STUDY OF THE IMPACT OF THE BLEACHING WITH 6% H_2O_2 SOLUTION ON TEETH WEAR

F.Rodrigues*, A.P.Serro, C.G.Figueiredo-Pina***,*******

* Centro de Química Estrutural, Instituto Superior Técnico, ULisboa, Lisboa, Portugal

** Centro de investigação Interdisciplinar Egas Moniz, Instituto Superior de Ciências da Saúde Egas Moniz, Quinta da Granja, Caparica, Portugal

*** Department of Mechanical Engineering, Setúbal School of Technology, Instituto Politécnico de Setúbal, Setúbal, Portugal

**** Center of Physics and Engineering of Advanced Materials, Instituto Superior Técnico, ULisboa, Lisboa, Portugal

Abstract:

Objectives: This study aims to evaluate the effect of a 6% hydrogen peroxide (H_2O_2) solution, activated with UV-light, in colour, wear, microhardness and roughness of enamel surface.

Methods: Five teeth were cut, polished and exposed to black tea solution to confer them a dark color. The specimens were tested before and after bleaching using a spectrophotometer colour equipment, a nanotribometer, a micro durometer and a SEM.

Results: On comparing with untreated, the treated enamel surface showed an improvement of colour but a reduction of microhardness and an increase of roughness and wear.

Conclusions: A 6% hydrogen peroxide solution, activated with UV-light, has capacity to induce alterations in enamel surface making it less hard and more susceptible to wear.

Keywords: Bleaching, Hydrogen peroxide, Dental wear

1. INTRODUCTION

Teeth aesthetic is very important for individual's self-confidence and the dark teeth are esthetically a great problem. The darkening of the teeth occurs due to extrinsic and/or intrinsic stains. The first appear as a result of accumulation of chromophore substances, for example from the food, drinks, poor oral hygiene and tobacco, in pellicle which consists in an organic film that cover the external surface of the teeth. In contrast, the intrinsic stains are located inside of the teeth, more specifically in dentin, from e.g. aging, antibiotics use and tobacco, and are the most difficult to remove. [1] [2] [3]

Tooth whitening or bleaching is comonly used to restore the natural teeth color or to go beyond the natural color. The bleaches are oxidizing agents, based generally in hydrogen peroxide (H_2O_2), that react with dental enamel eliminating the coloring substances. The bleaching teeth process isn't totally understood but some authors believed that the hydroxyl radical ($^{\bullet}OH$) cleaves the double bonds existing in chromophores making these molecules reflect less light, which produces a whitening effect [4] [5]. The peroxide radicals generated from H_2O_2 in enamel surface penetrate enamel, reacting with the pigments, and improve significantly the teeth's color [6].

However, several studies have shown that bleaches lead to changes in the enamel surface and also enamel properties [7]. Most of these changes are probably due to low pH and oxidative effect of bleaching products [8]. These changes undergo decrease in microhardness, alterations in morphology surface, variation in chemical composition and minor wear resistance [7].

The objective of the present study is to evaluate the effect of a bleaching agent (H_2O_2) at a concentration of 6%, on dental wear.

2. MATERIALS AND METHODS

Five healthy human molars were extracted and stored in a timol solution (0.1%) at 4ºC in order to ensure sterilization. After, the molars were cut longitudinally and then the cut surfaces were grinded and polished up to 1 µm diamond paste. All the plates were stained during 48 hours in 10 mL of black

tea solution (2 g in 50 mL) at room temperature. After, these samples were treated in a solution with 6% of H_2O_2 as bleaching agent. The samples were submitted to 11 bleaching treatments to obtain a maximum whiteness (shade B1). Each treatment consisted in the immersion of each dental sample in 10 mL of 6% of H_2O_2 solution (pH = 3.1) during 10 minutes. In order to activate the peroxide, the immerged samples were irradiated during 30 s with ultraviolet radiation (λ=350 nm) every 2.5 minutes (total time of irradiation 4x30s). After each treatment, the sample color was accessed using a color spectrophotometer (SpectroShade™ Micro). The differences in color during bleaching were calculated using the following equation [9]:

$$\Delta E = \sqrt{(\Delta L^2 + \Delta a^2 + \Delta b^2} \quad (1)$$

ΔE corresponds to the difference in sensation of color alteration and is a Euclidean distance between 2 points in the 3-dimensional space of shade; coordinate L represents shade alterations in the black and white scale; a represents shade and saturation in the red-green axis; and b represents saturation in the blue-yellow axis [9]. ΔL, Δa, Δb, represent the difference between the coordinates L, a, and b at the beginning and the end of the experiment.

Reciprocating pin-on-plate tests were performed in a Nanotribometer (CSM Instruments), where the plates were flat dental samples and the pins were 3 mm diameter zirconia balls. The tribological operational conditions are given in Table 1. The tests were performed in artificial saliva at room temperature. For each group of samples, ten wear tests were performed.

Table 1. Wear test operational conditions

Applied load (mN)	20
Stroke distance (mm)	1
Frequency (Hz)	2
Duration (min)	10
Max Lin. Speed (cm/s)	0.65

The surface roughness (Ra) was determined from Atomic Force Microscopy (AFM) images (100 x100 μm^2) obtained with a microscope Nanosurf Easyscan2 with silicon tips (PPP-NCLAuD-10) and a load of 20 nN.

The samples hardness was measured using a microhardness tester (Struers Duramin) with an applied load of 1.96 N and a dull time of 30s. Fifteen measurements were performed per condition.

The wear mechanisms were identified by scanning electron microscopy observation (Hitachi S2400 equipment). The samples were previously coated with gold.

3. RESULTS AND DISCUSSION

The initial applied compressive contact stress obtained by application of Hertz equation for elastic contact was 158 MPa, which is within the masticatory pressure. In fact, in the literature the mastication force varies between 70 to 700 N [10]. If it is considered an occlusal contact area of 2 mm^2, the compressive stress varies between 35 and 350 MPa during mastication. In the occlusal contact the sliding distance is around 0.9 to 1.2 mm. The tests were performed in lubricated medium in artificial saliva to mimic the oral conditions.

The difference in sensation of color alteration, ΔE, during the bleaching treatment is given in Figure1. At the beginning the stained teeth samples had shades of C3, D2, C4 and at end of sample treatment the shades achieved were B1, A3, A2 depending of the treated teeth. Similar results were obtained by other authors using 5-6% of hydrogen peroxide as bleaching agent [11]. The difference response of the various samples to the treatment is probably related to differences in the enamel structure or thickness and the type of intrinsic stains existing in teeth [4] that are not derived from the darkening with black tea.

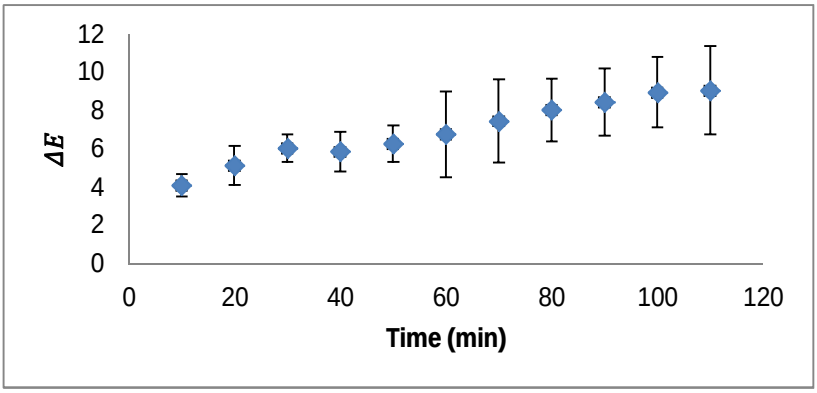

Figure 1. Difference in sensation of color alteration, ΔE, during bleaching application.

Table 2 shows the changes of hardness, roughness and friction coefficient due to bleaching treatment.

Table 2. Hardness, roughness and friction coefficient of treated (6% H_2O_2) and untreated dental samples.

	Before	After
Hardness (HV)	359±19	224±20
Ra (nm) in surface	64±52	91±51
Ra (nm) inside of wear tracks	75±10	173±12
Friction coefficient average	0.36±0.06	0.46±0.07

The results showed a reduction of teeth hardness after bleaching. Hardness reduction have been found in other studies at 6% or similar concentrations of peroxide [12] [13] [14] [15] due probably to enamel demineralization during the bleaching treatment, as a result of the low pH value and oxidative effect [8]. However, other studies suggest that 6% peroxide hydrogen doesn't have significant effect in enamel microhardness [14] [16] [17]. However, in these studies the teeth were exposed to artificial saliva after bleaching treatments, which promotes the remineralization of the enamel with the consequent recovery of the original microhardness.

Concerning to the surface roughness, the results show an increase of the average value after the bleaching treatment. However, it was observed a high scatter. Some works showed differences in surface morphology after bleaching to 6% or similar [13]. It is thought that the effects of the peroxide on the morphology of enamel surface are oxidation and a posterior partial lysis of organic material within the enamel [18]. Probably also the low pH of 6% H_2O_2 increased the roughness due to chemical attack of the enamel hydroxyapatite nanocrystals. In contrast, several other studies have demonstrated no significant alterations in morphology surface of enamel [7] [16] [18] [19]. Once again, some this studies exposed the enamel to artificial saliva after bleaching treatment.

The friction coefficient after treatment is higher probably due to the increase of surface roughness after bleaching (Table 2 and Figure 2). In addition, the friction coefficient becomes more irregular, suggesting an increase in the amount of third body particles. In what concerns the evolution of the friction coefficient during time, in teeth bleached, between 100 and 200s there was a sudden increase of friction coefficient, suggesting a change in friction mechanisms. In other study [15] friction coefficient after treatment was lower but they used a Biotene solution as lubricant.

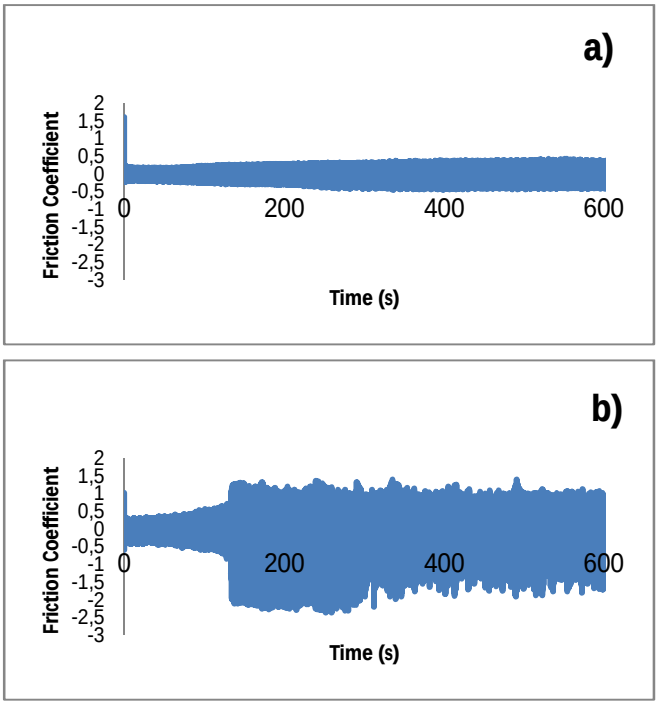

Figure 2. Evolution of the friction coefficient during time a) without bleaching, b) after bleaching.

Bleaching treatment results an increasing of wear. SEM analyses (Figure 3) show an increase of width of the wear tracks after treatment. The wear tracks obtained without treatment were smoother (Table 2). The enamel structure was not observed in the wear tracks of both groups of samples, due to the formation of a tribolayer that is constituted by nanometric enamel debris. This layer is more visible for the treated samples. During treatment, the glycoproteins, that coat the nanometer hydroxyapatite enamel crystals, are oxidized and posteriorly occurs a partial lysis of organic material. Probably all these mechanisms are also related to tribochemical effects, involving the release of debris in the tooth/zirconia that renders the contact surface rougher, changing the system to a three-body configuration [20]. In addition, and as explained previously, there is a chemical attack of the hydroxyapatite during treatment due to low pH. This both effects contribute to an increase of enamel wear.

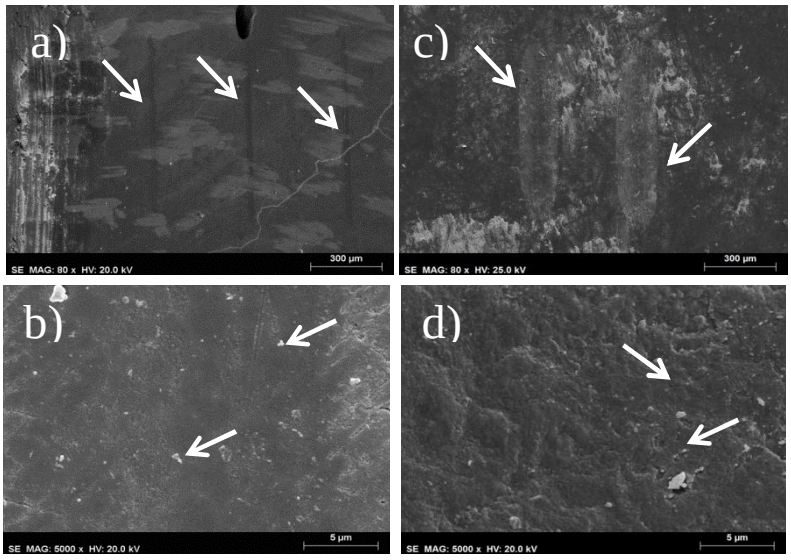

Figure 3. SEM morphology inside of wear tracks a) and b) without treatment, c) and d) with treatment. In a) and c), the arrows point to wear tracks. In b) and d), the arrows point to debris.

4. CONCLUSIONS

Overall, the results show that H_2O_2 penetrates enamel and induces a whitening effect in the teeth. However, the treatment decreases the resistance of enamel to wear, reduces the teeth microhardness and increases the surface roughness. Careful must be taken in the application of hydrogen peroxide in bleaching treatments due to its adverse effects.

REFERENCES

[1] A. Paula, Efeitos de um produto de branqueamento dentário à base de peróxido de hidrogénio a 6% na mucosa gástrica de ratos, MSc. Thesis, Universidade de Coimbra, Coimbra, Portugal, 2009.

[2] M. Alqahtani, Tooth-bleaching procedures and their controversial effects: A literature review, The Saudi Dental Journal 26, 2014, p. 33–46.

[3] U. Lendenmann, J. Grogan and F. G. Oppenheim, Saliva and Dental Pellicle-A Review, Advances in Dental Research 14, 2000, p. 22-28.

[4] A. Joiner, The bleaching of teeth: A review of the literature, Journal of Dentistry 34, 2006, p. 412-419.

[5] H. Eimar, R. Siciliano, M.-N. Abdallah, S. A. Nader, W. M. Amin, P.-P. Martinez, A. Celemin, M. Cerruti and F. Tamimi, Hydrogen peroxide whitens teeth by oxidizing the organic structure, Journal of Dentistry 40s, 2012, p. e25-e33.

[6] B. Xu, Q. Li and Y. Wang, Effects of pH Values of Hydrogen Peroxide Bleaching Agents on Enamel Surface Properties, Operative Dentistry 36 (5), 2011, p. 554-562.

[7] A. Joiner, Review of the effects of peroxide on enamel and dentine properties, Journal of Dentistry 35, 2007, p. 889-896.

[8] L. Sun, S. Liang, Y. Sa, Z. Wang, X. Ma, T. Jiang and Y. Wang, Surface alteration of human tooth enamel subjected to acidic and neutral 30% hydrogen peroxide, Journal of Dentistry 39, 2011, p. 686-692.

[9] B. Martin-Biedma, T. Gonzalez-Gonzalez, M. Lopes, L. Lopes, R. Vilar, J. Bahillo and P. Varela-Patiño, Colorimeter and Scanning Electron Microscopy Analysis of Teeth Submitted to Internal Bleaching, Journal of Endodontics 36 (2), 2010, p. 334–337.

[10] V. R. Moreira, Comportamento tribológico do sistema Zircónia/Ti6Al4V utilizado em implantes dentários, MSc. Thesis, Universidade de Lisboa, Lisboa, Portugal, 2014.

[11] M. Sulieman, M. Addy, E. MacDonald and J. S. Rees, The effect of hydrogen peroxide concentration on the outcome of tooth whitening: an in vitro study, Journal of Dentistry 32 (4), 2004, p. 295–299.

[12] C. Zantner, N. Beheim-Schwarzbach, K. Neumann and A. M. Kielbassa, Surface microhardness of enamel after different home bleaching procedures, Dental Materials 23, 2007, p. 243-250.

[13] C. F. Pinto, R. de Oliveira, V. Cavalli and M. Giannini, Peroxide bleaching agent effects on enamel surface microhardness, roughness and morphology, Braz Oral Res 18 (4), 2004, p. 306-311.

[14] T. Attin, P. R. Schmidlin, F. Wegehaupt and A. Wiegand, Influence of study design on the impact of bleaching agents on dental enamel microhardness: A review, Dental Materials 25, 2009, p. 143-157.

[15] S. Mundra, V. Mohan, J. Gwyer, N. Young, S. E. Franklin and L. -C. Gerhardt, Hardness, friction and wear studies on hydrogen peroxide treated bovine teeth, Tribology International, 2015, p. 1-10.

[16] A. Joiner, G. Thakker and Y. Cooper, Evaluation of a 6% hydrogen peroxide tooth whitening gel on enamel and dentine microhardness in vitro, Journal of Dentistry 32, 2004, p. 27-34.

[17] A. Joiner and G. Thakker, In vitro evaluation of a novel 6% hydrogen peroxide tooth whitening product, Journal of Dentistry 32, 2004, p. 19-25.

[18] T. Abouassi, M. Wolkewitz and P. Hahn, Effect of carbamide peroxide and hydrogen peroxide on enamel surface: an in vitro study, Clin Oral Invest 15, 2011, p. 673–680.

[19] B. Schemehorn, C. González-Cabezas and A. Joiner, A SEM evaluation of a 6% hydrogen peroxide tooth whitening gel on dental materials in vitro, Journal of Dentistry 32, 2004, p. 35-39.

[20] C. G. Figueiredo-Pina, N. Patas, J. Canhoto, R. Cláudio, S. M. Olhero, A. P. Serra, A. C. Ferro and M. Guedes, Tribological behaviour of unveneered and veneered lithium disilicate dental material, Journal of the mechanical behavior of biomedical materials 53, 2016, p. 226-238.