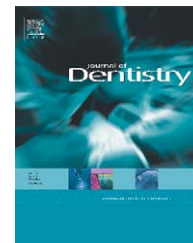


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Reaction kinetics of sodium ascorbate and dental bleaching gel

Andrea Freire^{a,*}, Evelise M. Souza^a, Danilo Biazzetto de Menezes Caldas^a,
Eivaldo Antônio Ribeiro Rosa^a, Cynthia França Wolanski Bordin^b,
Ricardo Marins de Carvalho^c, Sergio Vieira^a

^a School of Dentistry, Pontifical Catholic University of Parana, Curitiba, Parana, Brazil

^b School of Pharmacy, Pontifical Catholic University of Parana, Curitiba, Parana, Brazil

^c College of Dentistry, University of Florida, Gainesville, Florida, USA

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ABSTRACT

Objective: The aim of this study was to establish the reaction kinetics of 35% hydrogen peroxide and sodium ascorbate and to determine the mass of antioxidant required to neutralize the bleaching gel.

Methods: The method used to quantify sodium ascorbate was based on the United States Pharmacopeia (1995)²⁶. Oxidation–reduction titration was used to confirm the concentration of hydrogen peroxide and sodium ascorbate and to determine the reaction kinetics between them.

Results: The results indicated a direct correlation between the mass of hydrogen peroxide and that of the antioxidant agent. In addition, 5 min of contact was sufficient to neutralize the hydrogen peroxide used.

Conclusion: This *in vitro* study showed that the amount of sodium ascorbate required for reduction of hydrogen peroxide is directly related to the concentration of the latter. In addition, the reaction kinetics between oxidant and antioxidant showed that a longer application time for sodium ascorbate does not influence the effectiveness of the reaction and that 5 min is sufficiently long for this antioxidant to exert an antioxidant effect.

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1. Introduction

Peroxides are widely used in several areas of dentistry, such as restorative dentistry, where they are used for dental bleaching, and new bleaching methods are constantly being sought. Hydrogen peroxide, which is used in high concentrations, around 35%, is the most widely used materials for in-office dental bleaching.^{1,2}

It is a powerful oxidant that can produce other reactive oxygen species (free radicals), which are responsible for the

bleaching process.³ The oxidative potential of a bleaching agent is measured by the amount of reactive oxygen species released and the speed at which they are released, both of which depend on several factors, such as the concentration of peroxide.⁴

Many studies have reported the adverse effects of bleaching agents when applied to dental structures. These include root resorption,⁵ reduction in bond strength^{1,6–13} and increased microleakage in composite resin restorations performed after dental bleaching.^{14,15} These effects could be

* Corresponding author at: Programa de Pós-graduação em Odontologia, R. Imaculada Conceição, 1155, Prado Velho, Curitiba, PR 80215-901, Brazil. Tel.: +55 41 3271 1637; fax: +55 41 3271 1405.

E-mail address: andreavfreire@yahoo.com.br (A. Freire).

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related to the presence of residual hydrogen peroxide in the interprismatic spaces as well as in the dentinal matrix and tubules.^{16,17} The release of oxygen is frequently associated with small bubbles that can be viewed by scanning electron microscopy (SEM) at the bonding interface.¹⁸ These can prevent adequate infiltration of the bonding agent into the dental structures¹ and also inhibit its polymerization.¹⁹ Additionally, the presence of residual free radicals in the dental structure may interfere with the propagation of vinyl free radicals during light-curing of the adhesives, resulting in premature chain termination and incomplete polymerization.²⁰

To eliminate these effects, several studies have proposed the use of antioxidant agents after the bleaching procedure.^{2,20-25} Although these studies used different types and concentrations of peroxides, all used 10% sodium ascorbate as the antioxidant agent.

In light of the above, the aim of this study was to determine the amount of sodium ascorbate required to serve as an antioxidant agent after dental bleaching with 35% hydrogen peroxide and the ideal application time. The null hypotheses to be tested were that (i) there is no direct correlation between the initial amount of sodium ascorbate submitted to the action of the bleaching gel and the mass of ascorbate that reacts with hydrogen peroxide and (ii) that the application time for sodium ascorbate does not influence the effectiveness of this reaction.

2. Materials and methods

The methodology used in this study was based on the United States Pharmacopeia.²⁶ The materials used are listed in Table 1, along with the batch numbers and the names of the manufacturers.

2.1. Hydrogen peroxide dosage

Titration with potassium permanganate was used to confirm the concentration of the commercial hydrogen peroxide (H₂O₂) used in this study – Pola Office (SDI Ltd, Bayswater, Victoria, Australia). This was confirmed to be 35.57% for all the samples, indicating excellent homogeneity.

2.2. Equivalence of the reagents

To determine the amount of sodium ascorbate (98% purity, Sigma, Canton, MA, USA) required to reduce hydrogen peroxide, the principle of equivalence between the reagents was considered. The masses were calculated for both substances so that the balance between them could be determined. Using this method we found that 2 g of sodium

ascorbate would be needed for each gram of bleaching gel containing 35% hydrogen peroxide.

2.3. Determination of the mass of ascorbate that reacted with H₂O₂

Iodine oxidation–reduction titration was the method chosen for indirect determination of reactive ascorbate. One gram of 35% hydrogen peroxide gel was submitted to the action of different masses of sodium ascorbate, from 2 g to 6 g. The mass was calculated from different volumes of a 20% sodium ascorbate solution. The time for the substances to react was set at 35 min. After this period, the titrating solution (1N iodine) was added progressively until a change in color was observed, indicating the balance point. The surplus mass of sodium ascorbate, i.e., the ascorbate that had not reacted with the H₂O₂, was obtained using the following equation:

$$1 \text{ mL of 1N iodine} \dots\dots\dots 0.09905 \text{ g of sodium ascorbate} \\ V \times cf \dots\dots\dots \times \text{g of sodium ascorbate}$$

V = iodine (mL) volume; cf = correction factor of the standard solution.

The surplus mass of sodium ascorbate was subtracted from the initial mass, and the result was considered to be the mass that had reacted with the H₂O₂.

2.4. Kinetics of the reaction between hydrogen peroxide and sodium ascorbate

Based on the previous finding that 2 g of sodium ascorbate (98% purity, Sigma, Canton, MA, USA) was sufficient to react with 1 g of the 35% hydrogen peroxide gel, this mass was used to determine the reaction kinetics. The methodology used was the same as that described above except for the reaction times, which were set at 35, 30, 25, 20, 15, 10 and 5 min.

The tests were carried out in duplicate, and the data were subjected to regression analysis with a significance level of $\alpha = 0.05$. The dependent variable was the reactive ascorbate, and the independent variables were the time and amount of initial ascorbate. The regression model was adjusted using the ordinary least squares method to pass through the origin, as when the initial amount of ascorbate is zero, reactive ascorbate is also zero.

3. Results

The results showed there was a direct relationship between the initial amount of sodium ascorbate submitted to the action of the bleaching gel and the mass of ascorbate that reacted with the hydrogen peroxide ($p < 0.05$). The first null hypothesis was therefore rejected.

Table 1 – Materials used in the study.

Product name	Manufacturer	Batch number
Pola Office (hydrogen peroxide 35%)	SDI Ltd, Bayswater, Victoria, Australia	E476677
Sodium L-ascorbate A4034	Sigma, Canton, MA, USA	114K02071

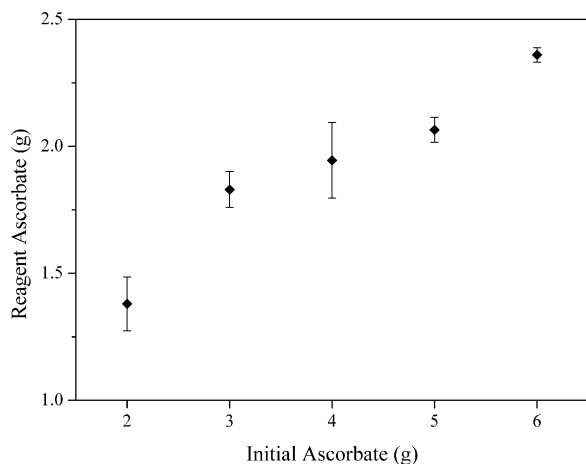


Fig. 1 – Variation of reagent sodium ascorbate mass reacting with the bleaching gel according to the initial amount of sodium ascorbate mass.

Fig. 1 shows that there was a very strong correlation between the amount of sodium ascorbate added to the reaction and the amount of hydrogen peroxide reduced by the sodium ascorbate ($r^2 = 0.9791$). When the data were plotted, a reaction curve obeying the following equation was obtained:

$$\text{Reactive ascorbate (g)} = 0.441697 \times \text{initial ascorbate (g)}$$

Fig. 2 shows that contact between hydrogen peroxide and sodium ascorbate for longer periods did not result in any further reaction ($p > 0.05$) and that even after a longer period, the amount of reactive sodium ascorbate was around 2 g, which is in agreement with the second null hypothesis.

4. Discussion

The main objective of this *in vitro* study was to determine the kinetics of the reaction between 35% hydrogen peroxide and

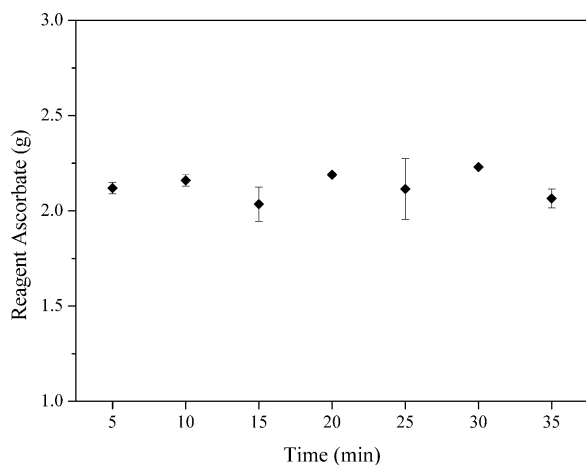


Fig. 2 – Variation of reagent sodium ascorbate mass in a function of time.

sodium ascorbate rather than comparing different brands or types of bleaching agents. A commercially available bleaching agent (Pola Office, SDI Ltd, Bayswater, Victoria, Australia) was chosen to simulate a real clinical situation. In a pilot study, no differences were found between the concentration of hydrogen peroxide in a solution prepared in a compounding pharmacy, the concentration of hydrogen peroxide in the commercial bleaching gel (powder mixed with the solution) and that of the hydrogen peroxide solution alone. Both the commercial bleaching gel and the hydrogen peroxide solution are included in the kit used.

Ascorbic acid and its salts are products with low toxicity (LD50 = 11,900 mg/kg) and are commonly used in the food industry as antioxidant agents, indicating that there is likely to be few to no adverse biological effects when they are used for this particular purpose.²⁰ While ascorbic acid has a pH of around 4, sodium ascorbate has a higher pH, approximately 7, and is therefore more appropriate for use on dental structures, as a neutral pH would avoid enamel and dentin being conditioned twice.²⁰

The results of this study show that there was an effective reaction between 35% hydrogen peroxide and sodium ascorbate. This can be explained by the mechanism of action of the bleaching agents as well as that of the antioxidants. Peroxides produce an oxidation reaction in the molecular chains of organic pigments by means of free radicals, as a result of which the chains are broken one by one and the pigments lose their color.³ Antioxidants are substances that react with free radicals, such as oxygen generated by the degradation of hydrogen peroxide, neutralizing them in the structure in which they are entrapped.²⁷

Another finding of this study is the direct relationship between the amount of hydrogen peroxide and the amount of sodium ascorbate, i.e., the amount of oxidant and antioxidant (Fig. 1). This is a fundamental finding since there are many bleaching agents available in different concentrations on the market. This study used 35% hydrogen peroxide, but other products with lower concentrations of hydrogen peroxide and carbamide peroxide intended for the same application are also available. Ten percent carbamide peroxide, the most commonly used bleaching agent for home use, decomposes to produce hydrogen peroxide at a concentration of around 3.5%.²⁸ This is 10 times lower than the concentration used in the present study and thus could probably result in different amounts of sodium ascorbate being required to balance the reaction.

This could explain why studies that used 10% sodium ascorbate reported reversion of the reduced bond strength after dental bleaching with 10% carbamide peroxide.^{15,21,22,25} However, after dental bleaching with 35% hydrogen peroxide followed by application of 10% sodium ascorbate as the antioxidant agent, bond strength increased but did not return to the original values for the non-bleached controls.² Sodium ascorbate was found to be effective in reversing the reduction in bond strength after treatment with 10%, 16% and 22% carbamide peroxide, but reduced values of bond strength were obtained when a greater concentration of carbamide peroxide was used.¹⁸

According to recent studies,^{15,21,24} sodium ascorbate should be applied for three hours after dental bleaching.

However, some authors^{2,18,22,23,25} proposed the use of sodium ascorbate for 10 min and reported that the adverse effects of the bleaching agent were successfully reversed. In the present study, it could be observed that the reaction between hydrogen peroxide and sodium ascorbate was fast and that 5 min was long enough for the antioxidant to reduce the bleaching gel (Fig. 2). As reaction time did not have a significant effect in our study, similar results could probably be achieved with shorter reaction times. An application time of 5 min is suitable for clinical conditions and also allows bonding procedures to be started sooner, thus eliminating the waiting time of 2–3 weeks after dental bleaching suggested by some authors.^{9,10,12} These results have great clinical significance, as many patients need to have restorations replaced or undergo esthetic procedures soon after dental bleaching.

Analysis of the kinetics of the reaction between sodium ascorbate and 35% hydrogen peroxide revealed that the amount of antioxidant had a greater effect than exposure time on the rate of reduction of hydrogen peroxide.

Further studies with enamel and dentin specimens are required to determine the ideal mass of sodium ascorbate for use after in-office dental bleaching, as only part of the hydrogen peroxide used is entrapped inside dental structures as a residue that could compromise the properties of bonding systems applied after the bleaching procedure. It is possible that even shorter clinical application times might be sufficient to reverse the adverse effects of bleaching agents on resin bonding.

5. Conclusion

The results obtained in this *in vitro* study show that the amount of sodium ascorbate required to reduce a 35% hydrogen peroxide gel is directly related to its concentration. Thus, in order to reduce 2 g of 35% hydrogen peroxide gel, 20 mL of a 25% sodium ascorbate solution is recommended.

In addition, the oxidant/antioxidant reaction kinetics showed that application of the sodium ascorbate for a longer period does not influence the effectiveness of the reaction and that 5 min is sufficiently long for the ascorbate to exert an antioxidant effect.

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