

ORIGINAL ARTICLE

***In vitro* evaluation of variances between real and declared concentration of hydrogen peroxide in various tooth-whitening products**ABDUL MAJEED¹, IMRAN FAROOQ², SIAS R. GROBLER & M. H. MOOLA³¹Department of Restorative Dental Sciences, ²Department of Biomedical Dental Sciences, College of Dentistry, University of Dammam, Dammam, Kingdom of Saudi Arabia, and ³Oral & Dental Research Institute, Faculty of Dentistry, University of the Western Cape, Cape Town, South Africa**Abstract**

Objectives. The aim of this *in vitro* study was to analyze the real hydrogen peroxide (HP) concentration in various commercially available tooth-whitening products containing HP and/or carbamide peroxide (CP). **Materials and methods.** Sixteen commercially available tooth-whitening products containing various concentrations of CP or HP were investigated. The products were divided into four groups: dentist-supervised home bleaching products (Group 1, $n = 5$), in-office bleaching products (Group 2, $n = 4$), over-the-counter bleaching products (Group 3, $n = 3$) and whitening toothpastes and rinses (Group 4, $n = 4$). The peroxide concentration was determined using the oxy-reduction titration method. All the reagents used in the study were of analytic grade and freshly prepared before the experiment. **Results.** The HP concentration in various dentist-supervised home bleaching products and in-office bleaching products ranged from 3.02–37.08% (expected range = 3–38%). The HP concentration of over-the-counter whitening products ranged from 1.24–5.57% (expected range cannot be estimated as no concentration of active ingredient was provided). Among whitening toothpastes and rinses, Colgate Plax whitening rinse showed more than 1% HP concentration, whereas it was lower than 0.05% in other whitening toothpastes and oral rinses (expected range cannot be estimated as no active ingredient was mentioned). **Conclusions.** HP concentration of most of the professional tooth-whitening products was different from the expected concentrations, although the deviations were small and most of the products were close to the expected concentration. No concentration of active ingredient was provided for over-the-counter whitening products and no active ingredient was mentioned for whitening toothpastes and rinses.

Key Words: *Tooth bleaching, tooth whitening, hydrogen peroxide, carbamide peroxide***Introduction**

Peroxides have wide-ranging industrial and medical applications, owing to their superior oxidizing properties [1]. In the field of dentistry, hydrogen peroxide (HP) [2] and one of its predecessors, carbamide peroxide (CP), are used in cosmetic products [3] such as teeth whiteners, toothpastes and mouth washes. Therefore, the concentration of peroxide in these products is critical because, in this case, peroxide comes into contact with living tissue [4]. HP has been used as a tooth-bleaching (tooth whitening) agent for more than 70 years, but its demand has increased dramatically in recent years [5]. Successful bleaching of teeth depends on a number of factors such as the type of bleaching agent, the type of stain

[6], frequency of application and the period for which the agent remains in contact with the tooth surface [7].

Bleaching products with high concentrations of peroxide are believed to produce quicker whitening of teeth as compared with products with lower peroxide concentrations [8]. Studies evaluating the efficacy of different concentrations of CP found that, although a lower concentration of peroxide takes a longer time to whiten the teeth, it eventually achieves the same result as achieved by higher concentrations [7,9].

A large number of whitening products are commercially available. These products have different compositions and concentrations. Previous studies have reported that even commercially produced

whitening products had lower concentrations of active bleaching agents specified by the manufacturers [10,11]. However, little data are present in the literature, which reports the real concentration of HP in professional and over-the-counter tooth-whitening products as opposed to that specified by the manufacturers for a specific product containing HP or CP.

The aim of this *in vitro* study was, therefore, to analyze the HP concentration in various commercially available tooth-whitening products containing HP and/or CP and to compare them with the concentration stated by manufacturers.

Materials and methods

Tooth whitening products used for investigation

Sixteen commercially available tooth-whitening products containing various concentrations of HP and/or CP were investigated in this study. These products were divided into four categories: dentist-supervised home bleaching products (Group 1, $n = 5$) (Yotuel[®] Patient, Opalescence[®] PF, Nite[®] White ACP and Opalescence[®] Treswhite Supreme), in-office bleaching products (Group 2, $n = 4$) (Yotuel[®] 10 minutes, Opalescence[®] PF Quick, Yotuel[®] Special and Opalescence[®] Boost), over-the-counter bleaching products (Group 3, $n = 3$) (White Glo, Absolute white and Speed white) and whitening toothpastes and rinses (Group 4, $n = 4$) (Plus + White whitening prerinse, Plus + White with peroxide, Pearl Drops whitening tooth polish and Colgate Plax whitening rinse).

Reagents used for chemical analysis

Reagents used for chemical analysis included the following: potassium iodide (10% solution in ionized water), ammonium molybdate acid mixture (0.18 g of ammonium molybdate, 750 ml of water and 300 ml of concentrated sulfuric acid), potassium iodate solution (0.1 N), starch solution (10 g/L) and standardized sodium thiosulfate solution (0.1 N).

Procedure of chemical analysis

Sixteen commercially available tooth-whitening products containing various concentrations of HP

and/or CP were investigated. Samples of all the products were measured in triplicate from three different packages. The peroxide concentration was determined using oxy-reduction titration method. All reagents used in the study were of analytical grade and freshly prepared before starting the experiment.

A weighed sample of whitening product was dissolved in 200 ml of deionized water in a 500 ml Erlenmeyer flask using a Bibby HC502 magnetic stirrer (BibbySterilin Ltd, Staffordshire, UK). Potassium iodide solution and acid mixture were added to the solution and mixed well. The flask was covered with a stopper and left to stand for 5 min. The color of the solution became light yellow to dark brown, depending on the peroxide concentration of the sample. The mixed sample solution was titrated with standardized sodium thiosulfate solution (0.1 N) in a 50 ml burette, until a light straw color was achieved. Then, a few drops of starch solution were added and titration continued until the color changed sharply from blue to colorless. The volume of sodium thiosulfate used for titration was recorded as 'A'.

The titration was repeated without the addition of a whitening product (control/blank) and the volume of sodium thiosulfate used was recorded as 'B'. The HP concentration was calculated according to the following formula [12]:

$$\text{Hydrogen peroxide \% w/w} = \frac{(A - B)(N)(1.7007)}{\text{Sample weight}}$$

with A being the titration volume of sodium thiosulfate, B being the titration volume of sodium thiosulfate for blank and N being normality of sodium thiosulfate.

Statistical analysis

Simple descriptive statistics such as mean were calculated. Analyses were performed using SPSS software (version 19.0; SPSS Inc., Chicago, IL). The HP concentration of 3–3.35% in 10% CP product was used as a standard for comparison purposes.

Results

The HP concentration in various dentist-supervised home bleaching products and in-office bleaching products ranged from 3.02–37.08% (Tables I and II).

Table I. Dentist-supervised home bleaching products.

Products	Active ingredient	Expected H ₂ O ₂	Mean H ₂ O ₂ concentration (%)
Yotuel [®] Patient	10% CP	3–3.35	3.02
Opalescence [®] PF	10% CP	3–3.35	3.40
Nite White [®] ACP	10% CP	3–3.35	3.75
Opalescence [®] PF	20% CP	6–6.67	6.31
Opalescence [®] Treswhite Supreme	10% HP	10	8.98

Table II. In-office bleaching products.

Product	Active ingredient	Expected H ₂ O ₂ %	Mean H ₂ O ₂ concentration (%)
Yotuel [®] 10 Minutes	30% CP	9–10	9.93
Opalescence [®] PF Quick	45% CP	13.5–15	16.24
Yotuel [®] Special	35% HP	35	27.19
Opalescence [®] Boost	38% HP	38	37.08

Table III. Over-the-counter bleaching products.

Products	Active ingredient	% H ₂ O ₂	Mean H ₂ O ₂ concentration (%)
White Glo	CP	Not provided	1.24
Absolute White	HP	Not provided	3.20
Speed White	HP	Not provided	5.57

The HP concentration in over-the-counter whitening products ranged from 1.24% for White Glo to 5.57% for Speed White (Table III). Colgate Plax whitening rinse showed more than 1% HP, although it was lower than 0.05% in other whitening toothpastes and oral rinses (Table IV).

Discussion

It has been reported that 10% CP dissociates into a HP concentration of 3–3.5% [13,14]. Therefore, CP-based whitening products were expected to have the corresponding HP concentrations. The results of the present study show that the HP concentration of most of the professional tooth-whitening products was different from the expected concentrations. Mean HP concentration of a few professional tooth-whitening products was higher but lower for some professional products as compared with expected HP concentration. However, deviations were small, and most of the products were close to the expected range, except Yotuel Special, which showed the largest variation, as it was expected to have 35% HP concentration when freshly prepared, but the concentration found was only 27.19%. A number of studies have demonstrated that the use of 10% CP or less applies no or minimal effect on enamel microhardness and mineral content [15–17]. However, in one study, which utilized bleaching products with 16% and 35% CP, it was established that the patients should be cautioned

against potential damage to the enamel minerals by these products [18]. Therefore, it is difficult to comment exactly about the safest concentration of HP that can be used by the consumer without damaging the tooth structure.

Although active ingredients were labeled on over-the-counter whitening products tested in the present study, no concentrations were provided by the manufacturers. As for whitening toothpastes and oral rinses, only Colgate Plax whitening rinse showed a HP concentration of 1.50%, whereas it was almost nil in the remaining products.

There are very few studies available in the literature which determine real HP concentration in professional and over-the-counter tooth-whitening agents. This fact makes it difficult to compare the results of the present study with data from the literature. However, few studies that assessed the CP concentration of professional tooth-whitening products showed that the concentrations of these products were lower than those expected [10,11,19]. It was evaluated in an *in-vitro* study that the concentration of 16% CP products produced commercially or dispensed by pharmacies were different from those expected in all products. However, the commercially produced bleaching product showed the best mean concentration close to the expected 16% [6]. The findings are in agreement with the results of the present study, which also found that HP concentration of bleaching products were marginally different from those expected.

Table IV. Whitening toothpastes and rinses.

Products	Active ingredient	Expected H ₂ O ₂ %	Mean H ₂ O ₂ concentration (%)
Plus + White whitening pre-rinse	Not provided	Not provided	< 0.05
Plus + White with peroxide	Not provided	Not provided	
Pearl Drops Whitening Tooth Polish	Not provided	Not provided	
Colgate Plax whitening rinse	Not provided	Not provided	1.50

In the present study, HP concentrations of three 10% CP products from different manufacturers were determined. The results reveal marginal differences among these products. These variances could be present because of the differences in formulations, manufacturing and quality of the products.

The rate of bleaching is related to peroxide concentration and application time [20] and lower concentrations require longer treatment times than HP concentrations. It has been reported previously that a higher CP concentration of 15% resulted in a quicker and greater whitening than 10% CP during the early phase of treatment. However, the whitening effect showed some relapse after the cessation of active bleaching treatment and no significant differences were found after 6 weeks [19]. The results of the present study revealed lower than expected peroxide concentrations for some professional tooth-whitening products such as Opalescence Treswhite Supreme and Yotuel Special. Therefore, these products would probably require longer treatment times than those recommended by the manufacturers.

Despite the results achieved, further studies should be carried out to investigate the efficacy and side-effects of these products on tooth structure, particularly enamel.

Conclusions

Based on the results of this study, the following conclusions can be drawn:

- (1) Professional (dentist-supervised home bleaching and in-office bleaching) products showed peroxide concentrations that differed marginally from the desired values, except Yotuel Special.
- (2) The concentration of HP in various over-the-counter tooth-whitening products ranged from 1.24–5.57%.
- (3) HP concentration in whitening toothpastes and rinses was negligible, except in Colgate Plax whitening rinse, which had 1.50% HP.

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