In vitro evaluation of tooth colour modifications using differing hydrogen peroxide concentrations

By David Bardwell DMD, MS, Aikaterini Papathanasiou, DDS & Simone Deliperi, DDS

Much of bleaching is still an unknown science. In this study, the authors look at products on the US market and evaluate the effects of different levels of hydrogen peroxide on tooth colour modification

One of the fastest growing areas of cosmetic dentistry today is the management of the discoloured and/or hypoplastic dentition. Bleaching is the most conservative treatment for discoloured teeth compared to resin-bonded composites, porcelain veneers and crowns. Tooth bleaching has become dentistry's most popular aesthetic treatment. The exact mechanism of action is not completely understood, but theorised. Hydrogen peroxide diffuses through the organic matrix of the enamel and dentine (Bowles et al 1987, 1986; Fuss et al, 1989). Because the radicals have unpaired electrons, they are extremely electrophylic and unstable and will attack most other organic molecules to achieve stability, generating other radicals. These radicals can react with most unsaturated bonds, resulting in disruption of electron conjugation and a change in the absorption energy of the organic molecules in tooth enamel. Simpler molecules that reflect less light are formed, creating a successful whitening action. This process occurs when the oxidising agent (hydrogen peroxide) reacts with organic material in the spaces between the inorganic salts in tooth enamel (Goldstein and Garber, 1995).

Since the introduction of carbamide peroxide for home bleaching (Haywood & Heymann, 1989; Haywood, 1992) approximately 12 years ago, continued development of new techniques and materials with improved properties have occurred (Garber, 1997; Settembrini et al, 1998) spurning greater case acceptance amongst clinicians. Safety and effectiveness of Nightguard Vital Bleaching (NGVB) has been widely reported in several studies (Leonard et al, 2001; Ritter et al, 2001; Haywood et al, 1994). Acceptable techniques include the dentist-prescribed in-office booster, the home-applied tray delivery system, or a combination of the two. The in-office bleaching technique employs a 15-35% hydrogen peroxide bleaching agent (heated or non-heated), while the dentist prescribed home-applied technique most commonly uses a 10 or 15% carbamide peroxide gel. The very slow response to NGVB in some cases (Barghi, 1998) and patients' demand for faster methods, have pushed the clinician to look for easier, more rapid means of obtaining whiter teeth.

The advantage of the in-office procedure is that it does not require patient compliance and immediate results may be seen. The disadvantage is the chairtime and cost to the patient, as this procedure usually requires multiple visits.

The introduction of very high intensity plasma arc lights and argon lasers in the market are a result of this increasing demand. However, no study to date has demonstrated these approaches to be more effective than traditional bleaching methods (Garber, 1997). There is evidence that these systems on their own do not bleach teeth without judicial use of hydrogen peroxide. It should also be noted that the increased temperature developed by these light curing systems may increase tooth sensitivity (Cohen, 1979; Seals et al, 1981).

The use of hydrous gel (Barghi, 1998), the development of a light cure gingival barrier (Barghi et al, 1997) and the optional use of the curing light (Kastali et al, 2001) have greatly simplified the in-office bleaching procedure. The association of in office and at home bleaching

The authors are based at Tufts University School of Dental Medicine, Boston, USA. David Bardwell DMD, MS is Director of Postgraduate Esthetic Dentistry, and is an associate clinical professor of Restorative Dentistry in the Divisions of both Fixed and Removable Prosthodontics and Operative Dentistry. Aikaterini Papathanasiou, DDS is an assistant professor of Restorative Dentistry. Simone Deliperi, DDS is a visiting instructor of Restorative Dentistry at Tufts University School of Dental Medicine

TABLE 1: VITA VALUE ORDER

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

has demonstrated encouraging results (Barghi, 1998; Kugel et al, 1997; Papathanasiou et al, 2001). The use of a more stable and less caustic hydrogen peroxide bleaching material, along with concomitant use of 10% carbamide peroxide containing fluoride and potassium nitrate may help to satisfy patients' increasing demand to achieve whiter teeth faster with more predictable results. Finally, current bleaching methods can offer a conservative, efficient, and economical approach to changing the colour of one's teeth.

MATERIALS AND METHODS

40 freshly extracted caries-free human teeth were used in this in-vitro evaluation. All teeth were scaled before being stored in physiologic saline. Teeth were randomly divided into four groups of ten. Each tooth was coded with the group and specimen numbers. All samples were evaluated for initial shade according to the Vita shade guide arranged by value order (lightest to darkest) and all shades will be recorded. A relative number was assigned to each Vita shade (B1-1, A1-2, B2-3, etc., as seen in Table 1). Shades were selected by three independent evaluators precalibrated at 85% reliability. Teeth were removed from physiologic saline and cleaned with a prophycup and prophypaste without fluoride. After being rinsed and air-dried, all teeth were exposed to hydrogen peroxide. Group I samples were exposed to 7.5% hydrogen peroxide (Table 3), Group

TABLE 2: MEAN SHADE CHANGE

Group I	4.7±2.6
Group II	6.7±2.0
Group III	5.1±1.4
Group IV	6.6±2.1

Figures 1 & 2: Before and after bleaching - note shade change

Figures 3 & 4: Bleaching on tetracycline-stained teeth

TABLE 3: GROUP I SAMPLES EXPOSED TO 7.5% HYDROGEN PEROXIDE

Group I

Baseline	1st tx	2nd tx	3rd tx	Total
A3	A3(0)	C2(2)	C2(0)	2
B4	B4(0)	D3(3)	D4(2)	5
A4	B4(2)	C2(6)	C2(0)	8
A4	A4(0)	C3(1)	B4(1)	2
A4	A4(6)	C2(2)	C2(0)	8
A4	C3(1)	C3(0)	C3(0)	1
A3.5	C2(5)	C1(1)	A2(1)	7
B4	A3(4)	C2(2)	C2(0)	6
C4	C4(0)	C4(0)	A4(1)	1
A4	A3.5(3)	A3.5(0)	A3.5(4)	3

II to 15% hydrogen peroxide (Table 4), Group III to 25% hydrogen peroxide (Table 5) and Group IV to 35% hydrogen peroxide (Table 6).

All bleaching materials were applied on the buccal/facial surfaces of the teeth, limiting it to enamel only, for 30 minutes for three consecutive days. All specimens were stored in saline between treatments. After each whitening session, shade evaluation was conducted for each tooth and recorded, in the same manner as performed initially.

Statistically analysis was employed to evaluate results. All groups were compared to determine if statistical difference exists between the groups.

STATISTICAL ANALYSIS

Statistical analysis was employed to evaluate the mean shade change when all groups were compared

When all test groups were compared, utilising the Kruskal-Wallis One Way Anova analysis, a p level of >0.1 was calculated, confirming no significant difference between the groups.

Results of this study showed no significant difference in tooth colour modification when utilising these four different concentrations of hydrogen peroxide (7.5%, 15%, 25% and 35%).Results of all treated samples yielded an average change in shade of 4.7±2.6 for Group I, 6.7±2 for Group II, 5.1±1.4 for Group III and 6.6±2.1 for Group IV. Shade changes were determined from the number of shade changes on the Vita Shade Guide when arranged in value order. Statistical analysis utilising the Kruskal-Wallis ANOVA revealed no statistically significant difference ($p>0.10$) between all groups. In conclusion, the results of this study showed no significant difference in tooth colour modifica-

TABLE 4: GROUP II SAMPLES EXPOSED TO 15% HYDROGEN PEROXIDE

Group II

Baseline	1st tx	2nd tx	3rd tx	Total
A3	A2(7)	B2(2)	B2(0)	9
A4	B4(2)	A3.5(1)	B3(1)	4
A3.5	D4(4)	C1(2)	A2(1)	7
B4	D3(3)	D4(2)	A2(3)	8
D3	C2(3)	C1(1)	C1(0)	4
A3	C1(3)	A2(1)	B2(2)	6
A3	C1(3)	A2(1)	D2(1)	5
A4	C2(8)	C2(0)	A2(2)	10
A4	B4(2)	D3(3)	D4(2)	7
A4	B4(2)	A3.5(1)	B3(1)	4

TABLE 5: GROUP III SAMPLES EXPOSED TO 25% HYDROGEN PEROXIDE

Group III				
Baseline	**1st tx**	**2nd tx**	**3rd tx**	**Total**
C4	C4(0)	A4(1)	B4(2)	3
C4	A3.5(4)	B3(1)	D3(1)	6
C4	A4(1)	A4(0)	B3(4)	5
D3	D4(2)	C2(1)	C2(0)	3
C4	A4(1)	A4(0)	B3(4)	5
A3.5	B3(1)	D4(3)	C2(1)	5
A4	A3.5(3)	A3(3)	D4(1)	7
A3.5	C2(5)	C1(1)	C1(0)	6
C3	A3.5(2)	C2(5)	C2(0)	7
A3	C1(3)	A2(1)	A2(0)	4

tion when utilising the four different concentrations of hydrogen peroxide (7.5%, 15%, 25% and 35%).

DISCUSSION

35% hydrogen peroxide has been the standard for bleaching of discoloured teeth for many years.

Tooth bleaching procedures became widely available with the 1989 introduction of dentist prescribed Nightguard vital bleaching (NGVB) (Haywood & Heymann, 1989). Since then, bleaching popularity has increased exponentially with numerous products available in the market containing differing concentrations of either carbamide (CP) or hydrogen peroxide (HP). Dentists can choose to bleach teeth using 5-22% CP and 1-10% HP home bleaching products, 15-35% HP in office bleaching materials and, as of late, 15% HP and 35% CP waiting room tooth whitening systems.

NGVB using 10% CP has become the standard for home bleaching and has been demonstrated to be safe and effective when appropriately administered (Haywood, 1992; Haywood, 1994; Li, 1998; Swift & Perdigao, 1998; Leonard et al, 2001; Ritter et al, 2001). Conversely, issues of safety and effectiveness are still controversial when higher concentrations (greater than 10% CP) are used. Numerous brands of differing HP concentrations are now available in the market; with lower concentrations being used for dentist prescribed home bleaching, and higher concentrations for in-office bleaching.

This in vitro study evaluated the effectiveness of differing HP concentrations with regard to tooth lightening. Four different concentrations were tested in this study. 7.5% HP (which can be equated to 20% CP) was the lowest con-

TABLE 6: GROUP IV SAMPLES EXPOSED TO 35% HYDROGEN PEROXIDE

Group IV				
Baseline	**1st tx**	**2nd tx**	**3rd tx**	**Total**
C4	C4(0)	A4(1)	3.5(3)	4
A3.5	D3(2)	D4(2)	A2(3)	7
A3.5	B3(1)	D(3)	C2(1)	5
A3.5	B3(1)	D(3)	C2(1)	5
C4	C4(0)	A4(1)	A3.5(3)	4
A3.5	C1(6)	A2(1)	B2(2)	9
A4	A3.5(3)	A3.5(0)	D3(2)	5
B3	A3(2)	A2(4)	A2(0)	6
C3	A3(5)	A2(4)	B2(2)	11
B4	B3(2)	A3(4)	C1(3)	7

centration used. It was chosen as a starting point due to one product presently found readily available to dentists in today's market (Day White- Discus Dental). Secondly 15% HP (which can be equated to 44% CP) was developed by Dentsply/Professional for dentist-prescribed waiting room use (Illumine - Dentsply Professional) (Papathanasiou, 2001). Next, 25% HP (not present in any product on the market that this author is aware of) was considered an intermediate concentration that deserved consideration. Finally, 35% HP, presently the most popular chairside concentration used for in office bleaching, (OpalesceneXtra - Ultradent; Hi Lite - Shofu) (Garber, 1997; Barghi, 1998) was tested.

The results of this study indicated that there was no statistically significant difference between the four groups when teeth where exposed to differing concentrations of HP for 30 minutes in three consecutive days. Even though not statistically significant, the individual tooth colour modifications may be significant from a clinical point of view. An increasing number of patients are asking for dramatic tooth colour modifications in only a few days. This may be achieved by using a combination of in office and home bleaching, utilising 15% (Group II) and 35% (Group IV) HP to boost the home bleaching program. This study demonstrated that teeth in groups II and IV yielded greater lightening than those in I and III. Average change in II and IV were two shades lighter than those in group I and 1.5 shades lighter than those in Group III. At the time of this writing we have no explanation for this result. It may be hypothesised that there is more than one range of effectiveness with respect to concentrations in which HP is supplied for tooth lightening. This may explain the lack of a 25% HP product presently in the market.

It should be noted that Mohakis et al (2000) demonstrated 7.5% HP to be as effective as 20% CP when NGVB is used. This concentration should be considered a home bleaching product only. The results of this study support 7.5% HP use as a take home product, which can be less effective than traditional chairside boosters.

15% HP was as effective as 35% HP in producing similar tooth colour modifications. This seems to confirm the hypothesis that HP is more effective in performing tooth bleaching when used in specific concentrations. It might be helpful comparing these two concentrations of HP to higher concentrations, such as 40 or 50% HP, with respect to efficacy. However, it should be noted that HP concentrations higher than 35% can result in adverse effects to either tooth structure, soft tissues or existing restorations.

Gokay et al (2000) demonstrated higher concentrations of HP can elicit greater pulpal peroxide penetration, which may result in increased tooth sensitivity. Moreover, Weiger et al (1993) and Price et al (2000) stated that the greater the HP concentration, the more acidic the pH of the bleaching solution. Morphological alterations in enamel, dentine and cementum are common when teeth are subjected to pH's lower than 5.2 (Weiger et al, 1993; Driessens et al, 1986; Rotstein & Friedman, 1991). Peroxides may also increase microleakage (Crim, 1992; Barkhordar, 1997; Bardwell, 2000) and reduce tensile and shear bond strength (Stokes et al, 1992; Garcia-Godoy et al, 1993; Titley et al, 1993; Perdigao et al, §998) and which may be time and dose dependent. Some controversy does exist in the international literature with respect to peroxide concentration and pH. Are varied concentrations and/or pH responsible for these alterations? Future investigation is needed to answer these questions, and to better understand the influence of HP on tooth structure and restorative materials.

CONCLUSION

This in vitro investigation helps us understand the effectiveness of differing HP concentrations with regard to tooth colour modifications:

- 7.5% HP was less effective in producing tooth whitening than 15%, 25%, 35% HP, but can represent an alternative to 10% CP for NGVB
- 15 and 35% HP produced the greater tooth colour modification and may be considered materials of choice in boosting a home bleaching programme
- 25% HP was not as effective as 15 and 35% HP. Due to its higher concentration and lower effectiveness it might not be indicated in-office bleaching.

REFERENCES

Bardwell D, Habib C, Kugel G, Mehta N, Leone C (2000). Microleakage of previously restored class II restoratives after exposure to 10% carbamide peroxide. *J Dent Res* **79:** IADR meeting, abstract #306

Barghi N (1998). Making a clinical decision for vital tooth bleaching: at home or in office? *Comp Cont Edu Dent* **19:** 831-838

Barghi N, Berry TG, Ghorbanian A (1997). Clinical comparison of two in office bleaching systems. *Contemporary Esthetics and Restorative Practice* **1(3):** 10-15

Barkhordar RA, Kempler D, Plesh O (1997). Effect of nonvital tooth bleaching on microleakage of resin composite restorations. *Quintessence Int* **28(5):** 341-344

Cohen SC (1979). Human pulpal response to bleaching procedure

on vital teeth. *J Endod* **5:** 134-138

Crim GA (1992). Pre-restorative bleaching: effect on microleakage of Class V cavities. *Quintessence Int* **23(12):** 823-825

Driessens FC, Theuns HM, Borggreven JM, van Dijk JW (1986). Solubility behaviour of whole human enamel. *Caries Res* **20:** 103-110

Garber DA (1997). Dentist monitored bleaching: a discussion of combination and laser bleaching. *JADA* **128(4):** 26s-30s

Garcia-Godoy F, Dodge WW, Donohue M, O'Quinn JA (1993). Composite resin bond strength after enamel bleaching. *Oper Dent* **18(4):** 144-147

Gokay O, Yilmaz F, Akin S, Tuncbilek M, Ertan R (2000). Penetration of the pulp chamber by bleaching agents in teeth restored with various restorative materials. *J Endod* **26(2):** 92-94

Haywood VB (1992). History, safety, and effectiveness of current bleaching techniques and application of nightguard of vital bleaching technique. *Quintessence Int* **23:** 471-488

Haywood VB (1994). Consideration and variations of dentist prescribed, home applied vital tooth bleaching techniques. *Comp Cont Edu Dent* **15:** s616-621

Haywood VB, Heymann HO (1989). Nightguard vital bleaching. *Quintessence Int* **20:** 173-176

Haywood VB, Leonard RH, Nelson CF, Brunson WD (1994). Effectiveness, side effects, and long-term status of nightguard vital bleaching. *JADA* **125(9):** 1219-1226

Kastali S, Papathanasiou A, Perry RD, Kugel G (2001). Clinical evaluation of a light to heat activated bleaching system. *J Dent Res* **80**

Kugel G, Perry RD, Hoang E, Scherer W (1997). Effective tooth bleaching in five days using a combined in office and at home bleaching system. *Compend Contin Educ Dent* **18:** 378-383

Leonard RH, Eagle JC, Garland GE et al (2001). *J Esthet Restor Dent* **13:** 132-139

Li Y (1998). Tooth bleaching using peroxide containing agents: current status of safety issues. *Comp Cont Edu Dent* **17:** s783-s794

Mokhlis GR, Matis BA, Cochran MA, Eckert GJ (2000). A clinical evaluation of carbamide peroxide and hydrogen peroxide whitening agents during daytime use. *J Am Dent Assoc* **131(9):** 1269-1277

Papathanasiou A, Bardwell D, Kugel G (2000). A clinical study evaluating a new chairside and take-home whitening system. *Compend Contin Educ Dent* **22(4):** 289-294, 296, 298

Papathanasiou A, Bardwell DN, Kugel G (2001). A clinical study evaluating a new chairside and take home whitening system. *Comp Cont Edu Dent* **22:** 289-298

Perdigao J, Francci C, Swift EJ Jr, Ambrose WW, Lopes M (1998). Ultra-morphological study of the interaction of dental adhesives with carbamide peroxide-bleached enamel. *Am J Dent* **11(6):** 291-301

Price RB, Sedarous M, Hiltz GS (2000). The pH of tooth-whitening products. *J Can Dent Assoc* **66(8):** 421-426

Ritter AV, Leonard RH, St-George AJ, Caplan DJ (2001). Ten years post-treatment safety and stability of nightguard vital bleaching. *J Dent Res* **80;** AADR meeting abstract #1685

Rotstein I, Friedman S (1991). pH variation among materials used for intracoronal bleaching. *J Endod* **17:** 376-379

Seale NS, McIntosh JE, Taylor AN (1981). Pulpal reaction to bleaching of teeth in dog. *J Dent Res* **60:** 948-953

Settembrini L, Gultz J, Kaim J, Scherer W (1998). A technique for bleaching nonvital teeth: inside/outside bleaching. *JADA* **129(9):** 1283-1284

Stokes AN, Hood JA, Dhariwal D, Patel K (1992). Effect of peroxide bleaches on resin-enamel bonds. *Quintessence Int* **23(11):** 769-771

Swift EJ, Perdigao J (1998). Effect of bleaching on teeth and restorations. *Comp Cont Edu Dent* **17:** s815-s820

Titley KC, Torneck CD, Ruse ND, Krmec D (1993). Adhesion of a resin composite to bleached and unbleached human enamel. *J Endod* **19(3):** 112-115

Weiger R, Kuhn A, Lost C (1993). Effect of various concentration of sodium perborate on the pH of bleaching agents. *J Endod* **19:** 239-241

This project was funded in part by a Grant from Dentsply Professional/York, Pa, USA