TOOTH WHITENING: EFFICACY, EFFECTS AND BIOLOGICAL SAFETY

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ABSTRACT

Personal appearance is important in today's society. Many products and procedures, including tooth whitening, are being marketed to the public as a method for enhancing personal appearance. People frequently ask dental professionals whether tooth whitening is effective and whether it would be appropriate treatment for them. In order to field the public's questions and promote informed choices, dental hygienists must be knowledgeable about tooth whitening products and procedures.

A MedLine search over a 25-year period was conducted to locate studies about the efficacy, effects and biological safety of tooth whitening products and procedures. The search resulted in approximately 60 articles. Additional articles were obtained through article references. The objective of the research was to prepare a literature review on tooth whitening.

The literature revealed that teeth can be bleached approximately two shades but a second follow-up treatment is usually required after one to three years. In-office and at-home bleaching techniques were studied. Bleaching materials were found to adversely affect dental hard tissues. Some evidence was provided to support the view that short-term effects of tooth whitening on tooth pulps appear to be reversible. Long-term effects of bleaching agents on hard and soft tissues remain unknown. Evidence shows there is a reduction in enamel-composite resin bond strength in teeth treated with peroxide agents though the clinical significance of this bond reduction is not known. Safety issues concerning the impact of peroxide agents on human oral mucosal antioxidant defense mechanisms were identified.

The writers' research found little consensus in much of the research. A number of significant areas of concern have not yet been thoroughly investigated. Long-term scientific human studies are recommended to address the unanswered questions about the efficacy, effects and biological safety of tooth whitening.

INTRODUCTION

As primary oral health care providers, dental hygienists often provide information about dental treatments and procedures to the public. Dental tooth whitening is a subject about which many people seek information and advice, so it is important for dental hygienists to possess current and accurate knowledge about tooth whitening products and procedures. This article provides information from the scientific literature that will help dental hygienists field questions and promote careful and reasoned choices by the public.

A MedLine search over a 25-year period was conducted. This paper provides a literature review that examines the efficacy of tooth bleaching and its effects on hard and soft oral tissues, the psychological impact of dental aesthetics, the impact of bleaching agents on selected restorative materials, and possible health issues surrounding tooth whitening.

PSYCHOLOGICAL EFFECTS OF APPEARANCE

Personal appearance is very important in society. Dentists are called upon to respond to requests from patients who wish to enhance their smiles.[1] The effect of a smile can be so significant that advertising experts refer to this phenomenon as "smile power".[2]

Social and psychological research has shown that appearance plays an important role in determining the quality of our interactions with others and is an important aspect of nonverbal communication.[2,3] How people look can affect how they see themselves, what others think of them, and how they attract others to them. By enhancing their appearance, people can change the impression they make on others. Physical attractiveness and self-evaluation have been positively correlated.[2,3] Research has shown that throughout their lives attractive individuals have significant advantages over those perceived by society to be less attractive.[2]

The influence of cosmetics in promoting psychological well-being and to the importance of self-perceived attractiveness is beginning to be recognized and understood in health care. Studies have shown that when increased attention is placed on appearance, patients' adjustments to illness and recuperation times are affected positively.[3] In dentistry, Jenny et al. confirmed that dental esthetics impact on the perceived levels of self-confidence in assessments of personality characteristics.[4] Cosmetic dentistry appears to be emerging as a health service. Researchers agree that more investigation into psychological factors associated with appearance is needed.

MECHANISMS OF ACTION

STAIN FORMATION

To date the process of stain formation is not well understood. Pellicle-coated enamel is known to have a net negative charge, so permitting selective adhesion of positive ions to tooth surfaces. This is believed to play a critical role in the deposition of stains on tooth surfaces.[5] It seems likely that ions from food and drink containing tannins as well as chromogens such as copper, nickel, and iron, attach to the negative charge on the pellicle-coated enamel, causing dental stains.

BLEACHING

The mechanism of action of bleaching is also unclear. Bleaching is an oxidation reaction. The enamel to be bleached donates electrons to the bleaching agent.[2] Ten per cent carbamide peroxide breaks down to 3% hydrogen peroxide and 7% urea. The hydrogen peroxide metabolizes into water and free radicals of oxygen. These free radicals possess a single electron, which is thought to combine with the chromagens to decolourize or solubize them.[5]

EFFICACY AND PROGNOSIS OF TOOTH WHITENING

Documented reports on the efficacy and prognosis of tooth whitening consist largely of clinical and anecdotal observations. There is a lack of consensus among researchers about the results of in-office and at-home tooth bleaching.[6,7] Haywood and Heymann were the first to report on the procedures and results of an at-home vital tooth bleaching system utilizing night guards and 10% carbamide peroxide.[8] This technique resulted in a lightening the teeth by the shade guide equivalent of approximately two shades. No detrimental effects on the teeth or gingiva were observed and no significant tissue problems, odour or bad taste were reported. Prior to Hayward and Heymann's report, in-office bleaching techniques were most commonly used. The in-office technique involved acid etching the enamel with 37% phosphoric acid. This was followed by the application of 30–35% hydrogen peroxide applied with supplementary heat using a specially designed lamp or a contact instrument. The literature records that in-office bleaching appears to be preferred by dentists because the procedure can be more readily controlled and monitored. However, at-home bleaching has become increasingly popular because it is easy to use, time-saving and cost-effective.[9–11]

There is well documented evidence that shows the unpredictability of tooth bleaching results. The degree of whitening or lightening that can be achieved, the length and number of treatments required, the type of stain that will respond, and how long the results of bleaching last, are difficult to predict. Bleaching tooth stain that requires prolonged treatment may result in a whiter but chalkier, rather dull and flat appearance that is not aesthetically pleasing. Some tetracycline stains may *appear* lighter after bleaching but do not become whiter. Researchers agree that brown-orange and yellow tooth stains in older adults bleach the fastest and easiest though similarly coloured stains in teens and young adults do not respond as well. Blue-gray stains are significantly more difficult to eliminate. Moderate to dark stains, and those caused by tetracycline, have been found to be the least likely to respond.[8] Reports indicate that vital night guard bleaching techniques can achieve acceptable esthetic results.[12–16] The effects of both at-home and in-office bleaching are unlikely to be permanent. Follow-up treatments have often been found to be necessary in between one and three years.[12–16]

EFFECTS OF HYDROGEN PEROXIDE ON HARD TISSUES

To date, studies examining the adverse effect of peroxides on the microhardness of dental hard tissues have shown conflicting results. Rotstein et al. subjected human premolars to solutions of 30% hydrogen peroxide, 10% carbamide peroxide, sodium perborate, and three commercially-prepared bleaching agents (utilizing 10-15% carbamide peroxide with pH ranges from 6.0 to 6.5).[17] Results showed that most of the bleaching agents caused changes in the levels of calcium, phosphorus, sulfur, and potassium in the hard tissues. Alterations in the inorganic components of hydroxyapatite are the result of changes in the calcium/phosphorus ratio found within the hydroxyopatite crystals of dental hard tissues. The decrease was more significant in cementum and dentin than in enamel. This was in all likelihood due to differences between the organic and inorganic matter of the tooth. It was concluded that bleaching materials may adversely affect dental hard tissues.

Lewinstein et al. also studied the microhardness of human enamel and dentin.[18] Thirty per cent hydrogen peroxide was used at 37°C and 50°C. This study found a reduction in the microhardness of enamel and dentin. The hardness reduction was time-related and results were statistically significant on dentin following a five-minute treatment and on enamel after a fifteen-minute treatment ($p < 0.05$). Researchers suggested that the use of high concentrations of hydrogen peroxide should be limited.

Shannon et al. evaluated the effect of three 10% carbamide peroxide bleaching agents with different pH values on enamel microhardness and surface morphology following 16 hours of daily exposure for two and four weeks.[19] Unlike other studies, this was a combined *in vitro* and *in vivo* study. Results indicated that there were no statistically significant differences between the microhardness values of the subject and control groups at two weeks or at four weeks, although hardness values of subjects were less than those of controls. There was an increase in microhardness at four weeks, which may have resulted from exposure of the enamel to artificial saliva. Remineralization potential exists with saliva substitutes containing calcium and phosphate ions. Scanning electron microscopy showed differences in surface topography of enamel treated with bleaching solutions. These changes were observed in surfaces treated with the lower pH carbamide peroxide agents and appeared as pitting and/or enamel erosion. Enamel remineralization resulting from exposure to saliva may modify this effect.[19,20]

Attin et al. observed an initial significant loss of enamel microhardness after bleaching.[20] Rehardening of the enamel after treatment was attributed to the remineralization capacity of saliva. Furthermore, results showed a decrease in enamel surface hardness in those samples treated with highly concentrated fluoride applications.

PULPAL CONSIDERATIONS

Studies have been conducted to examine the penetration of hydrogen peroxide and carbamide peroxide into the pulp chambers of teeth. Human and canine studies showed that both low (10%) and high (35%) concentrations of bleaching agents readily penetrate the pulp chamber.[21-24]

Cohen applied 35% hydrogen peroxide and heat for 30-minute sessions to human teeth due to be removed for orthodontic treatment.[21] Varying degrees of sensitivity, lasting from 24–48 hours, were reported by 78% of the subjects. Twenty-two per cent reported no sensitivity. Histological findings in both the experimental and control groups showed that, except for moderate vasodilation and aspiration of odontoblast nuclei into the dental tubules, all pulps were normal. There were no histological findings to explain the sensitivity experienced by the subjects. A possible explanation may be that pressure builds in the pulp chamber as a result of the heat applied, causing the sensation of pain. The sensitivity, moderate vasodilation and aspiration of odontoblasts into the dental tubules appeared to be reversible in most cases.[21–24]

Seale exposed the canine teeth of dogs to 35% hydrogen peroxide with and without heat.[23] The control teeth either received heat only or had no treatment at all. Histological examinations following exposure were conducted at 3, 15, and 60 days. Application of heat only caused some vasodilation in the canine tooth pulps but no other pulpal changes. The application of hydrogen peroxide with and without heat caused some initial severe pulpal changes that included obliteration of odontoblasts, hemorrhage, inflammation and internal resorption of dentin. The 60-day histological examination showed only a few changes in otherwise normal pulps. Apparently the pulps were able to recover within that time. The severity of pulpal change reported by Seale is in contrast to the findings of Cohen.[21] This may be explained by differences between canine and human teeth. The two studies agree that the observed pulpal changes were reversible. Although clinical observations and scientific literature report short-term, minimal hypersensitivity to in-office and at-home bleaching treatments, there have been studies published that raise concerns about possible harmful effects of some bleaching agents on the pulp.[25–30]

Glucose metabolism and protein synthesis, especially collagen synthesis, are the two most central metabolic processes occurring in the pulp. These metabolic reactions are catalyzed by enzymes that are sensitive to changes in environmental conditions.[29] Bowles and Thompson examined combined effects of heat and hydrogen peroxide on pulpal enzymes and found that most of the enzymes were relatively resistant to the effects of heat up to 50ºC.[27] However, nearly every enzyme tested was inhibited to some degree by hydrogen peroxide. At concentrations as low as 5% some enzymes were completely inactivated. Results indicated that a combination of heat and hydrogen peroxide might increase the permeability of the pulp and potentiate the effects of hydrogen peroxide on the pulp. While the pulp appears to be quite resilient, there is concern for patients who may apply bleaching agents for longer periods of time or more frequently than recommended in order to hasten the achievement of whiter teeth. The long-term effects of frequent or prolonged use of bleaching agents on pulps are unknown.[26–29]

The reasons for tooth sensitivity during vital tooth bleaching are not clear. Studies are inconclusive regarding the pulpal considerations of vital tooth bleaching. What is clear, however, is that case selection is critical. Considerations prior to initiating tooth whitening procedures should include assessment of the condition of existing restorations, cervical erosion, enamel cracks, and the estimated duration and repetition of bleaching required to obtain and maintain the desired effect.[30]

THE EFFECTS OF PEROXIDE BLEACHING ON COMPOSITE RESIN TO ENAMEL BOND STRENGTH

While there is a record in the literature of in-office and at-home tooth bleaching, many questions remain unanswered regarding the effects of bleaching agents on both tooth structures and restorative materials and procedures.[31] The literature is consistent in demonstrating a reduction in the enamel-composite resin bond strength in teeth previously treated with some form of peroxide agent.[31–34] Disagreement occurs with respect to the duration of this reduction, ways to reverse this effect, and the clinical significance, if any, of the reduced bond strength.

Dishman et al. studied the effects of 25% hydrogen peroxide on human teeth.[31] Results showed a reduction in enamel-composite bond strength that was time dependent. Although reductions in bond strength appeared to last less than 24 hours, bond strength tested one month after bleaching was significantly lower in the group that was bonded one week after bleaching than in the control group. This evidence indicates that there may be a longer-term effect on the enamel-composite bond strength from bleaching. The significance of this is unknown.

Titley et al. reported a statistically significant reduction in bond strength in bovine teeth following treatment with 35% hydrogen peroxide.[32] They also showed that the reduction in bond strength could be moderated to varying degrees by water immersion following exposure to the bleaching agent. However, the immersion time required to totally eliminate the effect on bond strength was undetermined.

Titley et al. studied the effect of 10% carbamide peroxide at pH 4.7 and 7.2 on bovine teeth.[33] The purpose of the study was to test whether the less concentrated peroxide (10% carbamide peroxide) commonly used in most at-home tooth-whitening products yielded the same effect as previous studies utilizing 35% hydrogen peroxide. The results of the shear bond strength tests revealed a statistically significant difference ($p < 0.01$). There were no statistically significant differences due to exposure time (3 hours vs. 6 hours) or pH (4.7 vs. 7.2). Although this study demonstrated a reduction of shear bond strength due to exposure to 10% carbamide peroxide, the reduction in bond strength was substantially less than where 35% hydrogen peroxide was used. The investigators stated that the results are not conclusive regarding the clinical significance of the reduction of enamel adhesive strength due to exposure to 10% carbamide peroxide products. They did recommend a delay of at least 24 hours for restorative treatment following any bleaching procedures using peroxide-based agents.

Stokes et al. conducted shear bond strength tests on human teeth treated with 35% hydrogen peroxide and 10% carbamide peroxide.[34] It was determined that the shear bond strengths of resin-enamel bonds following treatment with both types of peroxide were significantly lower than the controls. The use of lower concentration carbamide peroxide (10%) posed similar hazards to resin bonding as with the 35% hydrogen peroxide.

Researchers explain the reduction in the adhesive strength of the peroxide-treated enamel as the interactions occurring at the resin-enamel interface. There is evidence of voids in the bonding resin possibly caused by gaseous bubbles resulting from the oxidizing reaction of peroxide entrapped in the subsurface layer of the enamel. Elimination of the trapped peroxide, achieved by leaching in water, may cause an increase in adhesive strength of the enamel surface.[32,33] Decrease in adhesive strength following various bleaching regimens appears to be limited to the surface of the enamel and may not be a factor if the surface layer of the enamel is removed following bleaching. This procedure is thought to be effective since polymerization of bonding agents is known to be inhibited by oxygen. If the oxygen-rich surface layer of enamel is removed, the resin-enamel bond strength returns to near normal. The exact depth of this layer is not known, but must be greater than 5–10 microns, otherwise the acid etching prior to bonding would remove this oxygen-rich layer of enamel.[31]

BIOLOGICAL COMPATIBILITY OF PEROXIDE BLEACHING AGENTS

Methods of tooth whitening have existed for more than 100 years.[35] During the last decade increased attention to techniques of bleaching has raised safety concerns.[36] The review by Goldstein and Kiremidjian-Schumacher found 246 citations by cross-referencing hydrogen peroxide with toxicity.[36] There are safety concerns associated with the potential biological effects of free radicals, specifically free radicals of oxygen, that are by-products or intermediates of hydrogen peroxide metabolism.[35] A search of the literature shows a lack of any conclusive findings and often contradictions about the toxicity of hydrogen peroxide. The oxidative process is thought to be associated with the development of carcinogens, aging, stroke, liver disease, and other degenerative diseases.[35–39] Although hydrogen peroxide has been in widespread use for many years as an antiseptic in the healing of wounds, as a whitening agent for teeth, and as an adjunct in periodontal therapy in combination with salt and/or sodium bicarbonate, concerns persist and questions remain unanswered.[40,41]

The most common side-effects of tooth bleaching techniques are transient thermal sensitivity and oral irritation or ulceration.[30,40,41] A few reported cases have shown severe reactions to vital tooth bleaching.[24,25] The greater concern for safety relates to the subtle biological reactions that take place rather than the clinically observable reactions.

There is an oxygen paradox in aerobic life. While oxygen is essential for higher life forms, it is also toxic to all aerobes under certain conditions.[36,39] During respiration, humans metabolize oxygen into water. In this metabolic process, chemical reactions occur that result in the formation of water and by-products. A small fraction (2–5%) of the total oxygen consumed by all humans is diverted and forms semi-reduced forms of oxygen. These “activated oxygen species” are generally unstable, very reactive, and will act as chain carriers in chemical reactions. At least three such chemical species are involved in oxygen free radical damage in biological systems: hydrogen peroxide, superoxide, and the hydroxyl free radical.[37,39] Superoxide and hydrogen peroxide participate in oxidative reactions, which damage lipids, proteins and nucleic acids.[37]

All tissues are constantly subjected to oxidative stress because they exist in an aerobic or oxygen-rich environment. Nature has created enzymes (SOD, catalase, peroxidase) and antioxidants (ascorbate, vitamin E, glutathione) which help the body defend against the effects of oxidation. Biological systems exist in a state of dynamic equilibrium where the antioxidant defense capacity counteracts the oxidative damage potential. When the antioxidative capacity of the system is overwhelmed, serious consequences may occur.[37,39]

Weitzman et al. investigated the effects of 3% and 30% hydrogen peroxide alone and in combination with a known carcinogen, DMBA (9,10-dimethyl-1,2-benzanthracene, an analogue to a known ingredient in tobacco).[40] Four hydrogen peroxide solutions were applied topically to the buccal mucosa of Syrian hamsters twice a week for 22 weeks. All animals treated with 30% hydrogen peroxide alone exhibited hyperkeratosis and hyperplasia, and four of nine revealed hyperchromatic cells and mild dysplasia. In animals treated with DMBA alone, three of seven developed epidermoid carcinoma. Six of eleven animals treated with DMBA together with 3% hydrogen peroxide and all animals treated with DMBA plus 30% hydrogen peroxide developed carcinomas. It was concluded that long-term exposure to hydrogen peroxide can itself induce pathologic changes and may augment the oral carcinogenesis associated with DMBA. It is not known if exposure to hydrogen peroxide from tooth bleaching can deplete or overwhelm human oral mucosal antioxidant defense mechanisms. Although animal studies cannot be generalized to humans, these results suggest that caution should be exercised especially in concomitant use of tooth bleaching agents containing hydrogen peroxide for patients who are tobacco users.

Rees and Orth reported that 3% hydrogen peroxide delayed the healing of wounds, caused leukoplakia, ulcerations on the tongue, alveolar, and labial mucosa, and eroded papillae.[41] Evidence suggests that hydrogen peroxide may be harmful to oral tissues even when used for short time periods, and that with chronic use, injury may be more severe.

There is a strong association between oxygen free radicals and the development of cancer, although the exact mechanism is not well understood.[38] Carcinogens develop in a two-step process, initiation and promotion. Free radicals are thought to play a role in both processes. During initiation, changes occur in the genetic material of cells. DNA strand breakage is mediated by active oxygen species such as hydrogen peroxide, which damage specific amino acids in proteins. Initiated cells can remain dormant. An influx of oxidative potential could possibly promote already-initiated cells to express themselves.

Dental tooth bleaching involves the use of various concentrations of hydrogen peroxide or carbamide peroxide. The metabolism of hydrogen peroxide yields oxygen free radicals. These free radicals are very reactive and mobile. If they are able to gain access to connective tissue, the free radicals may adversely affect gingival fibroblasts and their ability to maintain the tissue and participate in healing.[42] Just how susceptible tissue is to oxidative stress depends on the magnitude of the stress and the antioxidant status of the tissue. A pre-existing tissue injury, chronic inflammation or the concurrent use of alcohol and/or tobacco while using tooth whiteners may exacerbate their toxic effects.[40,42–44] Animal studies have raised the issue of potential health concerns related to prolonged hydrogen peroxide use.[45] Overt signs of hydrogen peroxide toxicity in dental tooth whitening have not been recognized and researchers have yet to definitively determine the long-term effects of hydrogen peroxide when used in tooth bleaching agents.

CONCLUSION

What is evident from a review of the literature is the lack of consensus in much of the research. Many areas of concern have not yet been thoroughly investigated. It is well-documented that teeth can be bleached. Most authors conclude that retreatment is necessary but disagree on the intervals of time between treatments with reports ranging form one to three years. Transient clinical side-effects such as thermal sensitivity and mucosal irritation have been reported. Bleaching agents exert some changes in hard and soft oral tissues and in restorative materials, although it is uncertain if these changes are clinically significant. The short-term effects on dental hard tissues and pulpal tissues appear to be reversible.

Questions about the frequent and/or long-term use of bleaching agents and their impact on dental hard tissues, pulpal tissues and oral soft tissues remain. Hydrogen peroxide agents pose some health risk concerns when used in biological systems. The impact of hydrogen peroxide on human oral mucosal antioxidant defense mechanisms is not yet completely understood. Long-term scientific human studies are needed.

Because dental tooth whitening is likely to continue to be an available treatment option, dental hygienists can use the current literature to educate the public about the pros and cons of tooth whitening agents and procedures. When bleaching procedures are to be implemented, dental hygienists can ensure that the client is a non-smoker with healthy periodontium, has no cervical erosion or enamel cracks, and has intact restoration margins. Clients should be provided with custom-fitted bleaching trays with viscous bleaching gel and be advised to follow instructions very carefully. Clients should be firmly reminded not to retain the trays with bleaching agent in their mouths overnight while sleeping, nor to increase the amount of bleaching agent or the frequency of their use of bleaching agents without first consulting a dental professional.

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