An *in vitro* comparison of tooth whitening techniques on natural tooth colour

A. Patel,[1] C. Louca[2] and B. J. Millar[3]

VERIFIABLE CPD PAPER

IN BRIEF

- Supports the use of 10% carbamide peroxide for tooth whitening.
- This regime offers benefits over certain other whitening treatments and provides a similar benefit to power whitening with a halogen light.
- The whitening effect reduces over time after treatment is complete.
- There is a temperature rise within the tooth when using laser whitening.

RESEARCH

Objective Tooth whitening has become a popular treatment regime but there is little quantitative evidence to compare techniques and so confusion may exist for the clinician as to which regime to prescribe for greatest efficacy. The aim of this study was to compare immediate and longer-term colour change on natural tooth colour *in vitro*, using five current tooth whitening techniques with blind matched control groups. **Methods** A total of 100 human teeth of matched size were cleaned, stored in sterile deionised water at 4°C then randomly allocated to one of the five active treatment groups or five matched control groups. The active treatments were: 10% carbamide peroxide (CP) x 60 min, 35% CP x 30 min or 35% hydrogen peroxide (HP) treatment x 30 min activated by one of three sources of energy (diode laser, halogen light, and plasma arc curing light). Tooth colour was analysed with a colorimeter before and after treatment: immediate, one week and nine months post-bleaching designed to generate tooth colour value (L*) according to the L*a*b system. The change in colour was determined as ΔL (the difference in the value of the colour) for each tooth, then the mean differences were obtained for each group and compared. Tooth surface temperature was monitored. **Results** Comparing active treatments with controls it was found that 10% CP, 35% CP, 35% HP with halogen provided significantly greater tooth whitening. Comparing the different treatments showed that 10% CP was significantly more effective ($P < 0.05$) than all other treatments except 35% HP with halogen activation. The effect of each treatment regime over time showed that the 10% CP gave a significant gain immediately and one week later ($P < 0.05$), however, all the whitening effects were lost over time following these single treatments. The temperature rise on the tooth surface was greatest when using laser activation during power whitening. **Conclusion** This study suggests that 10% CP is an effective technique for tooth whitening and can offer significant benefits over alternative regimes.

INTRODUCTION

Tooth whitening is a popular dental procedure and increasing in demand following the recent smoking ban in the UK,[1,2] but treatment options vary with little to guide the clinician wishing to pursue an evidence-based treatment protocol. A popular technique is nightguard whitening in which a carbamide peroxide gel is used at-home, typically in concentrations of 10-16%. At-home techniques are considered to be safe and effective,[3] and are comparatively lower-priced due to the reduced chairside time.[4] The technique can be easily used for the treatment of single discoloured teeth[5] and in one clinical study an observable colour change was sustained in the maxillary anterior teeth of 66% of patients 22 weeks post-bleaching with a 10% CP bleaching gel.[6] However, in a study reporting on tetracycline stained teeth after six months of bleaching, 83% of patients reported no noticeable alteration or only a slight improvement, unnoticed by others, 54 months post-bleaching.[7]

Comparisons of the efficacy of carbamide peroxide concentrations of 10% with 15%,[6] and 5%, 10% with 16%[7] have been reported. Both these studies reported that the higher CP concentrations were more effective but, although it took longer for lower concentrations of CP to whiten teeth, ultimately they could attain an identical result as the higher concentrations.

One drawback with home bleaching is the reluctance to accept a procedure taking several weeks and with that there is the potential for poor patient compliance. Therefore, techniques are being encouraged which bleach teeth more quickly using higher concentrations of carbamide peroxide, for example 22% and 35% in trays, and 35% hydrogen peroxide in a single chairside visit as in 'power bleaching'. The latter uses a combination of a whitening agent and an auxiliary source of energy.[8]

The development of new techniques appears to have been driven by manufacturers of power bleaching equipment and materials rather than following an

[1]Dental Student, King's College London; [2]Senior Clinical Teaching Fellow, Eastman CPD, UCL Eastman Dental Institute, London; [3*]Director of Distance Learning, Senior Lecturer and Consultant in Restorative Dentistry, King's College London Dental Institute, London
*Correspondence to: Dr Brian Millar, Department of Primary Care Dentistry, King's College London Dental Institute, Denmark Hill Campus, Bessemer Road, London, SE5 9RW
Email: brian.millar@kcl.ac.uk

Refereed Paper
Accepted 24 October 2007
DOI: 10.1038/sj.bdj.2008.291

Table 1 Treatments under test and the colour value (L) before and immediately after, seven days, one month and nine months post treatment. The mean L value (ΔL), the mean of each difference in L value from each of the ten specimen teeth, at each review is listed. * = significant P <0.05

L	before	Immed	ΔL1	1 week	ΔL2	9 month	ΔL3
10% CP (active)	65.7	72.6	6.9*	69.9	4.2*	66.7	1.0
10% CP (control)	69.8	74.5	4.7	73.6	3.8	69.0	-0.8
35% CP (active)	73.1	74.8	1.7	73	-0.1	70.5	-2.6
35% CP (control)	69.4	69.3	-0.1	68.1	-1.3	65.6	-3.8
35% HP (active) + laser	73.3	74.2	0.8	73.8	0.5	70.0	-3.3
35% HP (control) + laser	67.9	69.3	1.4	70.1	2.2	67.0	-0.9
35% HP (active) + PAC	74.1	75.7	1.6	73.3	-0.8	68.9	-5.2
35% HP (control) + PAC	68.9	69.2	0.3	70.4	1.5	65.6	-3.3
35% HP (active) + halogen	69.5	73.6	4.2	73.2	3.7	68.6	-0.9
35% HP (control) + halogen	70.0	69.7	-0.3	69.8	-0.2	66.1	-3.9

evidence-based approach. There has not been a comparison of conventional nightguard techniques, high concentration CP techniques with power techniques, including activation by laser, plasma arc and halogen lights, with adequate blind controls in independent studies on natural tooth colour. Some recent studies[9-11] have tested whitening products on artificially tea-stained enamel and dentine. The effect of tooth whitening on this type of synthesised discolouration may not represent the colour change when using whitening products on natural dentine colours. Furthermore these studies have recorded colour change as the square root of the sum of the squares of each individual value of L, a and b. The effect of this computation does not distinguish between tooth lightening and tooth darkening due to the squaring process eliminating negative values. For this reason the present study has recorded raw data scores without manipulation to eliminate negative scores.

The aim of the study was to compare *in vitro* tooth colour change using a range of popular and currently available tooth whitening techniques with matched control materials on natural tooth colour.

METHODS

A total of 100 freshly extracted and unrestored human lower incisor teeth were selected for similarity in size and were decontaminated and stored in sterile deionised water at 4°C. Custom-made jigs were made from condensation-cured silicone putty (Coltene Whaledent, Alstatten, CH) to hold each tooth and ensure that the colorimeter tip could be accurately relocated in the same position for subsequent recordings.

The teeth were randomly divided into ten groups with ten teeth per group. Five groups were treated with an active whitening gel and five groups were controls which were treated in the same way with a deactivated whitening gel provided by the manufacturer in identical syringes (Table 1). Active and matched de-activated gels were supplied by the manufacturer in identical but coded syringes which were blind to the operator during treatment, recording and analysis procedures.

The active groups were:

1. Pola Night 10% carbamide peroxide (CP) – 1 x 60 min
2. Pola Zing 35% CP – 1 x 30 min
3. Pola Office 35% HP with laser light (diode laser designed for dental use) – 3 x 10 min
4. Pola Office 35% HP with PAC Light – 3 x 10 min
5. Pola Office 35% HP with Luma halogen light – 3 x 10 min.

The control groups were given identical treatments using deactivated gels of:

1. Pola Night 10% CP – 1 x 60 min
2. Pola Zing 35% CP – 1 x 30 min
3. Pola Office 35% HP with laser light (diode laser designed for dental use) – 3 x 10 min
4. Pola Office 35% HP with PAC light – 3 x 10 min
5. Pola Office 35% HP with Luma halogen light – 3 x 10 min.

Table 2 Comparison of active treatments and controls with P values

10% CP & control P = 0.044 sig
35% CP & control P = 0.006 sig
35% HP with laser & control P = 0.307 ns
35% HP with Plasma & control P = 0.118 ns
35% HP with Luma & control P <0.001 sig

At the beginning of each experiment individual tooth shades were determined using an electronic shade-taking device, the X-Rite Shade Vision System colorimeter (X-Rite, 4300 Grand Rapids, MI 49512 USA). Shade taking was carried out using L* values. This system was devised by the International Commission on Illumination (CIE) in 1976 (see http://www.cie.co.at). These values enable true tooth colour to be recognised and recorded and are more sensitive to colour change than approximating the colour to the nearest Vita Classic shade equivalent. The L* value was used in comparisons as it represents the whiteness of any colour. A customised box was placed around the colorimeter cone to ensure standard dark conditions were met.

The whitening procedures were carried out strictly according to manufacturer's instructions and at 35°C relevant

operating temperature. Groups requiring gel application in a tray system, ie those not activated by light sources, were placed on a custom-made tray in a standard water bath (Grant Instruments [Cambridge], Ltd) monitored using a standard digital thermocouple to ensure that temperatures stayed within the range close to 35°C. A humid atmosphere was also maintained. The surface temperature of teeth in the groups receiving the power techniques was monitored using a digital thermocouple placed on the tooth surface.

On completion of the bleaching procedure, the bleaching gel was entirely removed using warm water and a toothbrush. The shades of teeth were measured immediately after bleaching. The teeth were then individually wrapped in a wet gauze and then individually stored at 4°C. The individual tooth shades were measured again one week and nine months post-bleaching. The difference in L value (ΔL) between post-op and pre-op recordings for each tooth was calculated and used in analysis as not all teeth had identical L values at the start of the study. The t-test was used to compare paired active and control groups and ANOVA was used to analyse the group data followed by Dunn's post-hoc testing.

RESULTS

The active treatment groups were compared with their corresponding control groups and the results of mean ΔL can be seen in Table 1. In Table 2 the level of statistical significance (t-test) is provided and Figure 1 illustrates the comparisons between the active and matched control groups. This shows that significant differences were observed with 10% CP, 35% CP and 35% HP halogen but not in the 35% laser or PAC light groups.

A comparison of the change in L value immediately after treatment with the five different active treatment regimes (ANOVA P <0.001) shows that the significantly greater increases in colour value were obtained with 10% CP compared to the other treatments except for 35% HP with halogen activation (Dunn's post-hoc test, P <0.05).

A comparison of the colour value at each stage: pre-operative, immediate post-operative, one week and nine months later showed that the 10% CP treatment gave a significant gain immmediately post-op and one week later. All other treatments did not bring about a statistically significant increase in L* value. All increases in L* value reversed over the study period. Figure 2 shows the change in L value over time.

The temperature changes recorded in the power techniques were: Pola Office

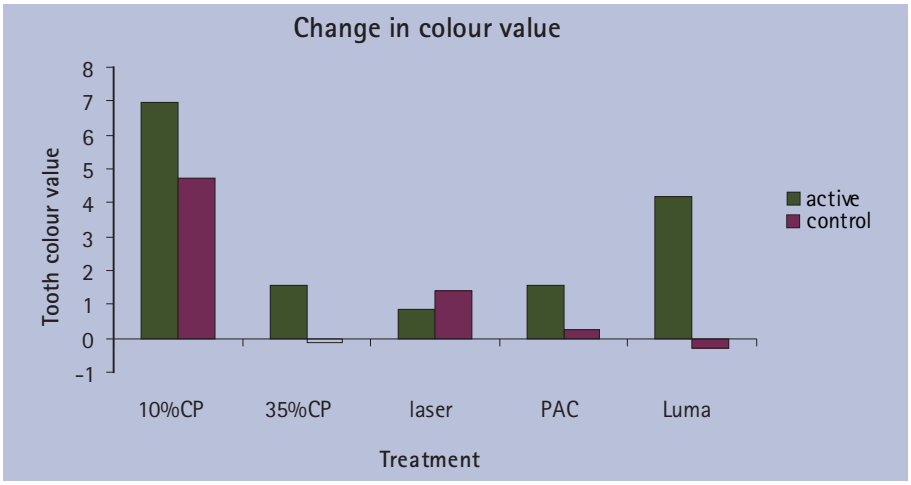

Fig. 1 Comparison of active groups and matched control groups

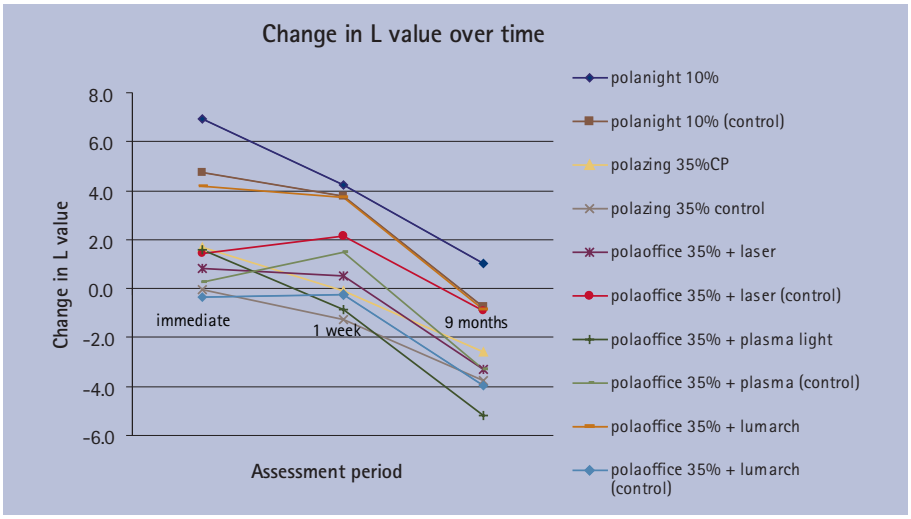

Fig. 2 Change in L value over time following treatments

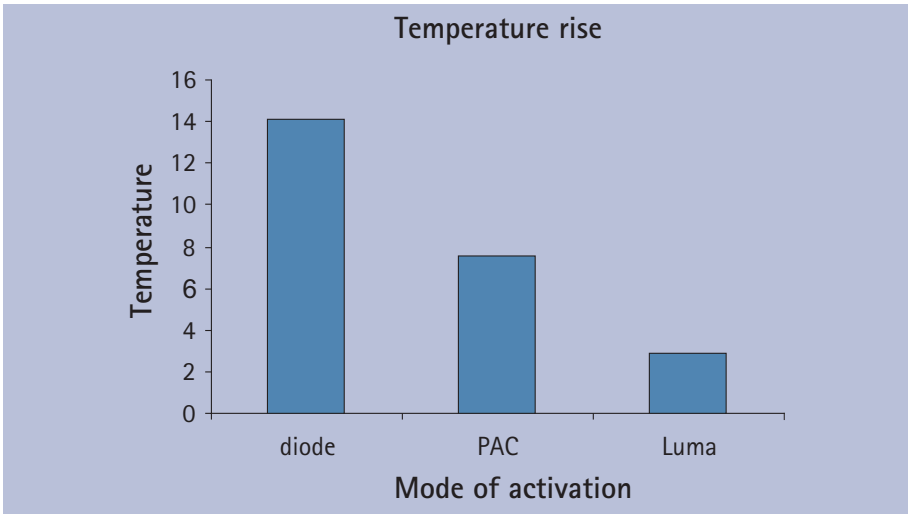

Fig. 3 Temperature rise on the tooth surface during activation of 35% hydrogen peroxide gel with diode laser, plasma arc lamp (PAC) and halogen light (Luma)

35% HP with diode laser 14.1 ± 5.6°C, Pola Office 35% HP with PAC light 7.6 ± 3.9°C, Pola Office 35% HP with the halogen light 2.9 ± 1.6°C. This can be seen in Figure 3. The temperature increase observed with the diode laser was significantly greater (ANOVA, P = 0.01) than that observed with the halogen light.

DISCUSSION

A comparison of active and control groups showed statistical significance for 10% CP, 35% CP and the technique using 35% HP and the halogen light indicating that these techniques did provide tooth whitening which could not be attributed to dehydration alone or the activation technique.

The increase in colour value in some of the control groups is likely to be due to the dehydration of the teeth which may be caused by the prolonged procedure of one hour in the case of the 10% gel control and the heat produced in the case of the laser used without an active gel.

A comparison of the active treatment groups indicates that the use of home-applied techniques with 10% CP for 60 min was the most effective technique which is in agreement with a recent study.[12] This technique is also associated with lower levels of tooth sensitivity,[13] is considered to be safe and effective,[3] cost-effective[14] and provides a sustained result.[6] Therefore it remains a recommended technique.

The use of high strength carbamide peroxide (35%) was significantly better than the matched control treatment and comparable in outcome as a 30 minute procedure to the majority of alternative techniques taking longer periods of time. This regime does not require the same level of gingival protection or the use of activation so there is less risk of damage to adjacent tissues.

Higher concentrations of whitening gel cause greater tooth sensitivity while too low a concentration has less effect.[7,15-17] The use of 10% carbamide peroxide may offer the best compromise between sensitivity and efficacy. Delivery systems also have an effect on the outcome[15] with tray-based application having more favourable treatment outcomes than paint-on or toothpaste techniques. The present study supports the use of tray based application and the use of at-home techniques as they require less chair time, reduced responsibility of staff members involved in the procedure, and less use of staff time during the procedure.

The use of the different methods of activation of the 35% HP brought about a temperature rise on the enamel surface. This is in agreement with other studies reporting surface temperature rises of 0.44°C with halogen light to 86.3°C with the diode laser[18] and temperature rises of up to 12°C with a 2W diode laser compared to 2-4°C with a plasma arc light.[19] Laser whitening is a popular technique, however, users should be aware of the laser activated whitening being no more effective that other techniques yet putting the teeth at greater risk due to the higher temperatures involved.

The results suggest that of the power whitening techniques the use of halogen light is effective in comparison with diode laser and PAC lights. It is known that different light actication systems produce different outcomes.[20] However, it is difficult to justify the use of power whitening techniques given the higher risk of tooth sensitivity, increased surgery time required and higher cost to patients when compared to 10% CP nightguard tooth whitening treatments. A three-month clinical study[21] reported that 84% of subjects found that 10% carbamide peroxide at-home treatment to be more effective that 35% hydrogen peroxide in office, supporting the findings of the present study.

The increase in tooth value was seen to regress over time as expected; however, the results should be viewed with caution as this is an *in vitro* study where the teeth were not subjected to normal levels of hydration. The number of applications required has been shown to be exponentially related to the concentration of hydrogen peroxide.[11]

CONCLUSION

This *in vitro* study showed that nightguard based vital beaching with 10% carbamide peroxide is an effective tooth whitening technique and there is a lack of evidence to support the use of laser whitening which has the highest temperature rise on the tooth surface. This study supports the use of 10% carbamide peroxide in a tray where legal to do so.

The support of SDI in providing materials and funding for this study is acknowledged.

1. BACD survey on cosmetic dentistry https://www.bacd.com/media/press-releases.html 18 September 2007
2. Orr C. Smoking ban ups demand for whitening. *Dental Tribune* 2007; **1:** 5.
3. Ritter A V, Leonard R H Jr, St Georges A J, Caplan D J, Haywood V B. Safety and stability of nightguard vital bleaching: 9 to 12 years post-treatment. *J Esthet Restor Dent* 2002; **14:** 275-285.
4. Haywood V B. Current status of nightguard vital bleaching. *Compend Contin Educ Dent* 2002; **28:** S10-S17.
5. Millar B J. Home-bleaching for single tooth color correction. *J Esthet Dent* 1994; **6:** 1-4.
6. Matis B, Mousa H N, Cochran M A, Eckert G J. Clinical evaluation of bleaching agents of different concentrations. *Quintessence Int* 2000; **31:** 303-310.
7. Leonard R H, Sharma A, Haywood V B. Use of different concentrations of carbamide peroxide for bleaching teeth: an *in vitro* study. *Quintessence Int* 1998; **29:** 503-507.
8. Sulieman M. An overview of bleaching techniques: 3. In-surgery or power bleaching. *Dent Update* 2005; **32:** 101-104, 107-108.
9. Sulieman M, Addy M, Rees J S. Development and evaluation of a method to study the effectiveness of tooth bleaching. *J Dent* 2003; **31:** 415-422.
10. Sulieman M, Addy M, MacDonald E, Rees J S. The bleaching depth of a 35% hydrogen peroxide based in-office product: a study *in vitro*. *J Dent* 2005; **33:** 33-40.
11. Sulieman M, Addy M, MacDonald E, Rees J.S. The effect of hydrogen peroxide concentration on the outcome of tooth whitening: an *in vitro* study. *J Dent* 2004; **32:** 295-299.
12. Sulieman M. An overview of bleaching techniques: 2. Night Guard Vital Bleaching and non-vital bleaching. *Dent Update* 2005; **32:** 39-40, 42-44, 46.
13. Auschill T M, Hellwig E, Schmidale S, Sculean A, Arweiler N B. Efficacy, side-effects and patients' acceptance of different bleaching techniques (OTC, in-office, at-home). *Oper Dent* 2005; **30:** 156-163.
14. Haywood V B. Current status of nightguard vital bleaching. *Compend Contin Educ Dentistry* 2000; **28:** S10-S17.
15. Gerlach R W, Zhou X. Clinical trial comparing two daytime hydrogen-peroxide professional vital-bleaching systems. *Compend Contin Educ Dent* 2004; **25 (Suppl 2):** 33-40.
16. Gerlach R W, Barker M L. Professional vital bleaching using a thin and concentrated peroxide gel on whitening strips: an integrated clinical summary. *J Contemp Dent Pract* 2004; **5:** 1-17.
17. Kihn P W, Barnes D M, Romberg E, Peterson K. A clinical evaluation of 10 percent vs. 15 percent carbamide peroxide tooth-whitening agents. *J Am Dent Assoc* 2000; **131:** 1478-1484.
18. Sulieman M, Addy M, Rees J S. Surface and intra-pulpal temperature rises during tooth bleaching: an *in vitro* study. *Br Dent J* 2005; **199:** 37-40.
19. Wetter N U, Walverde D, Kato I T, Eduardo Cde P. Bleaching efficacy of whitening agents activated by xenon lamp and 960-nm diode radiation. *Photomed Laser Surg* 2004; *22*: 489-93.
20. Sulieman M, MacDonald E, Rees J S, Addy M. Comparison of three in-office bleaching systems based on 35% hydrogen peroxide with different light activators. *Am J Dent* 2005; **18:** 194-197.
21. Zekonis R, Matis B A, Cochran M A, Al Shetri S E, Eckert G J, Carlson T J. Clinical evaluation of in-office and at-home bleaching treatments. *Oper Dent* 2003; **28:** 114-121.