Stephen Burrows

A Review of the Efficacy of Tooth Bleaching

Abstract: Current tooth lightening systems use hydrogen peroxide or carbamide peroxide which releases hydrogen peroxide as the bleaching agent. *In vitro* and *in vivo* studies, mostly comparing different bleaching systems, have demonstrated the efficacy of vital and non-vital tooth bleaching. Bleaching treatments are affected by a number of factors including the actual cause of tooth discoloration. All in-surgery bleaching agents are chemically activated and, whilst better results are possible with lights, these are not essential. Shade change can be evaluated subjectively and may be observed after only a few nights with Night Guard Vital Bleaching (NGVB). Objective methods of shade evaluation are used in most randomized controlled trials. There are a number of methods used to bleach teeth but NGVB using 10% carbamide peroxide in trays produces the optimal result with the least side-effects. The 'inside/outside' bleaching technique using 10% carbamide peroxide is the most effective and safest method of bleaching non-vital teeth. Although more than 90% success has been reported, regression of the colour change is a common problem in vital and non-vital tooth bleaching and retreatment is necessary in many cases, usually after 1–3 years. The overwhelming evidence indicates that tooth bleaching is effective if supervised by a dentist.
Clinical Relevance: The clinician should be able to inform patients that both vital and non-vital tray bleaching using 10% carbamide peroxide can produce excellent results when supervised. However, shade regression is likely in 1–3 years.
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Obvious discoloration of teeth can be a physical handicap that impacts on a person's self-image, self confidence, physical attractiveness and employability. It cannot therefore be dismissed as merely of cosmetic importance.[1] The aetiology of tooth discoloration is multifactorial, and tooth whitening will benefit patients with extrinsic and intrinsic discoloration.[2,3] However, the treatment of the discoloration shown in Figure 1 may prove to be a challenge!

In a study of patient satisfaction with their tooth colour, up to 50% of patients reported indifference while 30% were dissatisfied and 10% highly dissatisfied with their tooth shade.[4]

The American Dental Association (ADA) established efficacy and safety guidelines for tooth bleaching (Table 1).[5]

Stephen Burrows, BDS, DGDP(UK), MClinDent(Pros), AFAAID, General Dental Practitioner, St Helens, Merseyside, UK.

These guidelines require that manufacturers submit results of scientific studies showing that their bleaching product, when used as directed, is not harmful, is effective and requires that patients be followed up for a period of six months post-treatment to determine shade change and post-treatment side-effects.

Efficacy of tooth bleaching

Evaluation of efficacy

The reproducible, valid measurement of tooth colour, particularly in evaluating the efficacy of tooth whitening agents, remains a challenge.[6] Demonstration of tooth bleaching efficacy is controversial[7] and can be difficult owing to errors in the systems used to measure colour changes.[8] Evaluation of efficacy can be both objective and subjective, while the patient's opinion may differ from that of the dentist.[9] This issue is as critical as the measurement system used.[10] Clinical observation is reliable when comparing treated and untreated arches but is subjective, and there are no reliably sensitive quantitative measures to monitor gradual change. Furthermore, colour perception is complex and the evaluator's experience appears to have no bearing on his/her colour matching ability.[11] Moreover, lighting conditions can affect shade perception.

Figure 1. Generalized extrinsic and intrinsic tooth discoloration.

Shade evaluation should therefore be standardized to ensure

- Two double-blind trials with test material and non-active control.
- Assessment of the effects of treatment from 2–6 weeks.
- Two different systems of colour measurement to be used at the start and end of treatment.
- 3–6 months' colour duration measurements to assess regression.
- Must be capable of providing at least a two shade change.

Table 1. Efficacy Guidelines.

- Visual assessment with shade guides.
- Before and after photographs.
- Digital image analysis.
- Colorimeters measure the colour of objects with CIELAB values.[16]

Table 2. Methods of evaluating colour change.

Table 3
Shade guide ordered from light to dark: B1 to C4.

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

Figure 2. Vitapan Classical shade guide.

Figure 3. Vitapan Classical value ordered shade guide.

Figure 4. Evaluating shade before treatment.

reproducible conditions and thereby aid assessment of any measurable shade change. A number of methods are used to measure tooth colour in bleaching studies (Table 2).

The ADA has defined the degree of overall colour change that should be clinically important.[12] The ADA specifies the use of a value-oriented shade guide and/or electronic colour measurement devices. Both the Trubyte Bioform and Vita Classical guides can be arranged by value but a study by O'Brien *et al*[13] demonstrated that the order is flawed and the change in brightness is non-linear. The ADA recommended the Trubyte Bioform 24 shade unit which has a manufacturer-established value, hue and chroma colour-ordered shade guide in order to provide a more objective shade assessment. The use of a shade guide is the most common subjective way of demonstrating shade improvement (Figure 2). The Vita Classical shade guide has 16 shade values that can be ordered (Table 3) with shade tabs corresponding to a grade of lightness from 1 to 16 (Figure 3). The smaller number means the tooth is lighter. Figures 4 and 5 show the clinical use of shade tabs.

Freedman has stated that, although the shade guide is the most commonly used predictable method of evaluating efficacy when whitening teeth, it can be unreliable as there is often a poor match of shade tabs with normal teeth.[14] Dental shade guides contain a limited selection of colours compared to those found in human teeth. An error in shade selection is thus introduced since many tooth colours must be defined by approximation.[13] Photographs can provide a more durable baseline record, although there are many variables, such as lighting and film type, that can affect the evaluation of colour change. Computer digitization relies on camera/slide images but the software can be difficult to use in evaluating colour change.

Shade assessment using digital systems with controlled lighting can be expensive and can have the same subjective flaws as conventional shade guide assessment.

Matis *et al*[15] concluded that objective methods of colour evaluation could define more differences than subjective methods. Colorimeters provide objective quantitative data, and are used to measure L* a* b* colour spaces (where L* = lightness, a* = redness, b* = yellowness) defined by CIELAB[16] or the differences in them indicated as ΔE.

Colorimeters are used by scientific researchers and their efficacy studies cannot always be verified independently. Existing colorimeters are also unpredictable in intra-oral shade assessment as they are designed for flat surfaces. One such instrument used for assessing tooth colour in clinical whitening studies is the Minolta Chroma Meter CR-321. Li[6] concludes that, although this Chroma Meter provides quantitative and objective

Figure 5. Evaluating shade change during treatment.

- Age of patient
- Bleaching agent
- Strength of bleaching agent
- Type and severity of tooth discoloration
- Patient compliance
- Tray design
- Light and heat activation
- Number and duration of bleaching sessions

Table 4. Factors affecting efficacy.

measurements of tooth colour, it can be tedious to use with a custom alignment device. The Chroma Meter data are inconsistent with subjective methods such as Vita shade guides. It is also questionable whether the small areas that they are able to measure adequately represent the colour of the whole tooth, even though multiple measurements are usually taken.[6] In studies evaluating the efficacy of whitening systems there is a dearth of methods for interpreting the Chroma Meter data regarding tooth colour change.[6] Consequently, at present, the Chroma Meter data alone do not appear to be adequate for determining tooth colour change in whitening research, although the quantitative measurements may be useful as supportive data.[6]

Browning[10] concluded that shade guides should remain a critical element of any bleaching study as any colour change in bleaching must relate to subjective evaluation.

Simon *et al* [17] conducted an efficacy study of vital home bleaching and attempted to give a numerical value to the colour change through the use of a light transmission densitometer. This device was used to measure the difference in the density of photographic films of the treated maxillary teeth and the untreated mandibular teeth, which were used as the control. Of patients evaluated with the densitometer, 8% showed no colour change yet all patients were pleased with the results. This could have been a placebo effect or possibly problems related to visual acuity.

At present, there is no reliable, efficient method to determine whole tooth colour and measure colour change over time. As bleaching is an elective procedure in which patient satisfaction is paramount, the patient's opinion may be a more accurate determination of measure of efficacy than data that are measurable but not accepted by patients.[18] This study showed that determining success and continuing colour stability was based on patients' perception of colour.

Efficacy of external tooth bleaching

Haywood[8] states that the Night Guard Vital Bleaching (NGVB) technique should be considered as the first choice of treatment for any intrinsically discoloured teeth. Vital tooth bleaching can be carried out successfully as a more conservative approach to improving aesthetics than other options which include air abrasion, composite bonding, and much more destructive veneers and crowns.[19] Bleaching carries very minor biologic risks by comparison with other prosthodontic methods of treatment. These risks can be further minimized if bleaching is carried out by a dentist who makes a correct diagnosis of the discoloration and plans appropriate treatment. Haywood and Heymann[20] advocated taking radiographs to screen for periapical pathology and to assess pulp size as they considered that these factors could influence treatment outcome. However, in the author's opinion, and in the light of the Ionising Radiation Regulations,[21] this is no longer acceptable and pulp size does not need to be considered in adult patients. Haywood and Heymann[22] conducted a survey of 7,617 dentists and reported a success rate of 90% for dentist-monitored bleaching.

In a 1989 survey, 14% of those dentists who used home bleaching products were not satisfied, mostly because the degree of whitening was unpredictable and some dentists believed that bleaching did not work or relapsed in a week.[23]

Factors affecting efficacy

A number of factors influence efficacy of tooth whitening (Table 4).

Tooth whitening is effective in older patients with yellow teeth whereas teeth with severe tetracycline staining are difficult to bleach, often needing extended treatment, and the results are less predictable.[24] Figures 6 and 7 are 'before' and 'after' photographs showing

Figure 6. Before NGVB.

Figure 7. After NGVB.

the efficacy of a 2-week NGVB with 10% carbamide peroxide.

Age was found to be a factor that significantly contributes to shade improvement, with younger subjects experiencing a greater initial reduction in yellowness compared to older participants but not to post-treatment shade retention.[25] Nevertheless, most of the initial shade improvement remained at six months post-treatment.

Kowitz *et al*[26] found, in their Colgate Palmolive-supported blinded clinical study of two 10% carbamide peroxide tray bleaching agents, that the brand of the bleaching agent could affect efficacy. Not surprisingly, Colgate Platinum™ was 77% more effective after one week than Rembrandt Lighten™.

Matis *et al* [15,27,28] showed that carbamide peroxide-based products are active after 10 hours of use, improving the efficacy compared to hydrogen peroxide products which dissociate at a faster rate, rendering them inactive after one hour. Viscosity has an effect on tray seating: the more viscous the material, the greater the need for reservoirs; the lower the gel viscosity, the less the need for reservoirs. Miller *et al*[29] conducted a split-mouth design

study to determine the effect of reservoirs on bleaching efficacy in trays using a low viscosity bleaching material. They concluded that there was no difference in efficacy with or without reservoirs.

It is thought that peroxide concentration is related to efficacy. Matis *et al*[15] conducted a clinical study supported by *Ultradent* to evaluate the different concentrations of bleaching agents on the degree of colour change and any rebound effect of 10% or 15% carbamide peroxide tray bleaching treatment. They found that there was a significant difference in tooth whitening using 10% or 15% carbamide peroxide in home tray bleaching treatment at 2 weeks but no difference after 6 weeks.

Lu *et al*[30] suggested that the method of application, the number of applications and the duration of each bleaching treatment can all affect efficacy. Sagel *et al* [31] claimed, in their sponsored study, that bleaching strips were more effective in tooth whitening than 10% carbamide peroxide, but these findings have not been substantiated.

According to a number of studies, tray-based applications of 10% carbamide peroxide have the best long-term proven success.[32,33,34,35]

In a controlled study sponsored by Dentsply, Kihn *et al*[36]concluded that, after one week, there was no significant difference in colour change between two groups of subjects that were randomly assigned to a 10% control or 15% experimental carbamide peroxide NGVB regimen. However, at 2 weeks and 2 weeks post-treatment, the experimental group showed a statistically greater degree of shade change than did the control group. Unlike the study by Matis *et al*,[15] the shade was not evaluated at 6 weeks.

Kugel *et al*[37] found in their study that combining in-surgery and home bleaching treatment could shorten bleaching time and increase efficacy. Furthermore, warming the 35% carbamide peroxide 15 minutes prior to in-surgery application facilitated the bleaching process. This is understandable as the rate of dissociation is temperature-dependent; a temperature increase of 10° Celsius will double the rate of dissociation of hydrogen peroxide.[38]

Browning *et al*[39] found, in a randomized controlled trial of 22 participants sponsored by *Ultradent*, that there was a median colour change of 8 tabs on the Vita Shade Guide following NGVB with a tray application of a 10% carbamide peroxide gel for a minimum of 6 hours a night for 2 weeks. At 13 and 26 week reviews, the median shade change was also recorded as 8 tabs, implying that there was no shade regression. However, in the author's opinion, the mean colour change should have been reported for these results to be meaningful.

In a study by Deliperi *et al*,[40] a 90-minute application of 38% hydrogen peroxide resulted in nine shade changes with a two-shade rebound in 7 days. However, home bleaching can produce equally effective results with a longer duration of treatment.[41] In their 3-month single blind study, a 14-day home treatment using 10% carbamide peroxide in trays produced significantly lighter teeth than a 60 minute in-surgery treatment using 35% hydrogen peroxide.

Bleaching strips

In 2000, Crest Whitening Strips™ (Proctor and Gamble) were introduced to the US market.[42] These flexible, impregnated, polyethylene bleaching strips are designed to deliver hydrogen peroxide in various concentrations: 6%, 6.5%, 10% and 14%, depending on the brand, and were introduced in an attempt to reduce the cost of bleaching to consumers, to improve their market share and simultaneously minimize any appropriate dentists' input. They are applied in an adhesive gel form to the labial surface of anterior teeth. Dentists should be aware that the gel concentration is not stated on the package and, in the author's opinion, this could present a safety concern.

Paint-on gel

In 2004, a topically applied tooth bleaching system, in the form of a paint-on gel, was marketed in the USA by Colgate Palmolive to introduce a system that would have a more widespread cosmetic appeal, as it would be capable of being applied to individual problem teeth, avoid the need for trays and develop a range of bleaching systems that would be entirely over-the-counter (OTC). In theory, the use of OTC bleaching agents which are unsupervised and not professionally administered could increase the risk of adverse effects, which is less likely in a supervised treatment.

Li *et al* [43] studied the efficacy of a novel paint-on liquid whitening gel (Colgate Simply White Clear Whitening Gel™) which contains 18% carbamide peroxide, in a 3-week clinical trial using different exaggerated or simplified treatment regimens of 2, 3 or 4 times daily. Subjects who used this gel 3 and 4 times daily achieved the greatest shade improvement.

Gambarini *et al*[44] evaluated the efficacy of a paint-on 5.9% hydrogen peroxide tooth whitening system for use at home in an independent controlled clinical trial. The mean shade change, assessed by using Vita shade scores, was 3.56.

Comparison studies

Most of the randomized controlled clinical trials on bleaching efficacy have commercial sponsorship, are comparison studies and evaluate efficacy with a Chroma Meter. Whilst there is a reasonable validity in these studies, in the author's opinion, care should be taken in interpretation of these results and using them when selecting an appropriate bleaching treatment. There are a number of different comparison studies (Table 5) mostly comparing the efficacy of home bleaching methods, some of which have been outlined.

However, comparisons between efficacy studies are difficult because of the use of multiple variables and differences in study design and methodology.[9,24,25]

Tray vs tray

- In a randomized, controlled trial Matis *et al*[45]evaluated extended NGVB of tetracycline-stained teeth using different concentrations of carbamide peroxide gels (10%, 15% and 20%) for 6 months.

- Tray vs tray
- Tray vs strip
- Tray vs placebo
- Strip vs placebo
- Strip vs strip
- Paint-on gel vs paint-on gel
- Paint-on gel vs placebo
- Strip vs paint-on gel

Table 5. Comparison studies.

The most rapid whitening occurred in the first month and they reported that all bleaching agents were equally effective in removing tetracycline staining, although there was less sensitivity experienced with 10% carbamide peroxide gel than with 15% and 20% gels. In the author's opinion, less discomfort will improve compliance so that 10% carbamide peroxide appears to be the most appropriate bleaching agent for extended treatment. However, the higher the concentration, the more rapidly the lightness and colour difference changed. At 3 and 9 months, respectively, 91% and 85% of the subjects were at least 'a little pleased' whilst, in professional evaluation, 90% of the teeth were considered to have an excellent or satisfactory aesthetic result.[45]

■ Dental fluorosis is an endemic dental health problem around the world. Tooth bleaching is an appropriate initial treatment in most cases as it is the least destructive available option which maximizes enamel retention. Loyola-Rodriguez *et al*[46] carried out a randomized double-blind clinical trial comparing the efficacy of 10% carbamide peroxide, 20% carbamide peroxide and 7.5% hydrogen peroxide in a NGVB technique on teeth affected by dental fluorosis. All bleaching agents were found to be effective and there was no difference in efficacy when comparing 10% and 20% carbamide peroxide. The clinical success was only demonstrated in cases of Class 1–3 of the Tooth Surface Index of Fluorosis.[47]

■ *Ultradent* and *Discus* supported a study by Panich[48] in which two 30-minute daily tray applications of 15% carbamide peroxide gel were compared with 5.5% hydrogen peroxide in a split-mouth design. At 6 weeks, combined colour change, assessed by Chroma Meter, did not significantly differ between the products.

■ Mokhlis *et al*[49] conducted a double-blind study to evaluate the efficacy of 20% carbamide peroxide and 7.5% hydrogen peroxide applied in trays during daytime use. Use of the 20% carbamide peroxide resulted in significantly more lightness than the 7.5% hydrogen peroxide during the first 14 days but, at the end of the study, there was no significant difference in efficacy.

Tray vs strips

■ Discoloured teeth are up to five times more worrying than crooked teeth in studies supported by Proctor and Gamble,[14] who also sponsored a study to assess the efficacy of a 2-week vital bleaching treatment. Donly *et al*[50] found no significant difference in a group of 57 teenagers using hydrogen peroxide strips in two, 30-minute daily applications and 10% carbamide peroxide overnight tray bleaching when assessed by digital image analysis. The equivalent efficacy was achieved with shorter application time using the strips.

■ Karpinia *et al*[51] conducted a randomized clinical trial, supported by Proctor and Gamble, to compare the efficacy of two tooth bleaching systems. They found that twice-daily application of 6.5% hydrogen peroxide strips was more effective in tooth whitening than a 10% carbamide peroxide gel, equivalent to 3.35% hydrogen peroxide, applied in a tray for 2 hours a day with a total contact time of 21 and 28 hours, respectively. However, this is not how the lower concentrations of carbamide peroxide should be used.

■ Li *et al*[52] conducted a randomized clinical trial sponsored by *Discus Dental* to compare the efficacy of three at-home professional tooth whitening systems:

–Crest Whitestrips™ (Proctor and Gamble): 6.5% hydrogen peroxide twice daily for 30 minutes.

–Day White 2™ (*Discus Dental*): 7.5% hydrogen peroxide applied in a tray twice daily for 30 minutes.

–Nite White Excel™ (*Discus Dental*) 16% carbamide peroxide in a tray overnight.

Significant shade reductions were found with time in all three groups. Nite White Excel™ resulted in significantly greater shade changes at 7, 14 and 21 days from baseline than the other two systems, which were comparable.

Tray vs placebo

■ Matis *et al*[32] conducted a randomized 14-day double-blind clinical study to assess the efficacy of a 10% carbamide peroxide gel compared to a placebo used for NGVB. At 22 weeks post-bleaching, 66% of those treated with the active agent had clinically observable colour change based on photographic assessment. There was a 45% mean colour regression from weeks 2 to 24.

Strip vs strip

■ In a randomized, double-blind, placebo-controlled trial supported by Proctor and Gamble, Kugel and Kastali[53] compared the whitening efficacy of bleaching strips in two groups: Group 1 used a 2-week, twice-daily 5.3% hydrogen peroxide tooth bleaching gel delivered on polyethylene film; Group 2 used a film twice daily with gel but without hydrogen peroxide. Using the Vita shade guide, the shade change was significantly greater for Group 1 than Group 2. Use of the peroxide-containing gel led to a mean change in baseline Vita shade score of -3.70 +/- 0.35, compared with a change of -0.87 +/- 0.24 after use of a placebo gel.

■ Gerlach and Sagel,[54] in a randomized double-blind two-week study with 38 adults, sponsored by Proctor and Gamble, compared the efficacy of 0.1 mm polyethylene gel strips impregnated with 14% hydrogen peroxide and thicker 0.2 mm polyethylene gel strips impregnated with 6% hydrogen peroxide. The 14% hydrogen peroxide gel strip resulted in greater whitening, including 42–49% greater improvement in tooth colour and faster onset than that seen with the 6% gel strip.

Strip vs placebo

■ In a randomized, double-blind clinical trial, sponsored by Proctor and Gamble, Gerlach *et al*[55] studied the efficacy of a 5.3% hydrogen peroxide bleaching strip compared to a placebo and reported that the whitening strip group experienced a highly significant reduction in yellowness when compared to baseline, after the end of 2 weeks' treatment and also 6 months after treatment.

Paint-on gel vs paint-on gel

■ Brunton *et al*[56] conducted a randomized controlled clinical study sponsored by Colgate Palmolive and found no significant difference in efficacy between 16.4% and 18% carbamide peroxide paint-on gels applied to upper anterior teeth over a 2-week test period. However, in the author's opinion, the methodology of this comparison study was somewhat flawed as it was not split-mouth and there was no placebo-control.

■ Nathoo *et al*[57] conducted a randomized controlled trial supported by Colgate Palmolive to compare the efficacy of two paint-on bleaching gels. They found no significant difference in the shade between

teeth whitened with either 25% carbamide peroxide gel or 8.7% hydrogen peroxide gel, both of which have equivalent hydrogen peroxide concentrations.

Paint-on gel vs placebo

■ Gambarini *et al*[58] evaluated the efficacy of a 5.9% hydrogen peroxide paint-on tooth whitening gel compared to placebo gel in an unsponsored randomized placebo-controlled clinical study with 30 subjects. The mean colour improvement in Vita shade score from baseline after 2 weeks was 4.48, which was significantly greater than the mean colour change of 0.6 for the placebo. However, there was no long-term review to assess shade regression which, in the author's opinion, makes the findings questionable.

Strips vs paint-on gel

■ Cronin *et al*[59] conducted a randomized clinical study, supported by Pfizer, to compare two OTC bleaching systems: one was 6% hydrogen peroxide applied as a gel in a strip and the other was 18% carbamide peroxide gel applied by brush. They demonstrated that the strip system produced a statistically significant improvement in whitening compared to paint-on gel.

Summary

All tooth bleaching systems will lighten teeth but, in most cases, it seems that the greatest efficacy is achieved using 10% carbamide peroxide in a NGVB procedure. Teeth will lighten more quickly with higher concentrations of bleaching agents but this advantage is outweighed by the increased risk of tooth sensitivity.

Efficacy of intracoronal tooth bleaching

Intracoronal tooth bleaching was introduced in 1961 by Spasser[60] who described the 'walking bleach' method of sealing a mixture of sodium perborate and water in the pulp chamber for a week.

This was superseded by the 'combination walking bleach' technique described by Nutting and Poe[61] in which an intracoronal mixture of 30% hydrogen peroxide and sodium perborate enhanced efficacy when sealed in the pulp chamber for a week.

The 'thermocatalytic technique', introduced by Stewart in 1965,[62] involves the placement of an intracoronal bleaching agent followed by the application of a heated instrument into the pulp chamber. The 'inside/outside' bleaching technique was described by Settembrini *et al*,[63] Carillo *et al*[64] and later reported by Poyser *et al*.[65] It is the most effective intracoronal bleaching method using ultrasonic cleaning of blood containing debris from within the pulp chamber below the cemento-enamel junction prior to application of a low concentration of bleaching agent without heat. This method involves using a customized tray with reservoirs on the labial and palatal surfaces of the non-vital target tooth. The pulp chamber is left open and completely covered by 10% carbamide peroxide within the tray. The gel is changed every two hours and the patient is advised to wear the tray continuously, including night-time wear. Bleaching usually occurs within 2–3 days.

There are no long-term clinical regression studies on safe intracoronal non-vital bleaching treatment, such as the 'inside/outside' bleaching technique. However, the effective removal of blood breakdown products from the pulp chamber prior to bleaching should minimize the incidence of regression.

The efficacy of bleaching agents used for thermocatalytic intracoronal bleaching has been evaluated *in vitro* on artificially stained teeth. Lim *et al*[66] compared the bleaching efficacy of 35% carbamide peroxide, 35% hydrogen peroxide and sodium perborate for intracoronal bleaching on artificially stained extracted premolars. They found that 35% carbamide peroxide and 35% hydrogen peroxide were equally effective for intracoronal bleaching and significantly better than sodium perborate after 7 days. There were no significant differences between the different bleaching agents after 14 days.

In vitro studies have also shown that sodium perborate in water, sodium perborate mixed with 3% hydrogen peroxide, 30% hydrogen peroxide and 10% carbamide peroxide are all effective in internal bleaching of non-vital teeth.[67,68,69,70]

Howell[71] reported more than 90% immediate success with a version of the thermocatalytic method using 30% hydrogen peroxide. Friedman[72] also found a high success of intracoronal bleaching using 30% hydrogen peroxide in the short term but a high incidence of regression in the long term. There is an unnecessary risk of cervical resorption using 30% (and greater concentrations) of hydrogen peroxide, with or without heat, in now outdated intracoronal bleaching methods. Therefore, 'inside/outside' bleaching is much safer with lower concentrations of peroxide and equivalent efficacy if ultrasonic cleaning of the pulp chamber is carried out first. Furthermore, the safety issue should far outweigh any benefit of improved tooth colour, especially as tooth bleaching is an elective cosmetic procedure.

Light activation

High intensity lights, first reported by Abbot[73] in 1918, have been used in attempts to catalyse decomposition of hydrogen peroxide by raising the temperature, thus increasing the rate of tooth lightening, as a temperature increase of 10° Celsius will double the rate of dissociation of hydrogen peroxide.[38] However, early light-activated bleaching was an inefficient and unpredictable process that often resulted in severe tooth sensitivity. The efficacy of power bleaching has been studied by Rosenstiel *et al*[33] who, in 1991, reported that significant shade regression occurred after one treatment with 30% hydrogen peroxide. Tooth dehydration following treatment can lead to false evaluation of the actual shade change. The enhanced shade can regress quickly as teeth lose oxygen and rehydrate. They stated that chairside bleaching should be followed by home bleaching treatment, with 10% carbamide peroxide to improve efficacy, and thereby obviate any need for multiple costly appointments.

Papathanasiou *et al*[74] demonstrated that the most important factor is the concentration of bleach and not the light. They conducted a randomized parallel clinical study to evaluate the effectiveness of a 35% hydrogen peroxide in-surgery tooth whitening system, with and without light activation. Both bleaching protocols were found to be effective in lightening teeth and there was no

significant difference in efficacy between the two groups, ie the light made no difference to the outcome.

In a more recent sponsored study, Tavares *et al*[75] reported that hydrogen peroxide and light treatment significantly lightened teeth to a greater extent than hydrogen peroxide or light alone and claimed that 'power bleaching' can be achieved in a single practice visit. However, Swift *et al* showed that there are serious flaws in the controversial Tavares study.[76] One examiner was used instead of the usual protocol of two calibrated assessors. There was no indication of colorimeter calibration and there was a huge discrepancy between shade guide and colorimeter methods of evaluation. The rehydrating 'hydrogel' composition was not stated and the effects of dehydration on the bleaching effect were not considered. Shade assessments were made immediately after the procedure and not assessed one week later to allow for tooth rehydration and shade regression.

In a clinical trial, Hein *et al*[77] studied the effect of bleaching lights (LumaArch™, Optilux 500™, and Zoom™) to act as catalysts for lightening teeth in 83 pairs of contralateral anterior maxillary and mandibular teeth of 15 human subjects. The results showed that the three test lights did not lighten teeth more than the bleach gels alone.

Laser tooth bleaching

Laser bleaching started in 1996 with approval of argon and carbon dioxide lasers by the FDA.[78] There are only a few *in vitro* studies on the efficacy of laser bleaching, all on extracted teeth with limited clinical significance and no clinical studies with a split arch design to validate efficacy.

An *in vitro* study of laser bleaching by Jones *et al*[79] failed to show any demonstrable whitening after one session. Dostalova *et al*[80] found that lasers used with 38% hydrogen peroxide on extracted human maxillary central incisors shortened bleaching time. Luk *et al*[81] conducted a study to compare the whitening effects and tooth temperature changes induced by various combinations of peroxide bleaches and light sources in 250 extracted human teeth. They found significant temperature increases in the outer and inner tooth surfaces of the teeth and the infrared and CO_2 laser lights caused the highest increases. They reported 'a significant improvement in the whitening efficacy of some bleach materials with the application of the light' which has little or no validity or relevance to the normal clinical setting.

In the author's opinion, before considering in-surgery bleaching using a light source, the dentist should consider the benefit and cost effectiveness of this expensive treatment. It is apparent that 10% carbamide peroxide has the greater efficacy and least problems compared to power bleaching. However, power bleaching can be used as a 'kick start' prior to tray bleaching and, in certain cases, excellent results are possible without the need for further treatment.

Shade regression

Shade regression is a common problem that can be affected by a number of factors including:

- Tooth dehydration;
- The type of discoloration;
- The bleaching treatment;
- The bleaching agent; and
- The duration of treatment.

Haywood *et al*[18] concluded that a dentist using carbamide peroxide gel for tooth bleaching cannot predict the final degree of whitening based on initial tooth colour. According to a number of authors, patients undergoing bleaching treatment should be informed that retreatment may well become necessary in 1–3 years.[81,82]

Al Shetri *et al*[83] conducted a double-blind, randomized clinical trial to compare two in-surgery bleaching products, 35% and 38% hydrogen peroxide, and found no statistical difference between the products. However, colour regression began immediately after completion of the bleaching treatment and continued for 5 weeks.

Cibirka *et al*[84] found that a change in tooth colour was normally apparent within two weeks of starting bleaching treatment, although Zekonis *et al*[41] reported that the stable colour of power bleached teeth was seen after 6 weeks. A decrease in translucency of the tooth may appear as an improvement in 'brightness' of the tooth.[85] The tooth dehydration that occurs during treatment can lead to transient whitening.[86] In the author's opinion, it is therefore important, when assessing rebound and efficacy, to evaluate the shade at appropriate post-bleaching intervals of 2 and 6 weeks, as the initial brightening effect of residual oxygen in the enamel will give a false picture.

Five studies report long-term data of two years or more on efficacy:[18,87,88,89,90]

- In a 6-week study of 38 patients by Haywood *et al*,[18] in which NGVB was used with 10% carbamide peroxide, 92% of the subjects experienced some tooth whitening. These patients were followed up by postal questionnaires. Of the 26 respondents, 74% and of the 23 respondents, 62% reported no regression or slight colour regression after 1½ and 3 years, respectively. Patients who had re-treated their teeth did so after at least one year and retreatment required a much shorter time (one night per original week of treatment) than the original bleaching treatment.
- Leonard *et al*[87] studied efficacy and duration of efficacy and found that a 10% carbamide peroxide solution used in a NGVB procedure was effective in lightening teeth, with 98% success, and the effect lasted for 47 months in 82% subjects with no adverse side-effects.
- Leonard *et al*[88] conducted a NGVB study of tetracycline-stained teeth treated with 10% carbamide peroxide. They found that tetracycline-stained teeth could be whitened successfully using extended treatment time and that shade stability lasted at least 90 months.
- Swift *et al*[89] carried out a study to evaluate the effectiveness of a 2-week 10% carbamide peroxide NGVB treatment. They reported that the majority of patients' teeth lightened an average of eight shade values. None of the patients in this study found it necessary to repeat the bleaching 2 years after treatment.
- Ritter *et al*[90] found, in a retrospective study, 10% carbamide peroxide NGVB was a safe and effective treatment. Of participants, 92% had successful lightening of teeth and colour stability, as perceived by 43% of the 30 subjects, was stated to last between 9 and 12 years.

However, the need to re-treat teeth increases with time. According to Haywood *et al*,[18] shade retention can be expected in up to 90% of patients one year

post-treatment and in 62% three years; in their study patients rebleached on average at 25 months.

Conclusion

In evaluating efficacy, clinical observation is reliable when comparing treated and untreated arches, but is subjective, and there are no quantitative measures to monitor gradual change.

Generally, 10% carbamide peroxide is the most effective bleaching agent and an appropriate bleaching protocol should be determined following thorough examination to diagnose the cause of the discoloration and evaluate the patients' expectations.

Tooth whitening is as effective with or without light activation, although excellent results are possible in certain cases with power bleaching and without the need for further treatment.

Patients should be informed that there is a likelihood of regression from 1–3 years post-bleaching. But this is variable. Re-bleaching is quicker than the time taken to achieve the initial colour change. An application of one night per week of original treatment is usually all that is needed in such cases.

Intracoronal bleaching is a safe and effective way of improving the colour of a non-vital anterior tooth.

Evidence from clinical, animal and *in vitro* studies indicates that the supervised use of peroxide-containing bleaching agents is safe, effective and predictable if there has been a correct diagnosis of tooth discoloration and an appropriate protocol is followed.

Having reviewed the efficacy of tooth bleaching, a second paper will review the safety of tooth bleaching.

References

1. Kelleher MG, Roe FJ. The safety-in-use of 10% carbamide peroxide (Opalescence) for bleaching teeth under the supervision of a dentist. *Br Dent J* 1999; **187**(4): 190–194.
2. Dayan D, Heifferman A, Gorski M, Begleiter A. Tooth discolouration-extrinsic and intrinsic factors. *Quintessence Int Dent Dig* 1983; **14**: 195–199.
3. Hayes PA, Full C, Pinkham J. The aetiology and treatment of intrinsic discolourations. *J Can Dent Assoc* 1986; **52**: 217–220.
4. Odioso L, Gibb R, Gerlach R. Impact of demographic behavioural and dental care utilisation parameters on tooth colour and personal satisfaction. *Comp Cont Educ Dent* 2000; **21** (Suppl): 35–41.
5. ADA Guidelines for the acceptance of peroxide containing oral hygiene products. *J Am Dent Assoc* 1994; **125**: 1140–1144.
6. Li YJ. Tooth color measurement: techniques, advantages, and disadvantages using Chroma Meter. *Esthet Restor Dent* 2003; **15** (Suppl) 1: S33–S41.
7. Joiner A. Tooth colour: a review of the literature. *J Dent* 2004; **32** (Suppl 1): 3–12.
8. Haywood VB. History, safety and effectiveness of current bleaching techniques and applications of the Nightguard Vital Bleaching Technique. *Quintessence Int* 1992; **23**: 471–488.
9. Glockner K, Hulla H, Ebeleseder K, Städtler PS. Five-year follow-up of internal bleaching. *Braz Dent J* 1999; **10**: 105–110.
10. Browning WD. Use of shade guides for colour measurement in tooth-bleaching studies. *J Esthet Restor Dent* 2003; **15** (Suppl 1): S13–S20.
11. Horn D, Bulan- Brady J, Hicks M. Sphere spectrophotometer versus human evaluation of tooth shade. *J Endodont* 1998; **24**: 786–790.
12. **www.ada.org**
13. O'Brien WJ, Boeneke KM, Groh CL. Coverage errors of two shade guides. *Int J Prosthodont* 1991; **4**: 45–50.
14. Freedman G. Bleaching of vital teeth. *Quintessence Int* 1997; **28**: 426–427.
15. Matis B, Mousa H, Cochran M, Eckert G. Clinical evaluation of bleaching agents of different concentrations. *Quintessence Int* 2000; **31**: 303–310.
16. CIELAB Commission Internationale L' Eclairage 1978 *Commission Internationale de L'Eclairage Recommendations on Uniform Colour Spaces, Colour Difference Equations and Psychometric Colour Terms*. Supplement 2 to Publication 15. Paris: Bureau Central de la Cie, 1978.
17. Simon JF, Allen H, Woodson RG, Eilers AS. Efficacy of vital home bleaching. *J Calif Dent Assoc* 1993; **1**: 72–75.
18. Haywood VB, Leonard RH, Nelson CF, Brunson WD. Effectiveness, side effects and long-term status of Nightguard Vital Bleaching. *J Am Dent Assoc* 1994; **25**: 1219–1226.
19. Barghi N, Godwin J. Reducing the effect of bleaching on composite enamel bond. *J Esthet Dent* 1994; **6**(4): 157–161.
20. Haywood VB, Heymann HO. Response of normal and tetracycline stained teeth with pulp-size variation to Nightguard Vital Bleaching. *J Esthet Dent* 1994; **6**: 109–114.
21. **www.dh.gov.uk/en/Publicationsandstatistics.** The Ionising Radiation (Medical Exposure) Regulations 2000.
22. Haywood VB, Heymann HO. Nightguard Vital Bleaching: How safe is it? *Quintessence Int* 1991; **22**: 515–523.
23. Christensen G. To bleach or not to bleach. *J Am Dent Assoc* 1991; **122**(12): 64–65.
24. Haywood VB. Current status of Nightguard Vital Bleaching. *Compend Contin Educ Dent (*Suppl) 2000; Jun (28): S10–S17; quiz S48.
25. Joiner A. The bleaching of teeth: a review of the literature. *J Dent* 2006; **34**: 412–419.
26. Kowitz GM, Nathoo SA, Rustogi KN, Chmielewski MB, Liang LJ, Wong R. Clinical comparison of Colgate Platinum Tooth Whitening System and Rembrandt Gel Plus. *Compend Contin Educ Dent (Suppl)* 1994; **17**: S646–S651.
27. Matis BA, Gaiao U, Blackman D, Schultz FA, Eckert GJ. *In vivo* degradation of bleaching gel used in whitening teeth. *J Am Dent Assoc* 1999; **130**: 227–235.
28. Matis BA, Yousef M, Cochran MA, Eckert GJ. Degradation of bleaching gels *in vivo* as a function of tray design and carbamide peroxide concentration. *Oper Dent* 2002; **27**: 12–18.
29. Miller M, Castellanos I, Rieger M. Efficacy of home bleaching with and without tray reservoirs. *Pract Procs Aesthet Dent* 1998; **12**(6): 611–614.
30. Lu AC, Margiotta A, Nathoo SA. In-office tooth whitening: current procedures. *Compend Contin Educ Dent* 2001; **22**: 798–805.
31. Sagel PA, Jeffers ME, Gibb RD, Gerlach RW. Overview of a professional tooth-whitening system containing 6.5% hydrogen peroxide whitening strips. *Compend Contin Educ Dent* 2002; **23**: 9–15.
32. Matis BA, Cochran MA, Eckert G, Carlson T. The efficacy and safety of a 10% carbamide peroxide bleaching gel. *Quintessence Int* 1998; **29**: 555–563.
33. Rosenstiel SF, Gegauff AG, Johnston WM, Duration of tooth colour change after bleaching. *J Am Dent Assoc* 1991; **123**: 54–59.
34. Curtis JW, Dickinson GL, Doney MC *et al*.

Assessing the effects of 10% carbamide peroxide on oral soft tissues. *J Am Dent Assoc* 1996; **127**: 1218–1223.
35. Russell CM, Dickinson GL, Doney MC *et al*. Dentist supervised home bleaching with carbamide peroxide gel: a 6 month study. *J Esthet Dent* 1996; **8**: 177–181.
36. Kihn PW, Barnes *et al*. A clinical evaluation of 10% vs. 15% carbamide peroxide tooth whitening agents. *J Am Dent Assoc* 2000; **131**: 1478–1484.
37. Kugel G, Perry R, Hoang E, Scherer W. Effective tooth bleaching in 5 days: using a combined in-office and at-home bleaching system. *Compendium* April 1997.
38. Goldstein RE, Garber DA. *Complete Dental Bleaching*. Chicago: Quintessence Publishing Co, 1995.
39. Browning WD, Chan DC, Frazier KB, Callan RS, Blaolock JS. Safety and efficacy of a Nightguard bleaching agent containing sodium fluoride and potassium nitrate. *Quintessence Int* 2004 Oct; **35**(9): 693–698.
40. Deliperi S, Bardwell DN, Papathanasiou A. Clinical evaluation of combined in-office and take-home bleaching system. *J Am Dent Assoc* 2004; **135**: 628–634.
41. Zekonis R, Matis BA, Cochran MA, Al Shetri SE, Eckert GJ, Carlson TJ. Clinical evaluation of in-office and at-home bleaching treatments. *Oper Dent* 2003; **28**: 114–121.
42. Sagel PA, Odioso LL, McMillan DA, Gerlach RW. Vital tooth whitening with a novel hydrogen peroxide strip system: design, kinetics, and clinical response. *Compend Contin Educ Dent* (Suppl) 2000; **29**: S10–S15.
43. Li Y, Lee SS, Cartwright S, Wilson AC, DeVizio W, Petrone M, Volpe AR, Zhang YP. Comparative tooth whitening efficacy of 18% carbamide peroxide liquid whitening gel using three different regimens. *J Clin Dent* 2004; **15**: 11–16.
44. Gambarini G, Testarelli L, DeLuca M, Dolci G. Efficacy and safety assessment of a new liquid tooth whitening gel containing 5.9% hydrogen peroxide. *Am J Dent* 2004; **17**: 75–79.
45. Matis BA, Wang Y, Jiang T, Eckert GJ. Extended at-home bleaching of tetracycline-stained teeth with different concentrations of carbamide peroxide. *Quintessence Int* 2002 Oct; **33**(9): 645–655.
46. Loyola-Rodriguez JP, Pozos-Guilen A, Berumen-Maldonado R, Patino-Marin N. Effectiveness of treatment with carbamide peroxide and hydrogen peroxide in subjects affected by dental fluorosis: a clinical trial. *J Clin Paediatr. Dent* 2003; **28**: 63–68.
47. Horowitz HS, Driscoll WS, Meyers RJ, Heifetz SB, Kingman A. A new method for assessing the prevalence of dental fluorosis – The Tooth Surface Index of Fluorosis. *J Am Dent Assoc* 1984; **109**: 37–41.
48. Panich M. *In vivo evaluation of 15% carbamide peroxide and 5.5% hydrogen peroxide whitening agents during daytime use*. MSc thesis, School of Dentistry, Indiana USA, 2001.
49. Mokhlis GR, Matis BA, Cochran MA, Eckert GJ. A clinical evaluation of carbamide peroxide and hydrogen peroxide whitening agents during daytime use. *J Am Dent Assoc* 2000; **131**: 1269–1277.
50. Donly KJ, Kennedy P, Segura A, Gerlach R. Effectiveness and safety of tooth bleaching in teenagers. *Pediatr Dent* 2005; **27**: 298–302.
51. Karpinia KA, Magnusson I, Sagel PA, Zhou X, Gerlach RW. Vital bleaching with two at-home professional systems. *Am J Dent* 2002; Sept **15** (Spec No): 13A–18A.
52. Li Y, Lee SS, Cartwright SL, Wilson AC. Comparison of clinical efficacy and safety of three professional at-home tooth whitening systems *Compend Contin Educ Dent* 2003; **24**(5): 357–364 passim; quiz 378.
53. Kugel G, Kastali S. Tooth whitening efficacy and safety: a randomised and controlled clinical trial. *Compend Contin Educ Dent* (Suppl) 2000; **29**: S16–S21.
54. Gerlach RW, Sagel PA. Vital bleaching with a thin peroxide gel. The safety and efficacy of a professional-strength hydrogen peroxide whitening strip. *J Am Dent Assoc* 2004; **135**: 98–100. Erratum: *J Am Dent Assoc* 2004; **135**: 156.
55. Gerlach RW, Barker ML, Sagel PA. Objective and subjective whitening response of two self-directed bleaching systems. *Am J Dent* 2002; Sept **15** (Spec No): 7A–12A.
56. Brunton PA, Ellwood R, Davies R. A six month study of two self applied tooth whitening products containing carbamide peroxide *Oper Dent* 2004; **29**(6): 623–626.
57. Nathoo S, Stewart B, Petrone ME, Chaknis P, Zhang YP, DeVizio W, Volpe AR. Comparative clinical investigation of tooth whitening efficacy of two tooth whitening gels. *J Clin Dent* 2003; **14**(3): 64–69.
58. Gambarini G, Testarelli L, Dolci G. Clinical evaluation of a novel liquid tooth whitening gel. *Am J Dent* 2003; **16**: 147–151.
59. Cronin MJ, Charles CA, Zhao Q, Dembling WZ. Comparison of two over-the-counter tooth whitening products using a novel system. *Compendium* 2005; **26**(2): 144–148.
60. Spasser HF. A simple bleaching technique using sodium perborate. *New York Dent J* 1961; **27**: 332–334.
61. Nutting EB, Poe GS. Chemical bleaching of discoloured endodontically treated teeth. *Dent Clin North Am* 1967; Nov: 655–662.
62. Stewart GG. Bleaching discolored pulpless teeth. *J Am Dent Assoc* 1965; **70**: 325–328.
63. Settembrini L, Gultz J, Kaim J, Scherer W. A technique for bleaching non-vital teeth: inside/outside bleaching. *J Am Dent Assoc* 1997; **128**:1283–1284.
64. Carrillo A, Arrendondo Trevino MV, Haywood VB. Simultaneous bleaching of vital teeth and an open-chamber non-vital tooth with 10% carbamide peroxide. *Quintessence Int* 1998; **29**: 643–648.
65. Poyser NJ, Kelleher MGD, Briggs PFA. Managing discoloured non-vital teeth: the inside/outside bleaching technique. *Dent Update* 2004; **31**: 204–214.
66. Lim MY, Lum SO, Poh RS, Lee GP, Lim KC. An *in vitro* comparison of the bleaching efficacy of 35% carbamide peroxide with established intracoronal bleaching agents. *Int J Endodont* 2004; **37**: 483–488.
67. Rotstein I, Zalkind M, Mor C *et al*. *In vitro* efficacy of sodium perborate preparations used for intracoronal bleaching of discoloured non vital teeth. *Endod Dent Traumatol* 1991a; **7**: 177–180.
68. Ari H, Ungor M. *In vitro* comparison of different types of sodium perborate used for intracoronal bleaching of discoloured teeth. *Int Endo J* 2002; **35**: 433–436.
69. Freccia WF, Peters DD, Bernier WE. An *in vitro* comparison of non vital bleaching techniques in discoloured teeth. *J Endodont* 1982; **8**: 70–77.
70. Vachon C, Vanek P, Friedman S. Internal bleaching with 10% carbamide peroxide *in vitro*. *Pract Period Aesthet Dent* 1998; **10:** 1145–1152.
71. Howell RA. Bleaching discoloured root filled teeth. *Br Dent J* 1980; **148**: 159–162.
72. Friedman S. Internal bleaching: long-term outcomes and complications. *J Am Dent Assoc* 1997; **128**(Suppl): 51S–55S.
73. Greenwall L. *Bleaching Techniques in Restorative Dentistry*. London: Martin

Dunitz, 2001.
74. Papathanasiou A, Kastali S, Perry R, Kugel G. Clinical evaluation of a 35% hydrogen peroxide in-office whitening system. *Compendium* April 2002; **23**(4): 335–344 passim; quiz 348.
75. Tavares M, Stultz J, Newman M, Smith V, Kent R, Carpino E, Goodson JM. Light augments tooth whitening. *J Am Dent Assoc* 2003; **134**: 167–174.
76. Swift EJ, Heymann HO, Kugel G, Kanca J. More about tooth whitening. *J Am Dent Assoc* 2003; **134**(7): 809–811.
77. Hein DK, Ploeger BJ, Hartup JK, Wagstaff RS, Palmer TM, Hansen LD. Institution in-office vital tooth bleaching – what do lights add? *Compend Cont Educ Dent* 2003; **24**(4A): 340–352.
78. *Food and Drug Administration Hydrogen Peroxide: Irradiation in the Production, Processing and Handling of Food*. USPHS FDA 53 FR 53176, 1988.
79. Jones AH, Diaz-Arnold AM, Vargas MA, Cobb DS. Colourimetric assessment of lased and home bleaching techniques *J Esthet Dent* 1999; **11**: 87–94.
80. Dostalova T, Jelinkova H, Housova D, Sulc J, Nemec M, Miyagi M *et al*. Diode laser-activated bleaching. *Braz Dent J* 2004; **15**(Spec No): SI3–SI8.
81. Luk K, Tam L, Hubert M. Effect of light energy on peroxide tooth bleaching. *J Am Dent Assoc* 2004; **135**: 194–201; quiz 228–229.
82. Feinman R, Madray G, Yarborough D. Chemical, optical and physiological mechanisms of bleaching products: a review. *Prac Periodont Esthet Dent* 1991; **3**: 32–37.
83. Al Shetri S, Matis BA, Cochran MA, Zekonis R, Stropes M. A clinical evaluation of two in-office bleaching products. *Oper Dent* 2003; **28–5**, 488–495.
84. Cibirka RM, Myers M, Downey MC, Nelson SK, Browning WD, Dickinson GL. Clinical study to tooth shade lightening from dentist supervised, patient applied treatment with two 10% carbamide peroxide gels. *J Esthet Dent* 1999; **11**: 325–331.
85. Lyons K, Ng B. Nightguard vital bleaching: a review and clinical study. *N Z Dent J* 1998; **94**(417): 100–103.
86. Darnell DH, Moore WC. Vital tooth bleaching: the White and Brite technique. *Compendium*1990; **11**: 86–94.
87. Leonard R, Bentley C, Garland G, Knight M, Phillips C. Nightguard Vital Bleaching: a long-term study on efficacy, shade retention, side effects, and patients' perceptions. *J Esthet Rest Dent* 2001; **13**: 357–369.
88. Leonard RH Jr, Haywood VB, Caplan DJ, Tart ND. Nightguard vital bleaching of tetracycline stained teeth: 90 months post treatment. *J Esthet Rest Dent* 2003; **15**: 142–152.
89. Swift EJ, Jar May KN Jr, Wilder AD Jr, Heyman HO, Bayne SC. Two year clinical evaluation of tooth whitening using at home bleaching system. *J Esthet Dent* 1999; **11**: 36–42.
90. Ritter AV, Leonard RH, St Georges AJ, Caplan DJ, Haywood VB. Safety and stability of Nightguard Vital Bleaching: 9 to 12 years post-treatment. *J Esthet Rest Dent* 2002; **14:** 275–285.