

Guidelines for the selection of tooth whitening products amongst those available on the market

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SUMMARY

Background: Several tooth whiteners are available on the market, and the ideal choice should be determined by efficacy and optimal clinical results.

Objectives: The purpose of this study was to compare the reported clinical success rates of different tooth whitening products.

Search strategy: The relevant literature (1998 - 2011) was studied, using as sources the databases: Google Scholar, Science Direct, Medline and Pubmed.

Selection criteria: The material was clearly identified, the manufacturers' instructions were respected and the sample size stated.

Results and conclusions: This descriptive report on 49 papers focuses on the total colour change, measured with a calibrated shade guide and also numerically (colourimeter, chromameter or spectrophotometer), the relapse of the colour change and tooth sensitivity. In general, the dentist-supervised at-home bleaching and the in-office treatment gave approximately the same initial percentage improvement of tooth whitening. However, the relapse after a four week or longer period was significantly higher for the in-office treatment. The treatment of choice should be a dentist supervised at-home bleaching product which generally contains ~10% carbamide peroxide applied over about 14 days for about eight hours per night. Tooth sensitivity should not be a general problem although some subjects might choose to discontinue treatment as a result of sensitivity.

BACKGROUND

Dentists in clinical practice are faced with a large number of tooth whiteners available and advertised on the market. Furthermore, they are bombarded with results based on laboratory studies and to a lesser extent on clinical studies.¹⁻⁴ How then does the dentist select a tooth whitener which will be effective and provide optimal clinical results? Important also is the extent of colour relapse over time.

Peroxide is the chemical most frequently used as a tooth whitening agent with two types being generally employed i.e. hydrogen peroxide (H_2O_2) or carbamide peroxide ($CH_6N_2O_3$). Due to the instability of hydrogen peroxide it is mostly added to the whitener just before the application process, while carbamide peroxide is the more stable oxidising agent and can be included in the whitener itself. Thus, the hydrogen peroxide can be applied directly to the tooth surface as such or is produced from carbamide peroxide ($CH_6N_2O_3$, or $CH_4N_2O \cdot H_2O_2$) which dissociates into hydrogen peroxide (H_2O_2) and urea (N_2H_4CO) upon contact with water.^{5,6} Urea further breaks down into ammonia and carbon dioxide. It has been reported⁷ that a 10% carbamide peroxide solution can produce only about 3 – 3.35% hydrogen peroxide. Hydrogen peroxide is a very strong oxidising agent. When it decomposes it forms free radicals (O^{\cdot} and HO_2^{\cdot})^{5,6} which are responsible for the strong bleaching effect on organic and inorganic chemicals in and on enamel and dentine. However, more of the stronger per-hydroxyl (HO_2^{\cdot}) radical is formed in alkaline mediums with a resulting higher bleaching effect on teeth.⁶

To the public, the most important aspects of tooth whiteners are the effectiveness of the whitener, how long lasting is the effect, the cost of the treatment and the duration of the required treatment. Therefore, if money is not an issue, the in-office treatment would basically be the treatment of choice, since the resultant whitening effect can be observed just after the chair session.

Tooth-bleaching or tooth-whitening is mainly performed according to four different protocols: 1) dentist-supervised at-home bleaching, 2) in-office bleaching, 3) over-the-counter whitening products for self-application and 4) combination therapy (in-office followed by at-home treatment). In general, the most effective would be the first two, as the peroxide concentrations and application time of over-the-counter products are simply too low. In contrast, the

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Table 1: Shade Guide Measurements

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---------|------------------------------|--|------|------|---------------------|--|-------------------|----------------------|---------------------------------|
| Study # | Reference | Product | % CP | % HP | Category | Application | Tooth Sensitivity | % Colour improvement | % Colour relapse after 4 weeks+ |
| 1 | Browning 2008 ⁸ | Opalescence PF (plus nitrate and fluoride) | 10% | - | At-home | 2 weeks / x6 hours per night | 45% | 88% | 14% |
| 2 | Browning 2008 ⁸ | Opalescence formulation (F) | 10% | - | At-home | 2 weeks / x6 hours per night | 62% | 83% | 0% |
| 3 | Matis, 1998 ⁹ | Opalescence Tooth Whitening Gel | 10% | - | At-home | 2 weeks/8 hrs per night | mild | 73% | 41% |
| 4 | Matis, 2000 ¹⁰ | Opalescence F | 15% | - | At-home | 2 weeks/8 hrs per night | - | 69% | 18% |
| 5 | Matis, 2007 ¹¹ | Opalescence PF | 15% | - | At-home | 2 weeks/8 hrs per night | mild | 67% | 24% |
| 6 | Mokhlis, 2000 ¹² | Day White | - | 7.5 | At-home | 2 weeks/1hour twice a day | mild | 67% | 13% |
| 7 | Mokhlis, 2000 ¹² | Opalescence Tooth Whitening Gel PF | 20% | - | At-home | 2 weeks/ 1hour X2 daily | - | 67% | 11% |
| 8 | Zekonis, 2003 ¹³ | Opalescence Tooth Whitening gel | 10% | - | At-home | 2 weeks/8 hrs per night | mild | 67% | 46% |
| 9 | Matis, 2000 ¹⁰ | Opalescence Dental Whitening Agent | 10% | - | At-home | 2 weeks/8 hrs per night | - | 64% | 15% |
| 10 | Matis, 2007 ¹¹ | Nite White | 16% | - | At-home | 2 weeks/8 hrs per night | mild | 63% | 55% |
| 11 | Deliperi, 2004 ¹⁴ | Opalescence Xtra Boost plus Opalescence PF | 10% | 38% | In-office & At-home | 3 days (30 min in-office / 60 min at home) | none | 56% | - |
| 12 | Gurgan, 2009 ¹⁵ | Opalescence Xtra Boost | - | 38% | In-office | X2 /15 min | - | 54% | - |
| 13 | Matis2007 ¹⁶ | Brite Smile | - | 15% | In-office | 3 X 20 min | - | 54% | 68% |
| 14 | Gurgan, 2009 ¹⁵ | Laser-White 1--Laser Smile | - | 37% | In-office | X3 /8 min | mild | 54% | - |
| 15 | Gurgan, 2009 ¹⁵ | By White-Biowhite | - | 38% | In-office | X2 / 20 min | - | 53% | - |
| 16 | Deliperi, 2004 ¹⁴ | Opalescence Xtra plus Opalescence PF | 10% | 35% | In-office & At-home | 3 days (30 min in-office / 60 min at home) | none | 53% | - |
| 17 | Gurgan, 2009 ¹⁵ | Remewhite-Remecure | - | 35% | In-office | X3 / 20 min | - | 53% | - |
| 18 | Giniger, 2005 ¹⁷ | ACP containing bleaching gel | 16% | - | At-home | 2 weeks / 3 hours per day | mild | 51% | - |
| 19 | Browning, 2004 ¹⁸ | Experimental Product E | 10% | - | At-home | 2 weeks / 6 hours per night | mild | 50% | 0% |
| 20 | Swift, 1999 ¹⁹ | Nupro Gold bleaching gel | 10% | - | At-home | 2 weeks / 8 hours per night | - | 50% | 0% |
| 21 | Giniger, 2005 ¹⁷ | Nite White Excel 3 Regular | 16% | - | At-home | 2 weeks / 3 hours per day | - | 48% | - |
| 22 | Kihn, 2000 ²⁰ | Nupro Gold bleaching gel | 10% | - | At-home | 2 weeks / at least 4 hours per night | - | 48% | - |
| 23 | Heymann, 1998 ²¹ | Colgate Platinum Professional Overnight Whitening System | 10% | - | At-home | 1 week / 8 hours per night | mild | 47% | - |
| 24 | Matis, 2007 ¹⁶ | PolaOffice | - | 35% | In-office | X3 / 12 min | - | 47% | 69% |
| 25 | Matis, 2007 ¹⁶ | One-hour Smile | - | 35% | In-office | X3 /15 min | - | 44% | 54% |
| 26 | Zekonis, 2003 ¹³ | StarBrite | 35% | - | In-office | X2 / 3x10min | mild | 44% | 32% |
| 27 | Cibirka, 1999 ²² | Opalescence | 10% | - | At-home | 2 weeks / 8 hours per night | - | 44% | - |
| 28 | Matis, 2007 ¹⁶ | Niveous | - | 25% | In-office | 3 X 15 min | - | 43% | 72% |
| 29 | Matis, 2007 ¹⁶ | ArcBrite | - | 30% | In-office | 3 X 20 min | - | 41% | 53% |

Table 1: Shade Guide Measurements (continued)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|----|---------------------------------|------------------------------|--------------|-------------|-----------|---|------|-----|-----|
| 30 | Matis, 2007 ¹⁶ | Zoom! | - | 25% | In-office | X3 / 20 min | - | 39% | 50% |
| 31 | Matis, 2007 ¹⁶ | Accelerated | - | 40% and 30% | In-office | 5 X 3 Min | - | 39% | 81% |
| 32 | Li, 2005 ²³ | Opalescence Treswhite | - | 9% | At-home | 10 days / x1 hour daily | mild | 38% | - |
| 33 | Auschill, 2005 ²⁴ | Opalescence PF | 10% | - | At-home | 1 week / 8 hours per night | - | 38% | - |
| 34 | Auschill, 2005 ²⁴ | Opalescence Xtra Boost | - | 38% | In-office | 3 times / 15 min per time | - | 38% | - |
| 35 | Auschill, 2005 ²⁴ | Whitestrips | - | 5.3 | At-home | 2 weeks / 30 min twice daily | - | 38% | - |
| 36 | Zantner, 2006 ²⁵ | Odol-med3 gel | - | - | at-home | 2 weeks / X2 daily for 10 min | none | 33% | 0% |
| 37 | de la Pena, 2006 ²⁶ | Opalescence Ultradent | 10% | - | At-home | 4 weeks / 3 hours daily | mild | 31% | - |
| 38 | de la Pena, 2006 ²⁶ | FKD (Kin Lab) | - | 3.5 | At-home | 4 weeks / 3 hours daily | mild | 31% | - |
| 39 | Calatayud, 2009 ²⁷ | Vivastyle Paint on Plus | - | 6% | At-home | 10 days / X1 daily for 10 min | - | 30% | - |
| 40 | Calatayud, 2009 ²⁷ | Vivastyle Paint on Plus | - | 6% | In-office | 2 sessions 1 week apart/ 5 times 10 min | - | 29% | - |
| 41 | Kugel, 2000 ²⁸ | Crest Whitestrips | - | 5.3 | At-home | 2 weeks / X2 daily for 30 min | - | 28% | - |
| 42 | Zantner, 2006 ²⁵ | Colgate Simply White | - | 5.9 | at-home | 2 weeks / X2 daily for 15 min | none | 28% | 3% |
| 43 | Abu Alenain, 2009 ²⁹ | Opalescence Treswhite | - | 9% | At-home | 1 week / 60 min per day | mild | 28% | - |
| 44 | Matis, 2007 ¹⁶ | Illumine | - | 15% | In-office | X3 / 20 min | - | 25% | 18% |
| 45 | Cibirka, 1999 ²² | Nite White Excel | 10% | - | At-home | 2 weeks / 8 hours per night | - | 25% | - |
| 46 | Hannig, 2007 ³⁰ | Whitestrips | - | 6% | At-home | 2 weeks / X2 daily for 30 min | mild | 24% | - |
| 47 | Hannig, 2007 ³⁰ | Vivadent Vivastyle | 10% | - | At-home | 2 weeks / x1 daily for 60 min | mild | 24% | - |
| 48 | Abu Alenain, 2009 ²⁹ | White-Smile | 10% | - | At-home | 1 week / 2 hours daily | mild | 21% | - |
| 49 | Al Shethri, 2003 ³¹ | Star Brite | - | 35% | In-office | 2 treatments 1 week apart / X3 daily for 10 min | mild | 21% | - |
| 50 | Bernardon, 2010 ³² | Whiteness HP max FGM | - | 35% | In-office | 2 sessions, 3 applications per session, 15 day interval | - | 21% | - |
| 51 | Al Shethri, 2003 ³¹ | Opalescence Xtra Boost | - | 38% | In-office | 2 treatments 1 week apart / X3 daily for 10 min | mild | 20% | - |
| 52 | Bernardon, 2010 ³² | Whiteness HP max FGM | - | 35% | In-office | 2 sessions / 3 applications of 15 min / 15 day interval | - | 19% | - |
| 53 | Bernardon, 2010 ³² | Whiteness Perfect FGM | 10% | - | At-home | 2 weeks/8 hrs per night | - | 19% | 0% |
| 54 | Leonard, 2001 ³³ | Nightguard vital bleaching | 10% | - | At-home | 2 weeks / 8 hours per night | mild | 19% | 0% |
| 55 | Meireless, 2008 ³⁴ | Whiteness Perfect | 10% | - | At-home | 3 weeks / X2 hours daily | - | 14% | 9% |
| 56 | Meireless, 2008 ³⁴ | Whiteness Perfect | 16% | - | At-home | 3 weeks / x2 hrs daily | - | 13% | 2% |
| 57 | dos Santos, 2008 ³⁵ | Opalescence PF | 10% | - | At-home | 3 weeks / 8 hours per night | 36% | 13% | - |
| 58 | Braun, 2006 ³⁶ | Voco CP solution | 0% (Control) | - | At-home | 1 week / 2 hours daily | - | 10% | - |
| 59 | Abu, 2009 ²⁹ | CleverWhite over-the-counter | - | 6% | At-home | 1 week / 30 min per day | mild | 8% | - |
| 60 | Braun, 2006 ³⁶ | Voco CP solution | 10% | - | At-home | 1 week / 2 hours daily | - | 8% | - |
| 61 | Braun, 2006 ³⁶ | Voco CP solution | 17% | - | At-home | 1 week / 2 hours daily | - | 7% | - |

Column 1: Study number**Column 2:** Author(s)**Column 3:** Product tested**Column 4:** % age carbamide peroxide**Column 5:** % age hydrogen peroxide**Column 6:** Category of bleaching (at home, in office, combination)**Column 7:** Schedule of bleaching process**Column 8:** Resultant tooth sensitivity**Column 9:** Immediate tooth colour improvement**Column 10:** Relapse after four weeks or longer

peroxide concentrations (~35%) of the in-office bleaching whiteners are high (Table 1)⁸⁻³⁶ and applied for short bursts of time (~30 minutes) which might be repeated in the same session (or occasionally over more sessions) to show the effect before the patient goes home. Alternatively, the dentist-supervised at-home bleaching process normally makes use of lower peroxide concentrations (~10% carbamide peroxide) and patient self-application at-home, mostly over-night and over several days, for a good result.

OBJECTIVES

The objective of this study was firstly to evaluate and compare the clinical success rates of different commercially available tooth whitening products as reported in selected clinical trials in which the application was effected according to the instructions of the manufacturer. Secondly, to thereby enable clinicians to make an informed decision regarding the choice of the products which are most clinically effective.

SEARCH STRATEGY

This was accomplished by means of a comprehensive study of the literature which had reported on relevant clinical trials between 1998 and 2011, using the databases: Google Scholar, Science Direct, Medline and Pubmed respectively, with any combination of the keywords: tooth whitening, tooth bleaching, clinical studies, at-home, and in-office. The search was performed only on published, peer-reviewed articles.

CRITERIA FOR SELECTION OF STUDIES

The papers included were clinical studies in which:

- the whiteners had been applied according to the manufacturers' instructions. (The performance of the product could then be fairly evaluated in the circumstances under which it was expected to be applied in practice);
- the brand name of the tooth whitener was clearly specified;
- the sample size had been recorded.

Reporting the degree of relapse was not a criterion for inclusion, nor was assessment of tooth sensitivity, although, in the small number of cases where it was measured, the latter data were recorded on a word ordinal scale and in some cases as a percentage.

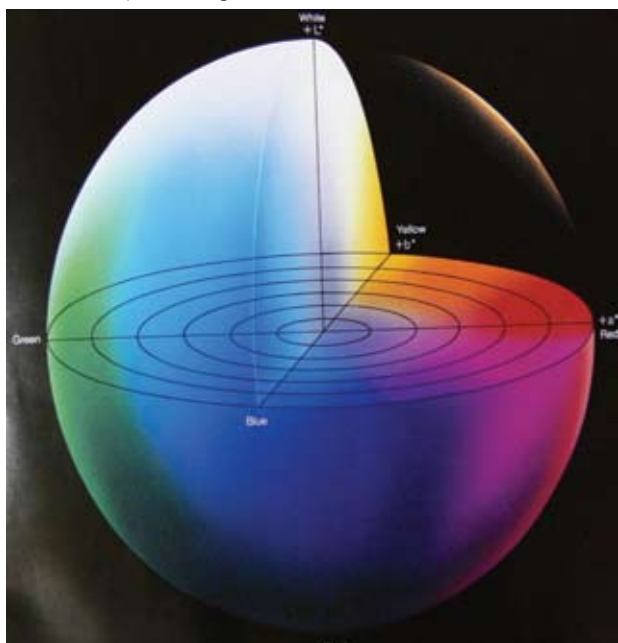


Figure 1: Representation of colour solid for L*a*b* colour space from Minolta.³

ASSESSING COLOUR CHANGES

Basically, there are two different ways to measure the effect of tooth whiteners, namely, by means of matching with a calibrated shade guide or numerically (colourimeter, chromameter or spectrophotometer). Some papers provided the shade guide assessments and some, numerical values, while a few provided both. These varied methods of reporting complicated the summary of the research results. Evaluations using a shade guide are subjective, while the numerical measurements are objective, providing more reliable and accurate results.^{1,2} Most important are the improved accuracy and the quantification of colours by measurement in a three dimensional colour space, of which the L*a*b* (also known as the CIELAB³) is presently the most popular for the measurement of tooth colour (Figure 1). In this space L* indicates lightness/darkness (white/black), a* varies from green (negative side) to red (positive side), while the b* value varies from blue (negative side) to yellow (positive side).⁴ (The asterisk is used to differentiate the CIELAB system from previous colour space descriptions.) As with the shade guide, colour change measurements with the spectrophotometer can be given in one value, namely the ΔE^*ab (Minolta), where $\Delta E^*ab = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ and ΔL^* , Δa^* and Δb^* provide the changes which occurred in these components.

MATERIALS AND METHODS

Based on the above selection criteria a total of ~49 full-length published articles were included. Most of these articles reported on two or more studies on different products and some 45 products had been tested. All data were recorded in Excel[®] tables. The variables for which data were sought are as follows: Product name; percentage carbamide peroxide (CP) and hydrogen peroxide (HP); Category (in-office or at-home bleaching); Application method; Tooth Sensitivity; percentage colour improvement; total colour change obtained immediately after the treatment process; percentage colour relapse after 4 weeks; and ΔE^*ab after treatment. Where the percentage colour improvement or relapse was not given, it was calculated from the results. These results were summarised in two tables (1 and 2). Table 1 reflects data according to shade guide measurements and Table 2 those according to numerical values (spectrophotometer, chromameter and colourimeter).

Each study included a number of trials from which the specific authors had calculated an average for their sample for colour changes. To gain an impression of the average efficacy in tooth whitening achieved by the products under test, the reported averages were added and an average of the averages derived. These data were used to compare the general efficacy of in-office and at home treatments.

RESULTS

Table 1 provides a summary of the results reported (or calculated) in the selected clinical studies assessing the efficacy of tooth bleaching through shade guide assessments.⁸⁻³⁶ The data were sorted from the highest to lowest percentage perceived colour improvement just after bleaching according to column 9 and the studies were numbered (column 1). The percentage colour relapse after a four week or longer period had been assessed and was recorded in column 10. In a few studies where both the shade guide and ΔE^*ab values were given in a study, the average percentage improvement of the two was calculated and noted (Table 1).

Table 2^{2,4,9-13,15,16,25,31,32,34,37-45} includes the same columns as for Table 1, except Column 9 now shows the ΔE^*ab values

Table 2: Numerical measurements

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---------|-----------------------------------|------------------------------------|----------|--------------|-----------|---|-------------------|-----------------------------------|---------------------------------|
| Study # | Reference | Product | % CP | % HP | Category | Application | Tooth Sensitivity | ΔE^*_{ab} after treatment | % Colour relapse after 4 weeks+ |
| 1 | Zekonis, 2003 ¹³ | Opalescence Tooth Whitening gel | 10% | - | At-home | 2 weeks / 8 hrs per night | mild | 12.32 | 46 |
| 2 | Matis, 2000 ¹⁰ | Opalescence F | 15% | - | At-home | 2 weeks / 8 hrs per night | - | 11.03 | - |
| 3 | Matis, 2007 ¹¹ | Opalescence PF | 15% | - | At-home | 2 weeks / 8 hrs per night | mild | 9.57 | 57 |
| 4 | Tsuburu, 2005 ³⁷ | Polanight | 10% | - | At-home | 2 weeks / 8 hrs per night | mild | 9.23 | - |
| 5 | Mokhlis, 2000 ¹² | Day White | - | 7.50% | At-home | 2 weeks / 1hour twice a day | mild | 9.2 | - |
| 6 | Matis, 2000 ¹⁰ | Opalescence Dental Whitening Agent | 10% | - | At-home | 2 weeks / 8 hrs per night | - | 8.79 | - |
| 7 | Matis, 1998 ⁹ | Opalescence Whitening Gel | 10% | - | At-home | 2 weeks / 8 hrs per night | mild | 8.6 | 41 |
| 8 | Bernardon, 2010 ³² | Whiteness Perfect FGM | 10% | - | At-home | 2 weeks / 8 hrs per night | - | 8.4 | 0 |
| 9 | Zantner, 2006 ²⁵ | Colgate Simply White | - | 5.90% | At-home | 2 weeks / X2 daily for 15 min | none | 8.38 | 3 |
| 10 | Zantner, 2006 ²⁵ | Odol-med3 gel | chlorite | chlorite | At-home | 2 weeks / X2 daily for 10 min | none | 8.22 | 0 |
| 11 | Matis, 2007 ¹⁶ | Niveous | - | 25% | In-office | 3 X 15 min | - | 8.1 | 72 |
| 12 | Matis, 2007 ¹⁶ | Nite White | 16% | - | At-home | 2 weeks / 8 hrs per night | mild | 8.04 | 55 |
| 13 | Matis, 2007 ¹⁶ | Brite Smile | - | 15% | In-office | 3 X 20 min | - | 7.9 | 68 |
| 14 | Tsuburu, 2005 ³⁷ | Opalescence | 10% | - | At-home | 2 weeks / 8 hrs per night | mild | 7.78 | - |
| 15 | Mokhlis, 2000 ¹² | Opalescence Tooth Whitening Gel PF | 20% | - | At-home | 2 weeks / 1hour X2 daily | - | 7.6 | - |
| 16 | Matis, 2007 ¹⁶ | ArcBrite | - | 30% | In-office | 3 X 20 min | - | 6.8 | 53 |
| 17 | Bernardon, 2010 ³² | Whiteness HP maxx FGM | - | 35% | In-office | 2 sessions / 3 applications of 15 min / 15 day interval | - | 6.64 | - |
| 18 | Matis, 2007 ¹⁶ | Accelerated | - | 40% and 30% | In-office | 5 X 3 Min | - | 6.6 | 82 |
| 19 | Bizhang, 2009 ⁴ | Illumine Home | 10% | - | At-home | 2 weeks / 8 hrs per night | - | 6.57 | 24 |
| 20 | Matis, 2007 ¹⁶ | Zoom! | - | 25% | In-office | X3 / 20 min | - | 6.4 | 50 |
| 21 | Bernardon, 2010 ³² | Whiteness HP maxx FGM | - | 35% | In-office | 2 sessions, 3 applications per session, 15 day interval | - | 6.17 | - |
| 22 | Matis, 2007 ¹⁶ | PolaOffice | - | 35% | In-office | X3 / 12 min | - | 5.9 | 69 |
| 23 | Ishikawa-Nagal, 2004 ² | Opalescence PF | 10% | - | At-home | 2 weeks / 4 hours daily | mild | 5.84 | - |
| 24 | Bizhang, 2009 ⁴ | Illumine Office | 15% | - | In-office | 45 min / X3 over 3 weeks | - | 5.77 | 20 |
| 25 | Gurgan, 2009 ¹⁵ | Laser-White 1--Laser Smile | - | 37% | In-office | X3 / 8 min | mild | 5.69 | - |
| 26 | Gurgan, 2009 ¹⁵ | Opalescence Xtra Boost | - | 38% | In-office | X2 / 15 min | - | 5.54 | - |
| 27 | Matis, 2007 ¹⁶ | Illumine | - | 15% | In-office | X3 / 20 min | - | 5.5 | 36 |
| 28 | Gurgan, 2009 ¹⁵ | By White-Biowhite | - | 38% | In-office | X2 / 20 min | - | 5.43 | - |
| 29 | Matis, 2007 ¹⁶ | One-hour Smile | - | 35% | In-office | X3 / 15 min | - | 5.4 | 54 |
| 30 | Zekonis, 2003 ¹³ | StarBrite | 35% | - | In-office | X2 / 3x 10min | mild | 5.32 | 32 |
| 31 | Grobler, 2010 ³⁸ | Nite White ACP | 10% | - | At-home | 2 weeks / 8 hrs per night | low | 5.29 | 27 |
| 32 | Grobler, 2011 ³⁹ | Nite White ACP | 10% | - | At-home | 2 weeks / 8 hrs per night | low | 5.29 | 31 |
| 33 | Gurgan, 2009 ¹⁵ | Remewhite-Remecure | - | 35% | In-office | X3 / 20 min | - | 5.28 | - |
| 34 | Benbachir, 2008 ⁴⁰ | Vivastyle Paint On Plus | - | 6% | In-office | 3 days over 2 weeks / 10min X5 times per session | - | 5.25 | - |
| 35 | Grobler, 2011 ³⁹ | Opalescence PF | 10% | - | At-home | 2 weeks / 8 hrs per night | low | 5.2 | 18 |
| 36 | Ishikawa-Nagal, 2004 ² | Nite White Excel | 10% | - | At-home | 2 weeks / 4 hours daily | mild | 5.03 | - |
| 37 | Luo, 2007 ⁴¹ | Crest White Strips | - | 6% | At-home | 2 weeks / 30 min X2 daily | - | 4.95 | -- |
| 38 | Meireless, 2008 ³⁴ | Whiteness Perfect | 16% | - | At-home | 3 weeks / x2 hrs daily | - | 4.6 | 2 |
| 39 | Gerlach, 2002 ⁴² | Crest Professional Whitestrips | - | 6.50% | At-home | 2 weeks / 30 min X2 daily | - | 4.55 | - |
| 40 | Meireless, 2008 ³⁴ | Whiteness Perfect | 10% | - | At-home | 3 weeks / X2 hours daily | - | 4.3 | 9 |
| 41 | Bizhang, 2009 ⁴ | Whitestrips | - | 6% | At-home | 2 weeks / 30 min X2 daily | - | 3.58 | 16 |
| 42 | Salem, 2010 ⁴³ | Yotuel Special | - | 35% | In-office | 20 min X3 (1 session) | mild | 3.56 | 53 |
| 43 | Grobler, 2010 ⁴⁴ | Opalescence PF | 10% | - | At-home | 2 weeks / 8 hrs per night | low | 3.25 | 8 |
| 44 | Karpinia, 2002 ⁴⁵ | Professional crest Whitestrips | - | 6.50% | At-home | 3 weeks / 30 min X2 daily | mild | 3.15 | - |
| 45 | Gerlach, 2002 ⁴² | Nite White Excel 2-tray system | 10% | - | At-home | 2 weeks / X2 hour daily | - | 2.55 | - |
| 46 | Al Shethri, 2003 ³¹ | Opalescence Xtra Boost | - | 38% | In-office | 2 treatments 1 week apart / X3 daily for 10 min | mild | 2.45 | - |
| 47 | Al Shethri, 2003 ³¹ | Star Brite | - | 35% | In-office | 2 treatments 1 week apart / X3 daily for 10 min | mild | 2.31 | - |
| 48 | Karpinia, 2002 ⁴⁵ | Nite White Excel2 | 10% | - | At-home | 2 weeks / 2 hours daily | mild | 1.94 | - |
| 49 | Luo, 2007 ⁴¹ | Colgate Great regular Flavour | - | 0% (control) | At-home | 2 weeks / x1 min x2 daily | - | 1.27 | - |

Column 1: Study number

Column 2: Author(s)

Column 3: Product tested

Column 4: % age carbamide peroxide

Column 5: % age hydrogen peroxide

Column 6: Category of bleaching (at home, in office, combination)

Column 7: Schedule of bleaching process

Column 8: Resultant tooth sensitivity

Column 9: Immediate tooth colour improvement

Column 10: Relapse after four weeks or longer

(total colour change) which indicate the colour improvement as measured numerically and column 10 the percentage relapse as calculated from the ΔE^*ab values. This table was also sorted according to highest to lowest ΔE^*ab values (column 9) immediately after treatment.

DISCUSSION

The values of shade guides cannot be directly compared with those numerically measured. A shade guide provides only a combination value for the three colour components (e.g. L*, a* and b*). The linear rankings of a tooth shade guide are not the same as those obtained from sequential delta E* (ΔE^*). The shades represented on a shade guide are not equi-distant when measured by the scientific and objective distances delta E* which relies on the three colour components (ie. L*, a* & b*). The distances between before and after colour measurements on each treated tooth differ when estimated with shade guides or taken numerically and these values could not be directly compared. Hence these data are assembled separately in two tables (Table 1 and Table 2).

As ΔE^* is a difference between two values the percentage change could only be determined in the relapse phase when there are indeed two such ΔE^* values. In relapse calculations where both methods had been used to determine the changes (a few cases only), the percentage relapses determined by shade guide and by numerical methods were first separately calculated and the average of the two then noted.

The percentage improvement (Table 2) could not be calculated for studies where only ΔE^*ab values were given as ΔE^*ab gives the difference between the tooth colour at base-line and that after treatment.

For the shade guide values, (Table 1), the top ten achievers were at-home products and likewise according to ΔE^*ab (Table 2) the top ten achievers were also at-home products. The highest values reported (Tables 1 and 2) were with a 10% or 15% carbamide peroxide treatment over a relatively long treatment period (two weeks 6/8 hours per night). In general, the treatment periods for top achievers (Table 1 and 2) were all scheduled over relatively long time-periods which, as seen in Table 1, varied from two hours/day for two weeks, to six hours/night for two weeks and to eight hours/night for two weeks. For Table 2 the first eight study achievers were for eight hours/night for two weeks (with the exception of study # 5 which was for one hour twice daily for two weeks. The shortest treatment period (Table 1) within the ten top achievers (study # 6 and 7) was one hour/twice-a-day for 14 days but this was a trial using 7.5% HP (~25% CP) and 20% CP in comparison with the more general treatment which uses 10% carbamide peroxide. In Table 2 the shortest treatment period within the top ten at-home achievers was twice a day for 15 min (study # 9) but as for Table 1, this study relied on a high peroxide concentration (5.9% HP). The other treatment with a short application time was with chlorite (study # 10). Therefore, it can be deduced that to obtain the same success rate as with 10% carbamide peroxide it seems that a shorter treatment period might be indicated but using a higher peroxide concentration.

In general, it can be seen that in-office treatments (even with high peroxide concentrations) were far less successful (Table 1 and 2) than at-home treatments with ~10% carbamide peroxide. On the ranking list, in-office applications came in well below the highest achievers at study # 11 (Table 1) and study # 11 (Table 2). Why then is the high peroxide concentration treatment unexpectedly found to be less successful? The reason may be found in the length of the application pe-

Table 3: Descriptive statistics of colour improvement (shade guide assessment) immediately after treatment for 'At-home' and 'In-office' treatment.

| Values | Category | |
|---|----------|-----------|
| | At-home | In-office |
| Number of studies | 40 | 19 |
| Number of studies indicating % colour improvement | 19 | 9 |
| Average of average of % colour improvements | 39.3% | 38.8% |
| Std Dev of % colour improvement | 22.4% | 12.7% |
| Min % colour improvement | 6.9% | 19.1% |
| Max % colour improvement | 88.1% | 54.4% |

Table 4: Descriptive statistics of colour relapse (shade guide assessment) after four weeks for 'At-home' and 'In-office' treatment.

| Values | Category | |
|---|----------|-----------|
| | At-home | In-office |
| Number of studies | 40 | 19 |
| Number of studies indicating % colour relapse after 4 weeks | 19 | 9 |
| Average of average % colour relapses after 4 weeks | 13.1% | 55.2% |
| Std Dev of % colour relapse after 4 weeks | 17.0% | 20.2% |
| Min % colour relapse after 4 weeks | 0.0% | 18.0% |
| Max % colour relapse after 4 weeks | 55.0% | 81.0% |

Table 5: Descriptive statistics of colour improvement (ΔE^*ab -scale) immediately after treatment for 'At-home' and 'In-office' treatment.

| Values | Category | |
|--|----------|-----------|
| | At-home | In-office |
| Number of studies | 29 | 20 |
| Number of studies indicating colour improvement | 13 | 11 |
| Average of average ΔE^*ab after treatments | 6.36 | 5.60 |
| Std Dev of ΔE^*ab after treatment | 2.80 | 1.48 |
| Min ΔE^*ab after treatment | 1.27 | 2.31 |
| Max ΔE^*ab after treatment | 12.32 | 8.1 |

Table 6: Descriptive statistics of colour relapse (ΔE^*ab - scale) after 4 weeks for 'At-home' and 'In-office' treatment.

| Values | Category | |
|---|----------|-----------|
| | At-home | In-office |
| Number of studies | 29 | 20 |
| Number of studies indicating % colour relapse | 13 | 11 |
| Average of average of % colour relapses | 26.02% | 53.60% |
| Std Dev of % colour relapses | 18.98% | 18.65% |
| Min % colour relapse | 2.17% | 20.45% |
| Max % colour relapse | 57.37% | 81.82% |

riod. In-office applications (Table 1, studies # 11-17; Table 2, study 11 and others) were performed over a short period in comparison with the dentist supervised at-home treatment procedures. The in-office treatment periods were normally short bursts, for example three x 15minutes/session, three x 20 minutes/session, etc. (Table 1 and 2). However, there were a few examples (Table 1, # 40, 49-52) where the in-office sessions were repeated over days but only two of these studies (Table 1, #11, 16) were further extended to an at-home treat-

ment. However, to allow subjects to personally handle such a high peroxide concentration is very risky and should not be recommended.

There are probably two main reasons for the short application period of in-office treatments: the first reason is financial, in that the longer the in-chair session the more expensive the treatment becomes, the second is that high peroxide application has a possible hazardous effect (related to the oxidising strength) on the soft tissue of the oral cavity.

From Table 3 (shade guide) it can be deduced that overall both at-home (39.3%) and in-office (38.8%) treatments showed more or less the same initial colour improvement. However, a major difference could be seen in the relapse after a four week or longer period (at-home 13.1%; in-office 55.2% :Table 4). From the ΔE^*ab (Table 5) numerical values, the initial colour improvements for in-office and at-home were also about the same (5.60 against 6.36).

When the relapse was calculated from ΔE^*ab values (Table 6), in-office treatment gave a value of 53.6%, similar to that found with the shade guide assessments (55.2%) (Table 4). However, the at-home relapse was 26.02% (Table 6) which is about double that when calculated from shade guide measurements (13.1%) (Table 4).

Other findings reported on the combination of dentally supervised at-home treatments: Leonard *et al.*³³ revealed that the whitening effected by 10% carbamide peroxide (Nite White Classic; eight to ten hours per day for 14 days) reported five tabs lighter teeth, an effect which lasted over a 3.8 year period. In two different articles^{46,47} reporting on 10% carbamide peroxide which was applied for two hours per day for three weeks, no relapse was reported after one year. No comparable results were reported for any in-office treatment. Only two studies reported results for a combination of in-office and at-home treatments (Studies # 11 and 16). Study 11 showed a colour improvement of 56% (Table 1) and study 16 also showed a high colour improvement of 53%. These results may indicate that a combination of the in-office and at-home treatments could produce the most positive results. Unfortunately no assessment on any colour relapse was reported in these two studies.

The most commonly tested product was Opalescence PF, a material evaluated in 11 studies. The average of the average colour improvements as reflected on the shade guide scale, was 54% compared with 36% for all the other products. With regard to numerical measurements, the five studies using that method of assessment recorded 6.9 (ΔE^*) for the average of the average colour improvements for Opalescence PF and an average of 5.95 (ΔE^*) for all the other products. These values can be considered high spectrophotometer readings, possibly highlighting the accuracy of the technology in comparison with shade guide measurements.

The mean relapse measured numerically after four weeks was 27.8% for Opalescence (n=3) which is considerably lower than the mean of 40.2% recorded for all the other products (n=21). Not all studies recorded relapse values (Opalescence 3 of 5; other products: 21 of 44) and these findings should therefore be regarded only as an indication of relapse potentials.

The next question which may be posed is which of the in-office or dentist supervised at-home treatments would give the lowest tooth sensitivity scores? Not all studies reported on this, but the data recorded in Tables 1 and 2 reveals no significant differences in tooth sensitivities between the routines, and overall these effects were low - with an exception of the two top achievers in bleaching (Table 1), where a higher sensitivity was in fact noted (62% and 45%). However, it should also be observed that in some instances during treatments, the sensitivity might be so high that the individual prefers to terminate the application. Some of the manufacturers (studies # 1 and 4) added chemicals (potassium nitrate and fluoride) to their bleaching products in an attempt to counteract sensitivity. However, the clinical data (Table 1) indicates uncertainty on the possible positive effects of those materials, or on amorphous calcium phosphate and no general conclusion could be reached.^{11,16,17,38,48,49} Furthermore, from the published results (Tables 1 and 2), it can also be concluded that in general, where tooth sensitivity was noted during the whitening process, it disappeared spontaneously after the treatment period.

CONCLUSION

This analysis of the data shows that the dentist-supervised-at-home-bleaching and the in-office treatment gave nearly the same initial tooth whitening improvement. However, the relapse after a four week or longer period was found to be much higher for the in-office treatment at a relapse of ~55% on average, while the at-home treatment showed a much lower relapse over the same period of about 13% to 26%. Overall, it can be concluded that the treatment of choice should be a dentist supervised at-home bleaching process using a product which in general contains about 10% carbamide peroxide applied over ~14 days and for ~8 hours per night on average. Tooth sensitivity should not be seen as a consistent problem although some subjects might choose to discontinue treatment as a result of experiencing the problem.

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