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Original Article

Effect of peroxide bleaching on the biaxial flexural strength and modulus of bovine dentin

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ABSTRACT

Objective: This study evaluated the effects of carbamide peroxide and hydrogen peroxide on the biaxial flexural strength and flexural modulus of bovine dentin. **Materials and Methods:** Thirty coronal dentin disks (0.5 mm thick × 6.0 mm diameter) were prepared from bovine teeth. The disks were randomly divided into three groups (n=10): A control group (unbleached), a group bleached with 10% carbamide peroxide (8 h at 37°C), and a group bleached with 38% hydrogen peroxide (three 10 min applications at 37°C). The specimens were tested in a biaxial flexural apparatus held in a universal testing machine at 1.27 mm/min until failure occurred, and the biaxial mechanical properties were calculated. For each test parameter, the data were statistically analyzed by Fisher's PLSD test (predetermined $\alpha = 0.05$). **Results:** The group bleached with 38% hydrogen peroxide demonstrated significantly lower flexural strength than the unbleached control group. Hydrogen peroxide treatment resulted in a significantly lower flexural modulus compared with the control group and with carbamide peroxide bleaching. **Conclusion:** Exposure of dentin to hydrogen peroxide significantly reduced both the flexural strength and the flexural modulus compared with the no-treatment control, whereas exposure to carbamide peroxide did not significantly affect either parameter.

Key words: Biaxial flexural strength, bleaching, carbamide peroxide, dentin, flexural modulus, hydrogen peroxide

INTRODUCTION

The use of hydrogen peroxide to treat discolored and stained teeth is older than the technique of night guard vital bleaching with 10% carbamide peroxide. For in-office treatment, the bleaching agent indicated is hydrogen peroxide at high concentrations (30–40%), which is a strong oxidizing agent. Hydrogen peroxide at high concentrations must not come into contact with soft oral tissues, and patients have reported both severe and mild tooth hypersensitivity during and after bleaching.[1-4]

Bleaching with 10% carbamide peroxide using a mouthguard was suggested by Heymann and Haywood in 1989.[5] The concentration of hydrogen peroxide in 10% carbamide peroxide is 10 times less than that in 35% hydrogen peroxide, resulting in low levels of hypersensitivity and lower surface morphology changes. In this technique, patients use a 10% carbamide peroxide gel for 3–8 h daily, whereas in the hydrogen peroxide technique, 35% hydrogen peroxide is applied to the buccal surfaces of the teeth for short periods of time. Nightguard vital bleaching with carbamide peroxide is considered an effective

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and safe technique for bleaching teeth.[1,2] In contrast, the use of high concentrations of hydrogen peroxide remains questionable, and some researchers have expressed concerns regarding the widespread use of this technique.[6-17]

Several studies have evaluated different types of peroxides at various concentrations, and have expressed concerns about such bleaching techniques and pointed out the limitations of those techniques. These concerns are related to changes in the enamel morphology and mineral content,[14,18-21] and to effects on the organic components of dentin and on the dentin–pulp complex.[15-17,22-24] However, few investigations have aimed at studying and comparing the effects of carbamide peroxide and hydrogen peroxide on the mechanical and physical properties of dentin, even though these effects are clinically important.[7-13] The purpose of this study was to compare the biaxial flexural strength and modulus of bovine dentin using dentin disks treated with hydrogen peroxide, disks treated with carbamide peroxide, and disks kept unbleached as a control group, simulating 1 day of a bleaching treatment. The null hypothesis tested was that the two peroxides would not affect the biaxial flexural strength or the flexural modulus of the dentin.

MATERIALS AND METHODS

Thirty sound bovine incisors free from structural cracks and defects were selected for this study. After pumicing, the incisors were stored in a 0.1% thymol solution at 4°C for 30 days. Bovine dentin disks (0.5 mm thick × 6.0 mm diameter) were obtained from the coronal buccal surfaces by use of a hole saw. The disks were polished with 1200- and 2000-grit silicon carbide paper (Norton, Guarulhos, SP, Brazil) and randomly divided into three groups (n = 10):

- A control group (unbleached). The disks in this group were kept at 100% humidity for 8 h at 37°C
- Dentin disks bleached with 10% carbamide peroxide (Opalescence PF, Ultradent Products Inc., Salt Lake City, UT, USA). Each disk in this group was immersed in 0.2 mL of peroxide gel for 8 h at 37°C. After bleaching, the disks were thoroughly rinsed with an air/water spray and then tested
- Dentin disks bleached with 38% hydrogen peroxide (Opalescence Boost PF, Ultradent Products Inc., Salt Lake City, UT, USA). Each disk in this group was immersed in 0.2 mL of peroxide gel for 10 min at 37°C and then rinsed with hydrogen peroxide (10 volume). This protocol was performed three times and then, after the last repetition, the specimens were thoroughly rinsed with an air/water spray and tested.

Both of the protocols used in this study simulated only one session of bleaching treatment (either a mouthguard technique or an in-office technique). Composition and batch number of bleaching agents used in this study are listed in Table 1.

The disks were individually placed in a custom-made testing jig and tested in biaxial flexure on a universal testing machine (Instron 5844, Instron Corp., Canton, MA, USA) at 1.27 mm/min until failure occurred.[25] The maximum load was recorded for each specimen, and the elastic modulus was determined from the linear portion of the stress/strain curve. The formula used for the biaxial flexural strength σ was:

$$\sigma = -0.238 \times 7P(X - Y) / b^2,$$

where σ is the maximum tensile stress in the center (in mega Pascals), P is the total load at fracture (in Newtons),

$$X = (1 + \nu)\ln(r_2 / r_3)^2 + [(1 - \nu) / 2](r_2 / r_3)^2,$$

$$Y = (1 + \nu)[1 + \ln(r_1 / r_3)^2] + [(1 - \nu)(r_1 / r_3)^2,$$

and b is the specimen thickness (in millimeters) at the origin of the fracture. In the above equations, ν is Poisson's ratio (a value of 0.25 was used), r_1 is the radius of the support circle (in millimeters), r_2 is the radius of the loaded area (in millimeters), and r_3 is the radius of the specimen (in millimeters). The flexural strength and modulus were calculated using the SRS biaxial-testing software package (Instron Corp., Canton, MA, USA). The data for the flexural strength and modulus were normal and homoscedastic. For each test parameter, the data were analyzed statistically using Fisher's protected least significant difference test (with a predetermined $\alpha = 0.05$).

RESULTS

The values of the biaxial flexural strength and modulus are presented in Table 2. Statistically

Table 1: Characteristics of bleaching agents used in this study

Product	Composition (batch number)
Opalescence PF	10% carbamide peroxide, 20% water, 0.11% fluoride, potassium nitrate, thickener (B66YB)
In-office bleaching agent (Opalescence Boost PF)	38% hydrogen peroxide, 1.1% fluoride, 3% potassium nitrate (B5SLH)

Table 2: Biaxial flexural strength (in MPa) and modulus (in GPa) means (SD) of the bovine dentin

	Control group (unbleached)	10% carbamide peroxide	38% hydrogen peroxide
Flexural strength	188.1 (44.8)^{A}	170.3 (53.0)^{AB}	137.6 (50.5)^{B}
Flexural modulus	9.0 (9.7)^{a}	9.0 (1.2)^{a}	6.8 (1.1)^{b}

Flexural strength and modulus of bovine dentin followed by different upper or lower case letters, respectively, are different by Fischer's test (P<0.05). SD: Standard deviation

significant differences were found among the groups for the flexural strength (P = 0.0309) and for the modulus (P = 0.0003). The dentin disks treated with 38% hydrogen peroxide exhibited a lower flexural strength and modulus than did the control group (unbleached), whereas bleaching with 10% carbamide peroxide resulted in no significant difference in the flexural strength and modulus from the control group (P > 0.05). The 38% hydrogen peroxide produced a significantly lower flexural modulus than did bleaching with 10% carbamide peroxide (P = 0.0002), whereas no significant difference was found between the two bleaching materials for the flexural strength (P = 0.1517).

DISCUSSION

Some studies have reported changes in the fracture toughness, tensile strength, and flexural strength of human dentin and enamel after bleaching; however, the type of bleaching agent and the duration of the bleaching treatment were not standardized.[6-13] Although many techniques and bleaching agents were used, the authors of these studies agree that caution is necessary when peroxides are used for prolonged treatment times, since the action of hydrogen peroxide is not specific against only pigments that discolor or stain teeth. The current study was aimed at comparing the effects of 10% carbamide peroxide and 38% hydrogen peroxide on the mechanical properties of bovine dentin, simulating only one appointment or session.

In most previous studies, bar-shaped specimens were used and a three-point flexural test was performed to evaluate the flexural strength and modulus of the dentin. In contrast, the present study used a biaxial flexural test and disk-shaped specimens, and it seems to be the first investigation in which the biaxial flexural strength and modulus of dentin have been studied.[7,12] Our biaxial test has the advantage of utilizing small specimens, which allowed the peroxide to be in contact with the entire sample. Flexural strength is a mechanical property that indicates the maximum stress before fracture. When the stress exceeds the flexural strength, the loading may lead to dental fracture, which compromises the integrity of the tooth. The biaxial test also provided another important property, the flexural modulus, which is the ratio between stress and strain in the elastic regime: In other words, it tells us how much stress is required to deform the material before the proportional limit is reached.[25]

According to the results of this study, one session in which bovine dentin was exposed to 38% hydrogen peroxide (three 10 min applications at 37°C) was enough to significantly reduce the flexural strength and modulus compared with the unbleached control group, whereas exposure to carbamide peroxide did not change the mechanical properties of the dentin. Thus, the null hypothesis stating that the two peroxides (carbamide peroxide and hydrogen peroxide) would not affect the biaxial flexural strength and flexural modulus of dentin was rejected, since 38% hydrogen peroxide altered both of these mechanical properties.

Although 10% carbamide peroxide used for just 8 h did not change the biaxial flexural strength and modulus of bovine dentin, some other authors have shown that, depending on the bleaching time, carbamide peroxide may affect the strength of teeth as hydrogen peroxide does. Studies have shown that the flexural strength and modulus of dentin can be reduced after 2 weeks or prolonged use (2 months) of 10% carbamide peroxide applied directly to the dentin.[7,24] In those studies, when the carbamide peroxide application was on enamel, the mechanical properties of underlying dentin was not affect. Toledano *et al*.[25] found that mouthguard and in-office bleaching gels induced collagenolityc activity when applied to human dentin. In that study, 21 carbamide peroxide applications with duration of 8 h/day can induced higher collagen degradation than three applications of 38% hydrogen peroxide for 20 min each. However, Seghi and Denry[6] investigated the effects of 10% carbamide peroxide on the fracture toughness, hardness, and abrasion characteristics of enamel and reported that the abrasion resistance and toughness decreased after only one 12 h session of bleaching.

Hydrogen peroxide is a binary compound of hydrogen and oxygen that is a highly reactive oxygen species in aqueous solution.[3,4] The color of the dentin disks treated with 38% hydrogen peroxide changed to white, demonstrating the visual effect of the oxidizing

effects of hydrogen peroxide. However, the carbamide peroxide bleaching did not modify the color of the dentin samples, nor did it change the mechanical properties measured. The dentin disks from the control (untreated) group showed higher values of the flexural modulus than the disks that were bleached with 38% hydrogen peroxide. A study reported that six applications during 3 weeks (1 h each application and 2 days/week) of 35% hydrogen peroxide did not cause a decrease in dentin flexural strength and modulus.[24] It used dentin bars (2 mm × 2 mm × 20 mm), while this study tested very thin and small dentin disks (0.5 mm thick × 6.0 mm diameter), which may be responsible, in part, for differences in the findings of studies. Thus, higher concentration of hydrogen peroxide and the dimension of dentin disks that facilitated the contact with entire sample and peroxide reaction caused the reduction of the two dentin mechanical properties.

Some authors have suggested that peroxides should not be applied over exposed dentin, in order to avoid the effects of bleaching on the mechanical properties of dentin.[7,10,11,13] The main hypothesis for why peroxides affect the mechanical properties of dentin is that peroxides can degrade or disorganize type I collagen fibrils, denature proteins, and cause loss of mineral components attached to the organic matrix.[25-29] Demineralization has been observed and measured by several different methods, such as scanning electron microscopy, polarized light microscopy, microhardness measurements, atomic absorption spectrometry, and Fourier transform Raman spectroscopy.[20-22,30] Jiang *et al*.[23] described the dissolution of dentin in hydrogen peroxide. According to these authors, the destruction of the organic components was due to the oxidizing ability of hydrogen peroxide while the changes in the mineral components were caused by its acidity.

High concentrations of hydrogen peroxide, such as 30 or 40%, can cause alterations in the surface morphology of human enamel and promote an increase in the permeability of dentin.[14,16,18,19] Furthermore, as reported by Costa *et al*.,[17] bleaching with 38% hydrogen peroxide for 45 min may lead to irreversible pulp damage in the lower incisors, because of the high permeability of dentin to hydrogen peroxide. However, despite the changes in the properties of dentin induced by hydrogen peroxide, is important to note that in the present study the bleaching agents were applied directly to dentin, whereas in clinical use they should be applied to dental enamel. Carbamide peroxide seems to produce less severe side effects than hydrogen peroxide, and this must be considered in relation to clinical indications for the use of bleaching techniques.

CONCLUSION

The exposure of bovine dentin to 38% hydrogen peroxide significantly reduced both the flexural strength and the flexural modulus compared with the no-treatment control, whereas exposure to 10% carbamide peroxide did not significantly affect either of these parameters.

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