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Fracture strength of incisor crowns after intracoronal bleaching with sodium percarbonate

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Abstract – *Objectives*: To compare the fracture resistance of bovine teeth after intracoronal bleaching with sodium percarbonate (SPC) or sodium perborate (SP) mixed with water or 20% hydrogen peroxide (HP). *Materials and methods*: Fifty extracted bovine teeth were divided into four experimental groups (G1–G4) and one control ($n = 10$) after endodontic treatment. Following root canal obturation, a glass ionomer barrier was placed at the cemento–enamel junction. After that, the pulp chambers were filled with: G1 – SP with water; G2 – SP with 20% HP; G3 – SPC with water; and G4 – SPC with 20% HP. No bleaching agent was used in the control group. Coronal access cavities were sealed with glass ionomer and specimens were immersed in artificial saliva. The bleaching agents were replaced after 7 days, and teeth were kept in artificial saliva for an additional 7 days, after which the pastes were removed and the coronal access cavities were restored with glass ionomer. Crowns were subjected to compressive load at a cross head speed of 0.5 mm min^{-1} applied at 135° to the long axis of the root by an EMIC DL2000 testing machine, until coronal fracture. Data were statistically analysed by ANOVA and Tukey test. *Results*: No differences in fracture resistance were observed between the experimental groups ($P > 0.05$). However, all experimental groups presented lower fracture resistance than the control group ($P < 0.05$). *Conclusion*: SPC and SP led to equal reduction on fracture resistance of dental crowns, regardless of being mixed with water or 20% HP.

Intracoronal bleaching is a conservative treatment for clinical situations involving coronal discolouration of endodontically treated teeth (1). Currently, most widely used bleaching agents rely on an oxi-reduction reaction, such as hydrogen peroxide (HP) at different concentrations; others are based on HP-releasing agents, such as sodium perborate (SP), either pure or diluted, and carbamide peroxide (CP), also known as urea peroxide, which can be employed alone or combined with other substances (1, 2).

The 'walking bleach' technique consists of intracoronal application of SP mixed with distilled water or HP at concentrations ranging from 3 to 30%. When water is used, more durable aesthetic results are achieved, but treatment requires longer periods (3, 4).

HP is released during decomposition of SP as mono, tri, or tetrahydrate, which originate different radicals or ions depending on the pH, photoactivation, temperature, presence of co-catalysts and of metallic ions. These radicals may rupture unsaturated double bonds of long, coloured molecules or reduce coloured metallic oxides, like Fe_2O_3, into colourless FeO (1, 5).

An alternative source of HP is sodium percarbonate (SPC), which is preferred over SP for industrial uses. In Japan, SPC is usually favoured for use in detergents because of its higher bleaching efficacy compared with SP (6). In Dentistry, SPC is a component of brush-on whiteners, which are applied to the buccal surface of the tooth with an applicator brush and may be used during the day or at night. These paint-on whiteners have been formulated to release peroxide slowly onto the tooth surface until their removal by normal tooth brushing (7, 8).

The bleaching effect of SPC appears to be similar to that of SP, because SPC dissociates into sodium carbonate and HP (6). *In vitro* studies comparing the effectiveness of SPC + distilled water, SPC + 30% HP or of SP + 30% HP for intracoronal bleaching of pulpless teeth demonstrated best results for SP + 30% HP. Nevertheless, no differences were observed between SPC mixed with distilled water or with HP (6). SPC is a bleaching agent with cytotoxicity and genotoxicity similar to other products commonly used for this purpose (9).

There is controversy surrounding the potential adverse effects of bleaching agents (10). Cervical root resorption has been observed following intracoronal bleaching, especially when high concentrations of HP in combination with heat are used (11). Another controversy is the coronal fracture resistance after intracoronal bleaching. Bonfante et al. (12) reported that internal bleaching with 37% carbamide peroxide did not significantly weaken the teeth after 21 days. However, Khoroushi et al. (13) concluded that the fracture resistance of endodontically treated teeth decreases after bleaching procedures using HP. In a clinical study, 60 human upper anterior permanent teeth were selected for bleaching using SP and HP. The bleached teeth were followed up for 3–16 years and 22.2% teeth restored without intracanal pins showed crowns fracture (14). Apparently, the occurrence of crown fracture of bleached teeth is related to various factors such as modifications in the structure of the tooth and the method and materials used (2, 15–18).

Some research report that intracoronal bleaching with HP or one of its precursors can increase dentine permeability (19), reduce microhardness of dentine and enamel (16, 17) and mechanically weaken dentine (15). Therefore, it is important to assess the effect of SPC, with water or HP in the resistance of endodontically treated teeth crowns to fracture.

However, no studies have yet compared the effects of dental bleaching on the resistance to coronal fracture when SPC is mixed with distilled water compared to mixing with HP. The aim of this study is to compare the resistance to coronal fracture of bovine teeth following intracoronal bleaching using SPC or SP mixed with distilled water or 20% HP.

Materials and methods

Fifty recently extracted bovine incisors from mature animals (i.e. mean age of 4 years) stored in 0.1% thymol at 4°C were selected. All teeth had similar dimensions, straight roots and completely formed apices. The teeth were washed in running water for 24 h to completely remove thymol residues and examined under 20× stereomicroscope magnification (Leica Microsystems, Wetzlar, Germany) to discard those with cracks or fractures. Buccolingual and mesiodistal radiographs were taken to certify that all teeth had single canals, no calcification or resorption, and similar internal anatomy. To prevent dehydration, the teeth were stored in water until use.

After pulp chamber access with a 1014 round diamond bur (KG Sorensen, São Paulo, Brazil), root canal preparation was performed by the crown-down technique (20) using K-files (Maillefer, Ballaigues, Switzerland) and 2.5% sodium hypochlorite. Specimens were apically prepared to an ISO size no. 80 followed by irrigation with 3.0 ml of 17% EDTA (Biodinâmica, Ibiporã, PR, Brazil) for 5 min. After that, the canals were irrigated with 10 ml of distilled water and dried with absorbent paper points (Dentsply-Herpo, Petropolis, Rio de Janeiro, RJ, Brazil). Subsequently, root canals were obturated by lateral condensation with gutta-percha (Dentsply Ind Com Ltda, Petropolis, RJ, Brazil) and AH Plus sealer (Dentsply De Trey, Konstanz, Germany). Radiographs were taken to verify the quality of the obturation.

A heated plugger was used to remove 3 mm of gutta-percha from the root canal, and a self-cured glass ionomer (Vidrion R; SS White, Rio de Janeiro, RJ, Brazil) was placed as a cervical barrier up to the cemento–enamel junction. After that, a cotton pellet was placed in the pulp chamber, the access cavity was sealed with IRM (Dentsply Ind Com Ltda), and the teeth were immersed in artificial saliva (0.375 g l $CaCl_2 \cdot 2H_2O$, 0.125 g l^{-1} $MgCl_2 \cdot 6H_2O$, 1.2 g l^{-1} KCl, 0.85 g l^{-1} NaCl, 2.5 g l^{-1} $NaHPO_4 \cdot 12H_2O$, 1 g l^{-1} sorbine acid, 5 g l^{-1} hydroxyethyl cellulosesodium and 43 g l^{-1} sorbitol solution) (School of Pharmaceutical Sciences of Ribeirão Preto, University of São Paulo, SP, Brazi), pH 6.7–6.9, at 37°C for 1 day to allow complete setting of the glass ionomer. In sequence, the roots were embedded in self-curing acrylic resin (Classic Jet, São Paulo, SP, Brazil) up to the cemento–enamel junction, using a circular plastic matrix (16.5 mm in width × 25.0 mm in length). All specimens remained intact for 1 h to allow resin polymerization.

Following that, the temporary restoration was removed and the pulp chamber was irrigated with 2.5 ml of 1.0% NaOCl. The smear layer was removed by applying 37% phosphoric acid (Condac 37; FGM Produtos Odontológicos Ltda., Joinville, SC, Brazil) for 15 s, followed by a 60-s rinse with sterile water (21), except in control group ($n = 10$). After that, the forty teeth were randomly distributed into four experimental groups ($n = 10$) according to the type of bleaching agent placed inside the pulp chamber: G1 – 2 g SP (FGM Produtos Odontológicos Ltda) mixed with 1 ml distilled water; G2 – 2 g SP mixed with 1 ml of 20% HP (Whiteness Perborato; FGM Produtos Odontológicos Ltda); G3 – 2 g SPC (Sigma-Aldrich, St. Louis, MO, USA) mixed with 1 ml distilled water; and G4 – 2 g SPC with 20% HP. The 20% HP concentration was used according to the manufacturer's instructions (Whiteness Perborato). The pulp chamber was filled with bleaching agent, which was covered with a cotton pellet. In the control group, only a cotton pellet moistened with distilled water was placed in the pulp chamber. Teeth in the control and experimental groups were temporarily sealed with a 1 mm thick layer of white gutta-percha (DFL, Rio de Janeiro, RJ, Brazil) and self-cured glass ionomer. All specimens were kept in artificial saliva for 7 days at 37°C. After that period, the coronal access was opened and the pulp chamber was washed with distilled water and dried with air. The bleaching agent was then replaced with a fresh mixture, the coronal access was re-sealed, and specimens were relocated to artificial saliva for an additional 7 days, totalling 14 days of treatment. The artificial saliva was replaced between sessions. Following that, the coronal seal was removed, the pulp chamber was rinsed with distilled water for complete removal of the bleaching agents, and air-dried. Specimens (control and experimental groups) were sealed with gutta-percha, restored with self-cured glass ionomer and kept in artificial saliva until the fracture resistance tests were conducted.

Specimens were subjected to a compressive load at a cross head speed of 0.5 mm min^{-1} (22) in an EMIC DL2000 electromechanical testing machine (EMIC, São José dos Pinhais, PR, Brazil), until fracture. For specimen adaptation to the assay apparatus, a cylindrical device with tapered tip was obtained (23).

The cylinder design allowed specimens to be fixed at a 45° angle, in such a way that the load was applied to the

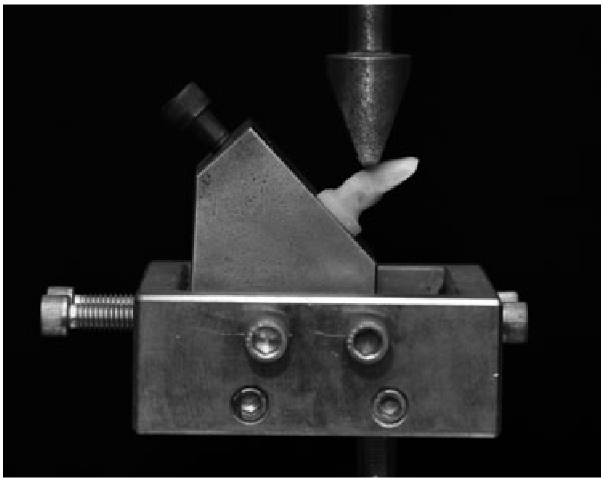

Fig. 1. Load being applied onto the buccal surface of the crown.

buccal surface of the teeth at a 135° angle in relation to the long axis of the root (Fig. 1). The ultimate load required to fracture the crown was recorded, and data were analysed statistically by one-way ANOVA and Tukey test at 5% significance level.

Results

Figure 2 shows the means and standard deviations of the loads required to fracture the crowns in each group. The control group required the highest load values to fracture (1775.57 ± 406.63 N) and differed significantly from the experimental groups ($P < 0.05$). No statistical differences were observed among the experimental groups G1

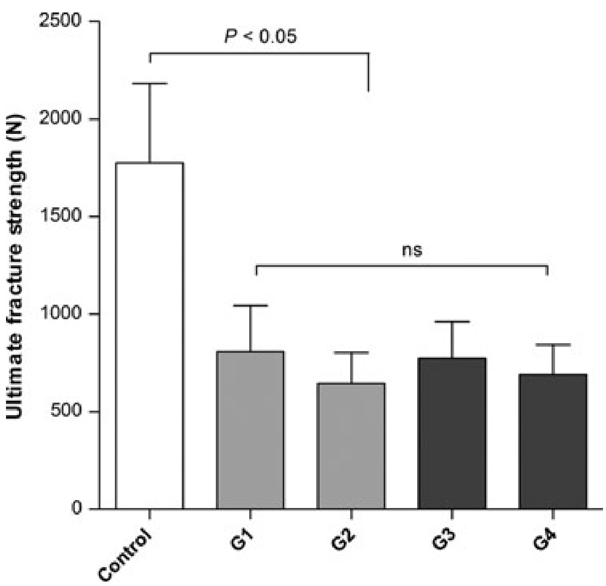

Fig. 2. Comparison of ultimate load required to fracture the bovine crowns in the different groups. G1 – sodium perborate (SP) with water; G2 – sodium perborate (SP) with 20% H_2O_2; G3 – sodium percarbonate (SPC) with water; and G4 – sodium percarbonate (SPC) with 20% H_2O_2.

(806.26 ± 237.21 N), G2 (643.47 ± 159.39 N), G3 (773.65 ± 186.96 N) and G4 (690.78 ± 151.28 N) treated with different bleaching mixtures ($P > 0.05$).

Discussion

Several innovations have been proposed for coronal bleaching of endodontically treated teeth, both in relation to the methods used (24, 25), as well as in regards to the materials utilized (26). On the other hand, several studies have demonstrated the negative effects of bleaching on the dental structure (10), such as reduced microhardness (17), increased dentine permeability (27, 28) and cervical root resorption (29). In present study, the SP or SPC, with water or HP, reduced the fracture strength of bovine crowns, compared to the control group.

Despite the different anatomical features presented by human and bovine teeth, particularly regarding their size, these teeth have similar values for ultimate tensile strength (104 and 91 MPa, respectively) and modulus of dentine elasticity (13–15 MPa) (30). Furthermore, bovine incisors show less anatomical variations in comparison with human incisors, allowing greater standardization during the fracture tests (31), and for this reason were selected in the present study.

During the fracture assays, the load cell impacted the coronal surface at an angle of 135° in relation to the long axis of the root, with the intent of reproducing the angle formed between the maxillary and the mandibular incisors (24, 32). Although the pendulum impact system simulates clinical impact fractures in human central incisors (32–35), various studies of fracture resistance of teeth submitted to endodontic treatment and bleaching have used slow compressive loading to fracture (12, 13, 24, 36). For this reason, this method was chosen in this initial test to assess the interference of SPC in tooth structure.

Glass ionomer was the material chosen to seal the coronal access because of its effectiveness in preventing diffusion of HP into the root canal (37). The bleaching protocol followed in this work involved applying the bleaching mixture to the pulp chamber twice as described in the 'walking' bleaching technique, recommended for cases with severe coronal discolouration (26). The ratio followed was 2 g of powder-to-1 ml of vehicle, as proposed in a previous study (38, 39). Between sessions, teeth were stored in artificial saliva, according to the composition described by Queiroz et al. (40) and used by Pobbe et al. (24).

The results from the present work demonstrated that both SP and SPC mixed with distilled water or 20% HP and applied in two treatment sessions significantly reduced the fracture resistance of the specimens, in comparison with specimens not subjected to bleaching (control group). No statistically significant difference was observed in fracture resistance among the experimental groups, similar to the results reported by Cavalli et al. (41).

Some important considerations that might explain the results are related to methodology. In present study, the protocol of bleaching for 14 days and replacing the mixture at 7 days led to marked reduction in resistance to fracture, which is in agreement with observations of Pobbe et al. (24). These authors reported that an increase in the number of bleaching sessions can decrease the fracture strength. Another factor is that the bleaching agents were applied intracoronal, in direct contact with the dentine. In a similar study in which the bleaching agent was only applied to buccal surface of the teeth, the HP group had no difference of control group (36). Bonfante et al. (12) used axial compressive fracture strength test, while in the present study, the load was applied in an angle of 135°.

Use of HP-based bleaching agents in high concentrations for prolonged periods leads to demineralization (16) and alterations in the organic (42) and inorganic (28) components of the dentine, lowering its microhardness (17) and consequently causing significant decrease in dentine flexural strength and flexural modulus (43). The effects of using different vehicles in association with SP on the pulp chamber dentine are controversial (2, 44). Although no direct relationship has been observed between reduction on dentine microhardness and its morphological structure, Oliveira et al. (17) observed reduced microhardness after the use of SP, which may explain the reduction in coronal fracture resistance observed in the experimental groups compared with the control group. In the present study, the dental crowns subjected to bleaching with SPC had similar results to those bleached with SP, regardless of the vehicle employed. Despite the fact that SPC has been described in the literature as having 30% higher rates of active oxygen compared with SP (6), future studies should be conducted to investigate its clinical efficiency.

Within the limitations of the present laboratory study, it is possible to conclude that both SPC and SP equally diminished the fracture resistance of dental crowns, regardless of their association with water or 20% HP.

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