhesives containing organic solvents and the application of organic compounds or antioxidant agents are the most used methods in the literature in an attempt to restore adhesion to bleached enamel [1,2,6,8,10-13,18].

WAITING PERIOD

Waiting for a certain period of time after the bleaching for performing adhesive procedures has proved the most common and effective method to reverse the bond strength to bleached enamel. The buffering and remineralization potential of artificial saliva minimize the adverse effects of bleaching, without interfering with the adhesion of the composite resin [11]. This period is important for the stability of dental color, removal of residual oxygen and obtains better esthetic results, which facilitates the selection of composite resin to be used [13].

According to the literature the recommended waiting period for restorative procedures on enamel after bleaching with 10% carbamide peroxide is 24 hours [4,11], 1 week [10-22] or 3 weeks [10]. The period of 24 hours is not enough to reestablish the bond strength to enamel for larger concentrations of carbamide peroxide as 16%, 20% and 22%. A waiting period from 1 [8] to 3 weeks [10] is necessary to perform restorative procedures. For 9.5%, 25%, 30%, 35% and 38% hydrogen peroxides at least 1 week must be waited for obtaining a good adhesion to bleached enamel [3,11,19,20].

In general the waiting period of 1 week is enough to eliminate all residual oxygen from bleached enamel and restore its bond strength, independent of the bleaching agent used.

Although the waiting period has advantages, conducting adhesive restorative procedures immediately after bleaching is not possible. Thus, the discussion of other methods for reversing the reduced bond strength to enamel after bleaching also becomes important.

APPLICATION OF DENTAL ADHESIVES CONTAINING ORGANIC SOLVENTS

Organic solvents such as acetone and ethanol present in the adhesives are able to interact positively with the residual oxygen and increase the bond strength to enamel [6,18]. The organic solvents promote the water displacement from the bleached tooth surface restoring the adhesion of composite resin to enamel [21].

Sung et al. [6], showed that the bond strength was restored after the use of adhesives with ethanol being similar to unbleached teeth. Other authors [21,22] observed that the presence of alcohol and acetone in dental adhesives was not enough to reverse the bond strength to enamel bleached with hydrogen peroxide in high concentration. However, a more recent study [6] showed that the enamel can be restored immediately after bleaching using acetone or ethanol based-adhesives, because these agents were able to increase the bond strength. In addition, the acetone-based adhesives showed higher resistance to shear when compared to control group. These divergent results are related to the difference in the methodologies applied in each study in relation to the type of substrate (bovine or human enamel) evaluated, method of application and concentration of the bleaching agent primarily. More concentrated peroxides produce greater adverse effects on bleached dental structure [6].

APPLICATION OF ORGANIC COMPOUNDS

Organic compounds applied on bleached enamel are able to remove residual peroxide by water extraction of hard tissues [13,23]. The major clinical availability and the lack of special storage makes ethanol and acetone agents clinically useful to reverse the reduced bond strength to enamel when esthetic procedures must be done immediately after dental bleaching [23]. Although these organic compounds increase the bond strength to bleached enamel, they are not able to reverse it completely.

Thus, further studies need to be conducted to prove its efficacy, toxicity and its effect on the longevity of adhesive restorations.

APPLICATION OF ENZYMES

The superoxide dismutase (SODs) are a class of metal cofactored enzymes discovered by Irwin Fridovich and Joe McCord that detoxify these free radicals by catalyzing the dismutation of superoxide into oxygen and hydrogen peroxide. SOD reduces and reverts superoxide-induced cell damage in the body and acts at the very starting point of the free radical generation that is superoxide ion [24]. SOD is of two types: Copper/zinc (Cu/Zn) SOD and manganese (Mn) SOD. Cu/Zn SOD defends the cytoplasm of the cells, and Mn SOD shields the mitochondria of the cells from free radical damage [25]. Kavitha et al. [24], applied the SOD for 10 minutes on the bleached enamel which resulted in a restoration of the adhesion force compatible with the application of 10% sodium ascorbate for 10 minutes. SOD is a nontoxic antioxidant which has been used for the 1st time in an *in vitro* application for the reversal of bond strength [24]. It provides newer avenues for advanced clinical research and exploring its further applications. However, further clinical studies are needed to confirm these findings.

ANTIOXIDANT AGENTS

Enzymatic agents such as catalase and peroxidase, and non-enzymatic agents as sodium ascorbate, flavonoids, lycopene and vitamin E have antioxidant properties [1,2,8,14,26-30].

Catalase is an enzymatic agent more effective in increasing bleached enamel adhesion than glutathione peroxidase. This is due to its mechanism of action, which requires a small number of molecules to promote an antioxidant effect. Catalase accelerates the conversion of hydrogen peroxide into oxygen and water, while glutathione peroxidase produces two hydrogen ions which react with hydrogen peroxide resulting in two molecules of water [31].

However, both enzymes are incapable of completely neutralize hydrogen peroxide when applied for a period of 20 minutes [31].

Sodium ascorbate and ascorbic acid, also known as vitamin C, are neutral, biocompatible, water soluble and they can remove the active free radicals in biological systems [14]. Due to their potent antioxidant effect, sodium ascorbate allows polymerization of free radical resin without premature interruption restoring the altered redox potential of the substrate and thus reversing the reduced adhesion [1].

These non-enzymatic agents can be used in solution or gel form without changing their antioxidant effect [9,31]. Gel of sodium ascorbate or ascorbic acid can be easily applied to a bleaching tray before composite resin procedures [2,32]. However, antioxidant solutions need to be applied on the enamel surface several times, increasing the cost and treatment period [33].

Sodium ascorbate has been evaluated at concentrations of 10%, 20% and 40%, being the first concentration more commonly used. 10% Sodium ascorbate has been shown to be effective in reversing the bond strength to bleached enamel when applied for 1 hour [32], 2 hours [34-36], 3 hours [2,9,32], 4 hours [34] or 10 hours [37]. There is no consensus in the literature regarding its use for short periods of time. Some studies report that the time application of 5 minutes [3], 10 minutes [32,34], 15 minutes [33] or 30 minutes [33,35] is not enough to reverse adhesion strength. Other studies show that the application of 10% sodium ascorbate over 10 minutes [28,38-41] or 15 minutes [42] is capable of But Alencar et al. [42], suggest that although the results are immediate and satisfactory statistically similar to the uncollated group, these values are reduced in comparison with the force of adhesion found in groups with a waiting time of 7 days, thus being safer for 7 days after bleaching to perform the adhesive restorative procedure. Good results with 10% sodium ascorbate in a short period of time has been possible when it is applied 24 hours after bleaching [43] or when the bleaching agent is used in a shorter time than recommended clinically [44]. According to Lai et al. [2], 10% sodium ascorbate should be used for at least one third of the time of the bleaching to be effective.

The application of antioxidant agents for a brief period and immediately after bleaching is essential for being clinically feasible.

Studies have shown that 10% ascorbic acid when used for 1 or 10 minutes over can create micromechanical retention on bleached enamel due to its low pH, which consequently increases the bond strength [45,46].

Antiseptic components, such as chlorhexidine, essential oils and sodium fluoride have an antioxidant potential which has been recommended for the prevention of caries lesions and periodontal diseases. However, the use of 5% potassium nitrate, 0.05% or 2% sodium fluoride has not been sufficient to neutralize the oxidative potential of 35% hydrogen peroxide [47].

Flavonoids which have the highest antioxidant properties are the anthocyanins (malvidin and pelargonidin) that are present in fruits and vegetables [16], catechins present in green tea [36] and proanthocyanidins found in high concentrations in various natural sources [48].

The malvidin and pelargonidin are non-enzymatic agents presents in cherries, strawberries, red grapes, teas, radishes, tamarind, fruits with dark pigments, and flowers. Although displaying antioxidant potential, both substances are not able to reverse the reduced bond strength to enamel when applied for 10 minutes [14].

The catechins have antioxidant, antimutagenic and anticarcinogenic properties that can prevent cardiovascular disease reduce dental erosion and periodontal inflammation. Its potent antioxidant action is justified by the presence of three adjacent hydroxyl groups that react more effectively with free radicals. The application of a 5% green tea solution for 10 minutes [49] or the application of a 10% green tea gel for 15 or 30 minutes after bleaching [33] has not been sufficient to reverse the bond strength [33,49], but the application for 1 hour after bleaching restored adhesion to enamel [36]. Epigallocatechin gallate (EGCG) is an antioxidant compound present in green tea and belongs to the group of catechins [41]. Lambert and Elias [50], concluded that EGCG had antioxidant activity. The antioxidant activity of EGCG is due to its chemical formulation and polyphenolic nature. The application of 1000 μmol EGCG solution for 10 minutes was able to revert the adhesion force to bleached enamel without statistical difference of the unbleached group [41].

Proanthocyanidins, a group of polyphenolic flavonoids, are found in high concentrations in natural sources such as pine bark extract, grape seed extract, lemon peel, cranberries tree as well as the leaves of the hazel tree [48]. A solution with 5% grape seed extract applied for 10 minutes on the bleached enamel was able to avoid the decrease in bond strength after bleaching [41]. However, the same result was not obtained in the 10% concentration in which there was no reestablishment of the adhesion force to the enamel [49]. From of grape seed extract, a concentration of 6.5% of proanthocyanidin applied for 10 minutes increased the bond strength to enamel, but it was not able to reverse it completely. This may be related to the fact that the surface treatment for the molecular weight of the antioxidant should be less than 500 g/mol for the efficient elimination of free radicals. The proanthocyanidin has molecular weight of 500-3000g/mol and it is a highly hydroxylated structure that can form insoluble complexes with proteins and carbohydrates hindering its action on the residual oxygen [50].

Pomegranate peel extract contains effective compounds such as polyphenols whose antioxidant benefits preponderate over green tea [49]. Despite this, the application of 10% pomegranate peel extract solution for 10 minutes on the bleached enamel was not able to avoid the decrease in bond strength [49].

Previous studies have shown that these herbal antioxidants can reverse the decreased bond strength of composite to bleached enamel [41,49,51]. The sage extract has demonstrated antioxidant properties is due to its polyphenolic nature and chemical formulation, however the mechanism of action has not yet been fully understood. Polyphenols such as caffeic acid, hispidulin, apigenin, rosmanol, carnosic acid, carnosol and ursolic acid are among the active ingredients. Similar to other antioxidants, these polyphenols inhibit the formation of reactive oxygen species [41,52]. The application of the 10% sage extract

for 10 minutes demonstrated adhesion strength to bleached enamel compatible with unbleached teeth or treated with antioxidants such as sodium ascorbate, grape seed extract and epigallocatechin gallate [41].

The lycopene, a carotenoid compound, is a natural pigment synthesized by plants and it can be found in ripe tomatoes, red peppers, watermelons and guavas. It has a potent anti-inflammatory effect due to antioxidant action and presence of free radical 5% lycopene. Although the lycopene can increase the bond strength to bleached enamel when applied for 10 minutes, its effectiveness is lower than other antioxidants such as sodium ascorbate and proanthocyanidin [53].

The α-tocopherol is the most active component of Vitamin E complex, and this organic substance is the most potent antioxidant in the lipid phase of the body. Its effectiveness in reversing the enamel bond strength has been verified when applied for 2 hours and can be attributed to active principles as methyl salicylate or the use of ethanol as a vehicle [47,54]. The application of α-tocopherol for 10 minutes is able to raise the adhesion strength to bleached enamel, but its adhesion strength is lower when compared to other antioxidants such as sodium ascorbate or the 7-day waiting period [30].This result is justified by the fact that the bond strength to bleached enamel is increased according to the period of application of an antioxidant agent [35].

Thus, the application of antioxidant agents for a short period of time has not been enough to neutralize reactive oxygen and reestablish the bond strength to bleached enamel. Although some antioxidant agents have been shown to be effective, its high cost and prolonged application become difficult its clinical use. Furthermore, the effect of these agents on the longevity of composite restorative is unknown. *in vivo* studies also show needed to evaluate the effect of antioxidants on the bond strength to the enamel immediately after bleaching.

CONCLUSION

Based on this literature review it was concluded that the most established method for reversing the reduced bond strength to bleached enamel is the waiting period of at least one week.

Further studies should be conducted to evaluate the application of alcohol, acetone, and antioxidant agents in different concentrations and for a short period of time to be clinically feasible and efficient in a short and long term.

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