

# Fracture Resistance of Endodontically-treated Teeth: Effect of Combination Bleaching and an Antioxidant

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## Clinical Relevance

The fracture resistance of endodontically-treated teeth decreases after combination bleaching. The use of sodium ascorbate as an antioxidizing agent reverses decreased fracture resistance. In addition, it decreases the treatment period and the risk of catastrophic crown fractures.

## SUMMARY

**This *in vitro* study assessed the fracture resistance of endodontically-treated teeth undergoing combination bleaching with 38% and 9.5% hydrogen peroxide gels as in-office and at-home bleaching techniques, respectively. In addition, the effect of an antioxidizing agent, sodium ascorbate, was investigated.**

**Methods and Materials:** Sixty maxillary premolars were endodontically-treated, received a glass ionomer barrier as a mechanical seal and were embedded in acrylic resin up to the cemento-enamel junction. The specimens were divided into four groups (n=15) as follows:

**G I:** no bleaching, access cavity restored with resin composite (negative control); **G II:** bleached for three weeks daily using 9.5% hydrogen peroxide for two hours and three sessions of in-office bleaching using 38% hydrogen peroxide every seven days, then restored (positive control); **G III:** bleached similar to G II and restored after one week; **G IV:** bleached similar to G II, along with the use of an antioxidizing agent for 24 hours, then restored. In each in-office and at-home bleaching session, the whitening gels were applied to the buccal surface of the tooth and placed inside the pulp chamber (inside/outside bleaching technique). Finally, the specimens underwent fracture resistance testing; the data were analyzed using ANOVA and Scheffé's test ( $\alpha=0.05$ ).

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**Results:** Significant differences were observed among the study groups ( $p < 0.05$ ). Groups I and II demonstrated the highest and lowest fracture resistance, respectively. The samples that were not bleached (Group I) and the 10% sodium ascorbate gel group (Group IV) demonstrated significantly higher fracture resistance than the positive control group ( $p < 0.05$ ). No significant differences were found between Groups III and II ( $p > 0.05$ ).

**Conclusion:** Within the limitations of the current study, it can be concluded that the fracture resistance of endodontically-treated teeth decreases after combination bleaching. The use of sodium ascorbate can reverse decreased fracture resistance.

## INTRODUCTION

Intrinsic discolorations of endodontically-treated teeth might result from pulp necrosis, intra-pulpal hemorrhage, pulp tissue remnants after endodontic therapy, products of tissue decomposition, inappropriate access cavity design that traps chromophore materials inside the pulp chamber and/or obturation materials remaining in the pulp chamber due to insufficient cavity cleaning and placement of a dressing.<sup>1-2</sup>

The bleaching agents most commonly used for the whitening of discolored endodontically-treated teeth are hydrogen peroxide, carbamide peroxide and sodium perborate.<sup>1</sup> Bleaching agents act by a redox reaction with the discolored substrate. When the bleaching agent is placed in the pulp chamber, reactive oxygen is released; the discolored substance is chemically reduced and transformed into a colorless material.<sup>3</sup>

The oxidation reaction occurs when peroxide diffuses through the dental structure, reaching the dark material inside dentin.<sup>4-5</sup> According to the literature, peroxide is capable of penetrating into sound enamel and dentinal structures; it has also been reported to influence the pulp chamber at different concentrations.<sup>4</sup> Benetti and others found that the higher the concentration of peroxide during bleaching, the greater the amount observed in the pulp.<sup>6</sup> Some factors, such as light or heat, can facilitate this reaction and accelerate the bleaching process.<sup>7-8</sup>

Recently, some authors have described the clinically successful use of external/internal bleaching of endodontically-treated teeth.<sup>1,9</sup> Use of the whitening agent in the labial/buccal aspects of the teeth, in addition to the pulp chamber, which is referred to as inside/outside bleaching, has been advocated for the bleaching of endodontically-treated teeth in a number of studies.<sup>9</sup> In addition, dental practitioners use the combination bleaching technique, including in-office

and at-home bleaching procedures, to obtain satisfactory results in a shorter period of time for these teeth.<sup>9</sup>

Although a large number of studies have shown that the bond strength to dental tissues decreases after bleaching with whitening agents,<sup>10-18</sup> there is controversy over the negative effect of the above-mentioned materials on the coronal fracture resistance of endodontically-treated teeth. Bonfante and others reported that the fracture resistance of endodontically-treated teeth is not affected by bleaching with 37% carbamide peroxide after 21 days.<sup>19</sup> On the other hand, in a recent study, Pobbe and others showed that the fracture resistance of endodontically-treated teeth decreases after two sessions of bleaching with 38% hydrogen peroxide activated by a LED-laser system.<sup>2</sup>

The compromise of bond strength due to bleaching procedures has been attributed to the residual free radicals of oxygen released from the whitening agent. This interferes with the resin infiltration into etched enamel or demineralized dentin, inhibiting the polymerization of resin placed immediately after bleaching.<sup>17,20-23</sup>

Although some methods have been used to reverse decreased bond strength, some studies put great emphasis on neutralizing oxygen by using an antioxidant. In recent decades, ascorbic acid and its sodium salt have been used as antioxidants, with the potential to reduce oxidative compounds, especially free radicals.<sup>17,24-25</sup> Furthermore, studies have recently demonstrated that antioxidants have a positive effect on the quality of bond and the polymerization of resin. Soeno and others recently reported that surface treatment with ascorbic acid and ferric chloride strengthens the bond of a kind of bonding agent to dentin. They reported that ascorbic acid acts as an antioxidizing agent to facilitate the polymerization of the bonding agent, contributing to effective adhesive bonding.<sup>26</sup> In addition, Da Cunha and others reported that a reducing agent, such as ascorbic acid, is capable of reversing the effect of dentin deproteinization by NaOCl and improving the bond strength of resin to dentin.<sup>27</sup> Turkun and others reported a more than 35% improvement in bond strength of a kind of two-step self-etching adhesive compared to the positive control group subsequent to bleaching and the application of sodium ascorbate.<sup>17</sup>

Therefore, the current study was designed to investigate: 1) the fracture resistance of root-filled teeth undergoing combination bleaching; 2) the same resistance when sodium ascorbate is used as an antioxidizing agent.

## METHODS AND MATERIALS

Following appropriate University Human Research Ethics Board approval, 150 extracted human premolars were collected and stored in 0.2% thymol solution

at 4°C. All of the teeth had been extracted for orthodontic reasons from patients 16 to 24 years of age. Then, 60 teeth with similar crown and root sizes, straight roots, mature apices and two canals with no radiographically confirmed calcifications or resorption, were selected. The teeth were stored in distilled water for 24 hours for complete removal of thymol residue. They were then examined under a stereomicroscope at a magnification of 20x (MBC-10, St Petersburg, Russia) to exclude those teeth with fracture/crack lines or fissures. After access cavity preparation, the working length was determined by subtracting 1 mm from the root length using a #20 K-file (Mani Inc, Takanezawa Facility, Tochigi-Ken, Japan). Instrumentation was performed with K3 instruments (SybronEndo, Glendora, CA, USA) up to a #50/.06 instrument. Irrigation was then carried out with distilled water and the canals were dried with absorbent paper points. The root canals were obturated using the lateral condensation technique with AH26 sealer (Dentsply DeTrey, Konstanz, Germany) and gutta-percha points (Ariadent, Asia Chemi Teb Co, Tehran, Iran). Radiographs were taken to verify the quality of the obturation.

A heated plugger was used to remove 2 mm of gutta-percha from the root canal and resin-modified glass ionomer was placed as a cervical barrier (Vitremer, 3M ESPE, St Paul, MN, USA) up to the cemento-enamel junction and light-cured for 40 seconds (Coltolux 2.5, Coltene AG, Feldwiesenstrasse Altstätten, Switzerland).

All of the teeth were embedded in auto-polymerizing acrylic resin (Acropars, Marlic Medical Co, Tehran, Iran) up to the cemento-enamel junction, using cylindrical molds. The specimens remained untouched for one hour to assure resin setting. At this point, the spec-

imens were randomly divided into four groups (n = 15) according to the following protocol:

Group I: unbleached (Negative Control: NC), restored with Single Bond and Z100 resin composite (3M ESPE); Group II: bleached and restored in the same manner as G I (Positive Control: PC); Group III: a one week delay in restoration after bleaching (Delay Bonding: DB); Group IV: 10% sodium ascorbate hydrogel was placed after bleaching for 24 hours (Sodium Ascorbate: SA). The specimens were restored with Single Bond and Z100 resin composite, according to the manufacturer's instructions (Table 1).

The whitening agents used were 38% hydrogen peroxide (Opalescence Xtra Boost, Ultradent Products Inc, South Jordan, UT, USA) and 9.5% hydrogen peroxide (Daywhite ACP, Discus Dental, Culver City, CA, USA). The gels were applied to the buccal surface and within the pulp chamber. Opalescence Xtra Boost, containing 38% hydrogen peroxide, was used without a light source. The gel was provided with two syringes: one syringe contained the activator, while the other contained hydrogen peroxide. Before use, the activator was mixed with the bleaching agent and the mixture was expressed directly onto the buccal surface and into the pulp chamber. The entire buccal surface of the specimen was fully covered with a 0.5-1.0 mm-thick layer to ensure a uniform effect. After 45 minutes, the gel was removed and the treated teeth were thoroughly rinsed with air-water spray. The procedure was repeated three times every seven days.

Between in-office sessions, the 9.5% hydrogen peroxide (Daywhite ACP, Discus Dental) was applied as an at-home treatment. The gel was used for two hours every day for three weeks. In each session, the related gel was aspirated and the surfaces were irrigated with

Table 1: Materials Used and Their Mode of Application According to the Manufacturers' Instructions		
Material	Mode of Application	Manufacturer
Vitremer	Vitremer primer was applied for 30 seconds, air dried for 15 seconds and light cured for 20 seconds. The Vitremer powder and liquid were mixed in a 2.5/1 ratio for 45 seconds. The paste was applied and light cured for 40 seconds.	3M ESPE, St Paul, MN, USA
Opalescence Xtra Boost	The activator syringe was mixed with the bleaching agent 10 times, and the mixture was expressed directly into the pulp chamber and onto the buccal surface for 45 minutes.	Ultradent Products Inc, South Jordan, UT, USA
Daywhite ACP (Hydrogen peroxide 9.5%)	The gel was applied in the access cavity and the buccal surface of each specimen for 2 hours/day for 21 consecutive days.	Discus Dental Inc, Culver City, CA, USA
Single Bond	The access cavity was etched with 35% phosphoric acid for 15 seconds, then rinsed with water spray for 10 seconds, leaving the tooth moist. Two consecutive coats of the adhesive were applied with a fully saturated brush tip and gently dried for 2 to 5 seconds, then light cured for 10 seconds each.	3M ESPE, St Paul, MN, USA
Z100 Composite	Z100 resin resin was applied in 2-mm layers. Each layer was light cured for 40 seconds.	3M ESPE, St Paul, MN, USA
Sodium Ascorbate (powder) C6H7NaO6	After preparing 10% hydrogel, the gel was applied in the access cavities and onto the buccal surfaces for 24 hours, then rinsed.	AppliChem GmbH, Darmstadt, Germany

distilled water. Between sessions, all the teeth were stored in artificial saliva (University of Isfahan, School of Pharmacy, Isfahan, Iran) at 37°C. The control group (no bleaching) remained in artificial saliva, which was replaced every seven days.

Subsequent to composite bonding, all of the specimens were thermocycled (500 cycles at 5°C to 55°C, 30-second dwell time and 12-second transfer time) (Mp Based, KARA 1000 Inc, Tehran, Iran) and stored in an incubator at 37°C and 100% relative humidity for 24 hours.

Finally, all of the specimens underwent a fracture resistance test using a universal testing machine (Dartec, HC10, Dartec Ltd, Stourbridge, UK). The test was carried out using a 5-mm diameter round bar positioned parallel to the long axes of the teeth and centered over the teeth until the bar just contacted the slopes of the buccal and lingual cusps of the tooth near the composite-tooth interface. Then, the forces necessary to fracture each tooth were measured in Newtons (N). A crosshead speed of 1 mm/minute was applied until the teeth fractured. The moment of fracture was determined by a sudden decrease in force measurements in the testing machine. The data were analyzed by ANOVA and Scheffé's test at a significance level of 0.05 using SPSS software Version 11.5.

According to the failure modes, the fractures were divided into two groups: 1) favorable fracture, including fractures stopping more than 1 mm coronal to the CEJ and 2) unfavorable fractures, including fractures stopping less than 1 mm coronal to the CEJ.<sup>28</sup>

## RESULTS

Fracture resistance in N (mean  $\pm$  SD) and minimum/maximum values for the groups are shown in Table 2. Analysis of variance revealed significant differences in fracture resistance among the four groups ( $p < 0.05$ ). The samples that were bleached (Group II) demonstrated significantly lower fracture resistance compared to the negative control group (Group I). Group IV specimens demonstrated significantly higher fracture resistance compared to the positive control group samples (Group II) ( $p < 0.05$ ). No significant differences were observed between Groups II and III and also between Groups III and IV ( $p > 0.05$ ) (Figure 1).

Regarding failure mode, the highest and the lowest rates of favorable fractures were observed in Groups I and II, respectively (Table 3). The number of favorable fractures was higher in Group IV when compared to Group III. However, no significant differences were

Table 2: Statistical Data for the Original Values (Newtons)

Groups	Group Code	Mean(SD)	Minimum	Maximum
1	NC	533.84(26.05) <sup>a</sup>	400	680
2	PC	280.71(15.06) <sup>b</sup>	190	400
3	DB	385.00(25.5) <sup>bc</sup>	230	600
4	SA	448.00(38.13) <sup>ac</sup>	170	720

Groups with the same superscript are not statistically different ( $p > 0.05$ ).

Table 3: Results of Failure Mode in Number (%)

Group	#	Favorable Fracture	Unfavorable Fracture
NC	15	9(60.0) <sup>a</sup>	6(40.0)
PC	15	4(26.7) <sup>b</sup>	11(73.3)
DB	15	7(46.7) <sup>a</sup>	8(53.3)
SA	15	8(53.3) <sup>a</sup>	7(46.7)

Different letters denote significant differences between study groups ( $p < 0.05$ ).

found among the study groups in terms of fracture modes, except for Group II ( $p < 0.05$ ) (Figure 2).

## DISCUSSION

Internal bleaching is a conservative procedure for managing discolored root-filled teeth. The primary indication for internal bleaching is intrinsic discoloration of a devitalized tooth. Internal bleaching is a procedure with predictable results. Color modification is usually "good," while the remaining cases are classified as "acceptable."<sup>29</sup> Recently, some authors have described an inside/outside technique for the above-mentioned teeth.<sup>1,9</sup> In this technique, the bleaching process can be performed spontaneously outside of the teeth, and the process can be carried out as an in-office and/or at-home treatment. The in-office procedure can also be accelerated by use of a light source.<sup>2</sup>

Although bleaching procedures are effective and certainly less destructive than any full or partial pros-

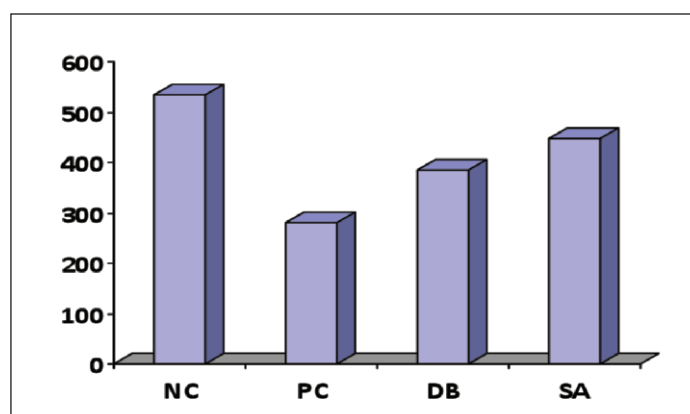


Figure 1. Mean values for fracture resistance in the study groups. (Newtons) (NC: Negative Control, PC: Positive Control, DB: Delayed Bonding, SA: Sodium Ascorbate).





Figure 2. Occlusal view of three specimens following the fracture resistance test.

thetic restoration, it is well known that there is no therapy without any risks. When these methods are used correctly, there are only minor complications; therefore, there is clinical tolerability.<sup>30</sup>

The unavoidable loss of dentin during endodontic treatment can increase tooth susceptibility to fracture.<sup>28</sup> In addition, recently, there has been increased concern about the effect of bleaching procedures on dental structures.<sup>2,30-31</sup>

In the current study, combination bleaching, combining in-office and at-home bleaching techniques, was evaluated. Recently, the combination bleaching procedure has been advocated because of its more appropriate and longer-lasting outcomes. In addition, use of the at-home bleaching technique has been recommended as a supplementary procedure to the in-office procedure.<sup>9</sup> In the current study, a potential chemical, Day White ACP (Discus Dental), with 9.5% hydrogen peroxide, was used for the at-home technique. As a result, contrary to a similar study,<sup>19</sup> in the current study, the coronal weakening of root-filled teeth occurred and the results obtained for Group II showed decreases in fracture resistance when compared with the negative control group ( $p < 0.001$ ).

In the current study, Group I demonstrated the highest fracture resistance, in which access cavities were treated simply after endodontic treatment. This finding is consistent with the results of similar studies.<sup>19,32</sup> Furthermore, bleaching significantly decreased fracture resistance in Group II when compared to Group I ( $p < 0.001$ ), which concurs with the results of a study carried out by Pobbe and others;<sup>2</sup> however, the results of the current study are not consistent with results obtained by Chng and others.<sup>33</sup> This discrepancy might be attributed to the application of different bleaching techniques and different bleaching regimens in the above-mentioned studies. According to Pobbe and others, the bleaching agent (Opalescence Xtra Boost) significantly decreases crown resistance to fracture when

applied in more than two in-office bleaching sessions.<sup>2</sup> Tam and others showed that the use of hydrogen peroxide in high concentrations and for long periods results in decreases in the flexural strength of dentin. Calcium loss results in decreases in microhardness, and the replacement of organic components by oxidants decreases enamel bond strength.<sup>32</sup> In the current study, the most powerful in-office and at-home bleaching treatments were used in a three-week period, which accounts for the significant decreases in fracture resistance. It seems logical that the higher the concentration of bleaching agent or agents, and the longer their period of

application, the higher the detrimental effect on fracture resistance.

In the current study, the effect of applying sodium ascorbate subsequent to the bleaching procedure as an antioxidant on fracture resistance was investigated for the first time. In this study, sodium ascorbate was used for 24 hours in the access cavity. Previously, Lai and others had recommended the application of this agent for 1/3 of the bleaching time.<sup>34</sup> The total bleaching time in the current study was nearly 44 hours. Allowing for a 24-hour waiting period was based on the possibility of replacement and rinsing of the agent by the clinician during the next appointment. On the other hand, during other studies on sodium ascorbate gel, the authors found that this hydrogel gradually attains a yellowish color, and after several days, it becomes completely dark yellow to orange. If this gel remains in contact with dentin in the access cavity for more than 24 hours, it may change the dentin color to yellow, reversing the bleaching outcome. Studies conducted on the application period of antioxidants have reported that its application, even in continuous rinsing for 10 minutes, is effective.<sup>35-37</sup> Furthermore, a more recent study has shown that shorter application times of sodium ascorbate, even for five minutes, can neutralize bleaching effects in terms of the chemical processes involved.<sup>38</sup>

In the current study, the use of sodium ascorbate significantly increased fracture resistance. Some studies have reported peroxide penetration into dental structures, including penetration into the pulp. Titley and others have reported that, if bleaching is immediately followed by bonding, the composite, number and length of the resin tags decreases and the pores are observed at interfaces.<sup>39</sup> In one study, Turkan and others applied this agent in access cavities after bleaching. In addition to reporting a significant decrease in microleakage, in SEM examinations, they observed that the

number and length of the resin tags were similar to unbleached cases.<sup>40</sup> No study has ever been carried out on the penetration capacity of antioxidants into dental tissues. The efficacy of ascorbic acid and its salts as antioxidants in decreasing the effect of different oxidative compounds, particularly free radicals, has been confirmed.<sup>17</sup> According to one theory, free radicals generated by hydrogen peroxide combine with hydroxyapatite and produce a structure called apatite peroxide, which degrades two main dental mineral components, calcium and phosphate, from hydroxyapatite.<sup>41</sup> Furthermore, it seems that the neutralizing effect of antioxidant leads to better resin-tooth adhesion due to the release of free oxygen radicals,<sup>26</sup> which may, in turn, improve the remineralization capacity of saliva.<sup>2</sup> Soeno and others reported that the use of ascorbic acid before bonding of a kind of experimental bonding agent improves bonding due to an increase in polymerization. Moreover, ascorbic acid acts as a polymerization promoter and co-initiator and has highly positive effects on resin bond to the tooth.<sup>26</sup> Recently, Turkan and others examined the effect of several adhesives on enamel bond after bleaching and antioxidant application. One of the interesting results of the study was an almost 35% increase in shear bond strength after application of the antioxidant.<sup>17</sup> Therefore, it seems the effect of antioxidants on bond strength and fracture resistance after tooth bleaching is far beyond merely a reducing effect. One of the primary and most important effects of this agent is the reduction of oxidation reaction, the omission of oxygen-free radicals from the bonding surface and the prevention of polymerization inhibition.<sup>17,38</sup> Another effect of antioxidant is the release of retained oxygen in deeper tissues of enamel and dentin, which facilitates polymerization and resin penetration into tissues and leads to the formation of a more proper hybrid layer, therefore, facilitating the formation of a strong bond between resin composite and enamel/dentin.

Another point is that previous investigations have reported that, subsequent to a bleaching procedure, some demineralization of enamel and dentin occurs.<sup>31</sup> Some studies have reported that bleaching leads to the removal of calcium, phosphate and other ions from dental structures.<sup>30-31</sup> The authors assumed that, in this case, compared with unbleached dental tissues, the penetration of antioxidant is facilitated and thus, considering the adhesion promotion capacity of antioxidant, a stronger resin-tooth interlocking is obtained. This finding is consistent with the results of a recent study by Turkan and others.<sup>17</sup>

In the current study, most fractures occurred in the buccal cusp and most favorable fractures (fractures coronal to CEJ) were observed in Groups I, III and IV, which is consistent with fracture resistance values.

Furthermore, in the Group III samples, which were kept in artificial saliva for one week after bleaching sessions, fracture resistance was significantly different from the negative control group ( $p < 0.001$ ). The effect of saliva on reversing the negative effects of bleaching on the amount of enamel and dentin minerals, hardness and microstructure of dental tissues, and the transient effects of bleaching mentioned in previous studies, are consistent with the results of the current study.<sup>2,35-36</sup> The results from this group were not as satisfactory as those obtained for Group IV; therefore, it seems that the application of antioxidant in this regard has a stronger role, compared with delayed bonding, but more structural and microstructural investigations are deemed necessary in future studies.

## CONCLUSIONS

Within the limitations of the current study, it can be concluded that:

1. The combination bleaching procedure significantly decreases the fracture resistance of endodontically-treated teeth.
2. The use of an antioxidant is effective in compensating for the decreased fracture resistance of endodontically-treated and bleached teeth. In addition, it decreases the treatment period and the risk of catastrophic crown fractures. Further investigation is recommended.

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## Departments

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### Erratum

In *Operative Dentistry*, 2010, **35-5**, 530-537, Fracture Resistance of Endodontically-treated Teeth: Effect of Combination Bleaching and an Antioxidant, the first author was erroneously listed as Maryam Khoroushi, DDS, MS, professor, Department of Operative Dentistry & Torabinejad Dental Research Center, School of Dentistry, Isfahan University of Medical Sciences, Isfahan, Iran. Dr Khoroushi's correct university title is assistant professor. This update has been posted online.