

# The pH of various tooth-whitening products on the South African market

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**A Majeed:** BDS, PDD, MSc (Dent). Oral and Dental Research Institute, Faculty of Dentistry, University of the Western Cape, Cape Town, South Africa.

**SR Grobler:** MSc, PhD, DSc. Oral and Dental Research Institute, Faculty of Dentistry, University of the Western Cape, Cape Town, South Africa

**MH Moola:** BDS, MSc, DDPH RCS, LDS RCS. Oral and Dental Research Institute, Faculty of Dentistry, University of the Western Cape, Cape Town, South Africa

## Corresponding author

**A Majeed:** Oral and Dental Research Institute, Faculty of Dentistry, Private Bag X1, Tygerberg, 7505, Republic of South Africa. Tel: 021 937 3024,

Fax: 021 937 3025. E-mail: amajeed@uwc.ac.za.

## ABSTRACT

**Objectives:** The purpose of this *in vitro* study was to investigate the pH of 21 commercially available tooth-whitening products.

**Methods:** Tooth-whitening products were divided into four categories: dentist supervised-home bleaching products (n = 5); in-office bleaching products (n = 5); over-the-counter bleaching products (n = 4) and whitening toothpastes and rinses (n = 7). The pH of three samples of each product was measured using an Orion Expandable Ion Analyzer EA940 with a Sure-Flow<sup>®</sup>, Epoxy-body combination pH electrode. The group data were analysed using one way ANOVA (significant at p<0.05).

**Results:** The five dentist supervised-home bleaching products had a mean pH of 6.21 ± 0.76 and ranged from 4.88 to 6.81. The five in-office bleaching products had a mean pH of 6.26 ± 1.19 and ranged from 5.30 to 7.85. The four over-the-counter whitening products had a mean pH of 5.07 ± 1.74 and ranged from 3.76 to 8.03 and the seven whitening toothpastes had a mean pH of 7.66 ± 1.19 and ranged from 6.61 to 9.68. The pH of the over-the-counter category was significantly lower (more acidic) than all other categories (p<0.05). The whitening gel of Rapid-White had the lowest acidic pH of 3.76 and Colgate Advanced Whitening toothpaste showed the highest alkaline pH of 9.68.

**Conclusions:** The pH of all tooth-whitening products showed a wide range from 3.76 (highly acidic) to 9.68 (highly alkaline). Over-the-counter whitening products showed the lowest pH levels and in general these can be expected to damage enamel more than the other products. Dentists should be vigilant with regards to products used outside their surgeries and should warn their patients accordingly.

**Clinical implications:** The acidic pH of many of the whitening products other than in-office bleaching products is of concern and the general public should be better informed by the dental professionals of the dangers of these products.

**Keywords:** Tooth-whitening, bleaching, pH, enamel

## INTRODUCTION

Tooth-whitening has become increasingly popular in recent years. Peroxides in the form of hydrogen peroxide or carbamide peroxide are the most common active ingredients in tooth-

whitening products. Several studies have evaluated the safety, effectiveness and side effects of whitening products on intraoral soft and hard tissues.<sup>1-5</sup> The American Dental Association has granted its seal of acceptance to a number of products. However, the currently available whitening products vary in composition, concentration, pH and type of active ingredients. Some products have been reported to have a pH as low as 3.67 (acidic), while others have been reported to have a pH as high as 11.13 (alkaline).<sup>6</sup> Weiger, Kuhn and Lost<sup>7</sup> reported that the greater the peroxide concentration, the lower the pH of the whitening product.

During the bleaching procedure teeth and soft tissues will be exposed to the pH of the bleaching agent for a varying period of time. Some studies<sup>8</sup> reported demineralisation of enamel at a pH below 5.2, while others<sup>9</sup> reported a pH of 5.5 as the critical pH for dental enamel. Dawes<sup>10</sup> reported that the critical pH below which enamel is dissolved varies from 5.1 to 6.5 and depends on the concentrations of calcium and phosphate in the solution. Current literature suggests that a low pH and high acid concentrations cause enamel erosion.<sup>11,12</sup>

Scanning electron microscope studies have reported alterations in the surface morphology of enamel following bleaching with carbamide peroxide and/or hydrogen peroxide products.<sup>13-19</sup> Other investigators, however, reported contradicting evidence that there were no changes in the enamel morphology following exposure to some bleaching agents.<sup>20-22</sup>

Bleaching products may affect the bond strengths and properties of composite restorative materials. However, it is not known if the effects are related to the pH or peroxide concentration of the bleaching products.<sup>6</sup> The majority of the studies reported that the bond strength of composite restorative materials to enamel was significantly reduced when the bonding procedure was carried out immediately after bleaching treatment.<sup>23-26</sup> Polymerisation inhibition of the resin adhesive systems, due to the presence of oxygen released by the bleaching process on the enamel surface and within the dentinal tubules, is the likely mechanism to the reduction in bond strengths.<sup>23,27</sup> Alternatively, loss of mineral content of the enamel may also adversely affect the bond strengths.<sup>28-29</sup>

A large number of whitening products are available on the market. These products differ greatly in composition, mode

**Table 1:** The mean pH of dentist-supervised home-bleaching (DSHB) products.

Product name	Manufacturer	Lot no.	Application time	Mean pH ( $\pm$ SD)
Nite White <sup>®</sup> ACP 10% CP	Discuss Dental, Inc. Culver City CA, USA	9068046	8 hrs/d	4.88 $\pm$ 0.02
Yotuel <sup>®</sup> Patient 10% CP	Biocosmetic Laboratories, Madrid Spain	Z311	8 hrs/d	6.43 $\pm$ 0.02
Opalescence <sup>®</sup> PF 10% CP	Ultradent Products, Inc. South Jordan Utah, USA	B2CR6	8 hrs/d	6.46 $\pm$ 0.02
Opalescence <sup>®</sup> PF 20% CP	Ultradent Products, Inc. South Jordan Utah, USA	B33RW	8 hrs/d	6.81 $\pm$ 0.03
Opalescence <sup>®</sup> TrèswHITE Supreme 10% HP	Ultradent Products, Inc. South Jordan Utah, USA	B2FJF	30 min/d	6.45 $\pm$ 0.17

SD = Standard deviation, CP = carbamide peroxide, HP = hydrogen peroxide

**Table 2:** The mean pH of in-office bleaching (IOB) products.

Product name	Manufacturer	Lot no.	Application time	Mean pH ( $\pm$ SD)
Yotuel <sup>®</sup> 10 Minutes 30% CP	Biocosmetic Laboratories, Madrid Spain	A023/Z321	2x10 min/session	5.38 $\pm$ 0.07
Opalescence <sup>®</sup> PF Quick 35% CP	Ultradent Products, Inc. South Jordan Utah, USA	-	30 min/session	7.23 $\pm$ 0.04
Opalescence <sup>®</sup> PF Quick 45% CP	Ultradent Products, Inc. South Jordan Utah, USA	B3LWK	30 min/session	5.54 $\pm$ 0.00
Yotuel <sup>®</sup> Special 35% HP	Biocosmetic Laboratories, Madrid Spain	08YT35005	45-60 min/session	5.30 $\pm$ 0.09
Opalescence <sup>®</sup> Boost 38% HP	Ultradent Products, Inc. South Jordan Utah, USA	B3MDL	60-80 min/session	7.85 $\pm$ 0.13

SD = Standard deviation, CP = carbamide peroxide, HP = hydrogen peroxide

of application and availability to the public and may require a prolonged contact time with intraoral structures. It would be reasonable to expect that these products would have neutral or near neutral pH values so as to minimise damage to enamel.

Therefore, the purpose of this *in vitro* study was to determine the pH levels of 21 commercially available tooth-whitening products containing carbamide peroxide, hydrogen peroxide or other bleaching ingredients.

## MATERIALS AND METHODS

Twenty one tooth-whitening products commercially available on the South African market were chosen for the study (Tables 1-4). The products were divided into four categories: dentist-supervised home bleaching (DSHB) products (n = 5); in-office bleaching (IOB) products (n = 5); over-the-counter (OTC) whitening products (n = 4) and whitening toothpastes (WT) (n = 7). The pH was measured using an Orion Expandable ion Analyzer EA940 (Orion Research Inc. MA, USA) and an Orion 9165BNWP Sure-Flow<sup>®</sup>, Epoxy-body combination pH electrode (Thermo Electron Corporation, Beverley, MA, USA). The pH electrode was calibrated using two buffering solutions of pH 4 and 7 (Beckman Instruments Irvine, CA, USA) and the electrode response to the buffer solutions (recalibration) was checked after each 6 sample measurement. The products were placed in disposable cups and stirred with the pH electrode to ensure a uniform contact with the electrode tip. The electrode tip was left in contact for about five minutes at room temperature to allow the pH value to stabilize. Three samples of each product were measured and in between samples, the electrode was thoroughly washed and rinsed with distilled water to completely remove residual material. The pH of a commonly utilised carbonated soft drink (Coca Cola) was also measured for reference purposes.

Simple descriptive statistics such as mean, minimum, maximum and standard deviation were calculated. The pH levels of tooth-whitening products between different categories were compared using the Kruskal-Wallis one-way ANOVA test with a significance level of 5%.

## RESULTS

The mean pH values of the whitening products are given in Tables 1 to 4 and represented in graphical form in Figure 1.

Overall, the pH of all tooth-whitening products ranged from 3.76  $\pm$  0.07 (highly acidic) to 9.68  $\pm$  0.03 (highly alkaline). The five dentist-supervised home bleaching products had a mean pH of 6.21  $\pm$  0.76 and ranged from 4.88 to 6.81 (Table 1 and Figure 1). The five in-office bleaching products had a mean pH of 6.26  $\pm$  1.19 and ranged from 5.30 to 7.85 (Table 2 and Figure 1). The four over-the-counter whitening products had a mean pH of 5.07  $\pm$  1.74 and ranged from 3.76 to 8.03 (Table 3 and Figure 1) and the seven whitening toothpastes had a mean pH of 7.66  $\pm$  1.19 and ranged from 6.61 to 9.68 (Table 4 and Figure 1).

There was a significant difference between the pH values of the four categories (Kruskal-Wallis one-way ANOVA;  $p < 0.05$ ). The pH of the over-the-counter category differed significantly from all the other categories ( $p < 0.05$ ). The whitening gel of Rapid-White (over-the-counter) had the lowest acidic pH of 3.76  $\pm$  0.07 and Colgate Advanced Whitening toothpaste had the highest alkaline pH of 9.68  $\pm$  0.03. The pH of the Coca Cola drink was found to be 2.62  $\pm$  0.04.

## DISCUSSION

The pH of various tooth-whitening products evaluated in this study ranged from 3.76 to 9.68. The tested hypothesis was rejected because the range was far from the expected neutral pH of 7.0. In a previous study, Price *et al.*<sup>6</sup> reported an even higher variation for 26 commercially available tooth-whitening products (3.67 to 11.13). Exposure of oral soft and hard tissues to highly acidic or alkaline solutions may result in detrimental effects. However, the degree of damage depends mainly on the contact time and the frequency of application of a bleaching agent as far as pH is concerned. The products evaluated in the present study also differed greatly in treatment time and frequency of application; therefore, it is important to consider these factors when evaluating the possible side effects of a product.

The recommended application time for the various products ranged from 5 minutes per day to 8 hours per day (Tables 1 to

Table 3: The mean pH of over-the-counter (OTC) bleaching products.

Product name	Manufacturer	Lot no.	Application time	Mean pH (±SD)
Rapid White Step 1 Accelerator	Rapid White Products, Tonawanda, NY, USA	LK429	-	8.03 ± 0.30
Rapid White Step 2 Whitening gel	Rapid White Products, Tonawanda, NY, USA	LK429	5-10 min/d	3.76 ± 0.07
Rapid White combination of step 1 & 2	Rapid White Products, Tonawanda, NY, USA	LK429	5-10 min/d	3.76 ± 0.03
Absolute White™	Dr. Fresh, Inc. La Mirada, CA, USA	-	30 min/d	3.94 ± 0.02
Speed White	CCA Industries, Inc. E Rutherford, NJ, USA	7610	5-10 min/d	4.65 ± 0.04
White Glo	Barros Laboratories Pty Ltd. NSW, Australia	11615	20 min/d	6.30 ± 0.03

SD = Standard deviation

Table 4: The mean pH of whitening toothpastes

Product name	Manufacturer	Lot no.	Application time	Mean pH (SD)
Colgate Advanced Whitening	Colgate-Palmolive (Pty) Ltd. Boksburg, RSA	7134ZA10	2-4 min/d	9.68 ± 0.03
Plus White Xtra with peroxide whitening	CCA Industries, Inc. E Rutherford, NJ, USA	27243X	2-4 min/d	6.61 ± 0.08
Opalescence Whitening TP	Ultradent Products, Inc. South Jordan Utah, USA	B2CR6	2-4 min/d	6.70 ± 0.02
Plus White Xtra Cool Mint TP	CCA Industries, Inc. E Rutherford, NJ, USA	-	2-4 min/d	8.69 ± 0.06
Rapid White Whitening TP	Rapid White Products, Tonawanda, NY, USA	LK429	2-4 min/d	7.04 ± 0.04
White Glo Whitening TP	Barros Laboratories Pty Ltd. NSW, Australia	-	2-4 min/d	8.11 ± 0.10
Aqua Fresh White & Shine TP	GlaxoSmithKline South Africa, Bryanston, RSA	-	2-4 min/d	6.81 ± 0.06

SD = Standard deviation

4). Most dentist-supervised home bleaching products are in contact with the teeth for an extensive period of time. The pH was nearly neutral for most of these products, ranging from 6.43 to 6.81 except for one product (Nite White ACP) which had a pH of 4.88 (Table 1) possibly due to the buffering action of amorphous calcium phosphate.

However, an increase in the pH of the oral environment has been reported during nightguard home bleaching with 10% carbamide peroxide.<sup>30</sup> It is believed that a 10% aqueous solution of carbamide peroxide ( $\text{CH}_6\text{N}_2\text{O}_3$ ) decomposes into a 3.35% solution of hydrogen peroxide ( $\text{H}_2\text{O}_2$ ) and 6.65% of urea ( $\text{CH}_4\text{N}_2\text{O}$ ).<sup>20</sup> Subsequently, urea breaks down into ammonia and carbon dioxide which increases the intraoral pH.<sup>30,31</sup> Furthermore, dentist-supervised home bleaching products are generally applied in custom-fitting trays which prevent the contact of bleaching product with the soft tissue and minimize the risk of injury.

In the present study, two over-the-counter whitening products namely Rapid White and Absolute White showed the lowest pH of 3.76 and 3.94 respectively (Table 3 and Figure 1). Rapid White is a non-peroxide whitening product containing sodium chlorite and citric acid. Previous studies<sup>5,20</sup> also reported low pH values for over-the-counter whitening products containing sodium chlorite. On the other hand, Absolute White is a paint-on whitening gel containing hydrogen peroxide. Over-the-counter products are applied either in prefabricated trays or directly onto the labial surfaces of teeth. Therefore, one would expect damage to the soft tissues and even greater risk of swallowing the bleaching agent.

Most solutions with low pH levels are known to soften enamel and produce dental erosion.<sup>32-34</sup> In an *in vitro* study, Hunter et al<sup>11</sup> observed that increasing the frequency of exposure to a low pH drink resulted in a non-proportional increase in dental erosion. However, reducing the frequency of exposure by half did not result in a similar reduction in tissue loss. Although a product such as Nite White ACP (pH 4.88) does not have a highly acidic pH, an application of 8 hours per day for 14 days may be enough to cause damage. The mean pH of in-office bleaching products

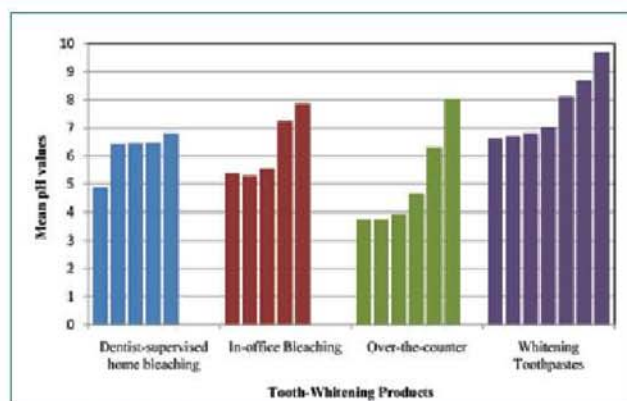


Figure 1: The pH of the whitening products in various categories.

in the present study ranged from 5.30 to 7.85 (Table 2). These products are applied for shorter durations than the dentist-supervised home bleaching products. To determine the possible damage caused by in-office bleaching products at these pH levels and length of exposure requires further investigation. In-office bleaching treatments are generally repeated 3 to 7 days after the first application only if desired results have not been achieved. Furthermore, fluoride, amorphous calcium phosphate (ACP) and potassium nitrate have been introduced in recent bleaching products to prevent either demineralisation or hypersensitivity.<sup>35</sup>

The pH levels of 21 commercially available tooth-whitening products were measured in this study. The wide range of pH observed in different categories of whitening products also requires further investigation. Additionally, the pH of whitening products also changes inside the oral cavity during the bleaching process. However, it is not known if the changes in pH occur at the same rate for products containing hydrogen peroxide or carbamide peroxide, or if the pH changes adversely affect oral soft and hard tissues.<sup>6</sup>

In this study every effort was made to carry out all measurements at standardised room temperature ( $23 \pm 2^\circ\text{C}$ ). However, the

pH of whitening products may be affected by the higher intraoral temperatures, the temperature of water used to brush teeth can influence the pH of toothpastes and the temperature of in-office bleaching products change when bleaching lights are used.

## CONCLUSIONS

1. The pH of all tooth-whitening products showed a wide range of 3.76 (highly acidic) to 9.68 (highly alkaline).
2. Over-the-counter whitening products showed the lowest pH levels and in general these can be expected to damage enamel more than the other products.
3. Dentists should be vigilant with regard to products used outside their surgeries, should be aware of the dangers, and should warn their patients accordingly.
4. In-office and dentist-supervised home bleaching procedures can be recommended as possibly the only safe bleaching procedures, and perhaps professional dental Associations should communicate the concerns raised by this study to the profession and to the manufacturers and retailers.

**Declaration:** No conflict of interest.

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