Effects of At-home and In-office Bleaching Agents on the Shear Bond Strength of Metal, Ceramic, and Composite Brackets to Enamel

Abstract

Aims and Objectives: This study aimed to evaluate the effects of at-home and in-office bleaching on the shear bond strength (SBS) of metal, ceramic, and composite orthodontic brackets and to compare their SBSs. Subjects and Methods: A total of 96 human lower premolar teeth were used for this study. Six teeth were used for scanning electron microscopic study while the remaining ninety were divided into three equal groups. Each group was further subdivided into three subgroups with ten samples each. Three protocols were used. In the at-home bleaching group (n = 30), opalescence non-PF (potassium nitrate and fluoride) bleaching agent (10% carbamide peroxide) was applied onto the teeth daily for 14 days and left for 8 h each day. Teeth in the in-office group (n = 30) were treated twice in consecutive days with Opalescence boost PF (40% hydrogen peroxide). After bleaching, the specimens were stored in distilled water for 1 day before bonding. SBS testing was performed on all teeth using Instron universal testing machine. Results: Analysis of variance indicated a significant difference (P < 0.005) among the groups. Maximum SBS was shown by ceramic brackets in control group (Ib) and minimum was shown by composite brackets of in-office bleached group (IIIic). Conclusions: The results showed that at-home bleaching did not affect the SBS significantly whereas in-office bleaching reduced SBS of metal, ceramic, and composite brackets significantly. It is preferable to use metal or ceramic brackets than composite brackets for bonding 24 h after bleaching.

Keywords: Carbamide peroxide, shear bond strength, sodium perborate, universal testing machine (Instron)

Introduction

Discoloration of teeth is one of the biggest aesthetic concerns of dental patients. Tooth discoloration is classified as intrinsic, extrinsic, or a combination.[1] Vital and nonvital bleaching with various whitening agents has now gained popularity among clinicians and patients for teeth lightening, but there is structural change in enamel and composition induced by these bleaching agents that decrease the shear bond strength (SBS) of orthodontic brackets.[2]

Orthodontic patients, including a growing population of adults, not only need an improved smile, but they are also increasingly demanding better esthetics during treatment.[3] Hence, the options available for them are esthetic brackets, lingual orthodontics, or Invisalign.[4] Among these, esthetic brackets are comparatively cheaper compared to the other options; composite or plastic brackets are so much cheaper than the ceramic brackets.

Even though plastic brackets were introduced long back, their acceptance by orthodontists as an aesthetic alternative to metal brackets was short lived because they lacked strength and stiffness resulting in bonding problems, tie wing fractures, and permanent deformation.[4] During the 1990s, manufacturers came up with reinforced plastic brackets, also known as composite brackets, i.e., ceramic-reinforced, fiberglass-reinforced, and metal slot-reinforced polycarbonate brackets, with claims of essentially no adverse clinical effects.[5] Ceramic brackets were introduced in the 1980s, which have many advantages over the popular traditional esthetic appliances; they provide high strength, more resistance to deformation and wear, better color stability, most importantly superior esthetics to the patient, and rely solely on mechanical retention to prevent enamel damage during debonding.[6]
Today, bleaching method is done in two ways: either in-office or at-home bleaching. The most commonly used tooth bleaching agents contain hydrogen peroxide as the active ingredient. Hydrogen peroxide may be applied directly or produced by a chemical reaction from sodium perborate or carbamide peroxide.

Many authors found no adverse effect of bleaching on bond strengths of orthodontic brackets, although many others have reported a significant reduction in bond strength after dental bleaching. The purpose of this study was to evaluate the effects of at-home and in-office bleaching agents on the SBS of metal, ceramic, and composite orthodontic brackets.

**Subjects and Methods**

In this study, a total of 96 human extracted teeth are required which include the teeth needed for scanning electron microscope (SEM) studies. Inclusion criteria comprised premolar teeth extracted for orthodontic purpose. Exclusion criteria included grossly decayed or fractured teeth, teeth with restoration on buccal surface, randomized controlled trial-treated teeth, and previously bleached or previously bonded teeth. After extraction, any remaining soft tissue was removed with dental scaler, and the teeth were stored in distilled water at room temperature.

Each group consisted of thirty teeth subdivided into three subgroups with ten teeth each. Detailed description of the test groups is given in Table 1 and Figures 1-3. Six additional teeth were used for SEM studies. Six extracted human lower premolar teeth were used for the study. Enamel surface morphology was examined at $\times1500$ and $\times3000$ under Hitachi S 2400. SEM detailed description of SEM specimens is as follows: specimen 1: normal enamel [Figure 4]; specimen 2: acid etched with 37% phosphoric acid for 30 s and rinsed with water for 30 s [Figure 5]; specimen 3: bleached with at-home bleach for 8 h a day for 14 days and rinsed for 30 s with water every day after bleaching [Figure 6]; specimen 4: bleached with in-office bleach for 20 min and rinsed with water for 30 s, repeated once the next day [Figure 7]; specimen 5: bleached with at-home bleach for 8 h a day for 14 days followed by acid etching 1 day later with 37% phosphoric acid for 30 s and rinsed with water for 30 s [Figure 8]; and specimen 6: bleached with in-office bleach for 20 min and rinsed with water for 30 s, repeated once the next day. It was subjected to acid etching a day later with 37% phosphoric acid for 30 s and rinsed with water for 30 s [Figure 9]. Specimens were sputter coated with gold prior to the examination using Hitachi E 1010 ion sputter. They were then viewed under SEM (Hitachi S 2400) and photographed at 2 magnifications, i.e., $\times1500$ and $\times3000$.

Armamentarium used is shown in Figure 10. Teeth were mounted vertically in self-cure acrylic resin (Acralyn R, Asian acrylates, Mumbai) block so that the crown portion alone was exposed. The teeth were mounted on acrylic blocks such that the root portion was embedded in the acrylic up to the cementoenamel junction leaving only the crown portion exposed. The blocks were coded with colored numbers such as black, blue, and red for easy identification.

**Table 1: Description of the test groups**

| Groups | Number code | Subgroups | Sample size | Bleaching agent used | Bracket used |
|--------|-------------|-----------|-------------|----------------------|--------------|
| Group I | Black       | Group Ia  | 10          | None                 | Metal        |
|        |             | Group Ib  | 10          |                      | Ceramic      |
|        |             | Group Ic  | 10          |                      | Composite    |
| Group II| Blue        | Group IIa | 10          | At home              | Metal        |
|        |             | Group Iib | 10          |                      | Ceramic      |
|        |             | Group IIc | 10          |                      | Composite    |
| Group III| Red        | Group IIIa | 10          | In office            | Metal        |
|         |             | Group IIIb | 10          |                      | Ceramic      |
|         |             | Group IIc | 10          |                      | Composite    |
identification. The buccal enamel surface was pumiced, washed, and dried before bleaching.

In-office bleaching was done using hydrogen peroxide 40% (opalescence boost PF) and at-home bleach was done using carbamide peroxide 10% (opalescence non-PF).

At-home bleaching was done by applying the bleaching agent on the labial surface directly from the syringe for 8 h a day for 14 days. After each daily bleaching session, the gel was washed away using an air–water syringe for 5 s. Teeth were then stored in distilled water during the intervals. In-office bleaching was done by applying the bleaching agent directly from the syringe on to the labial surface and was kept undisturbed for 20 min. Then, the teeth were washed and stored in distilled water. The process was repeated again the next day. After both types of bleaching, teeth are stored in distilled water for 24 h before bonding.

Then, Groups Ia, IIa, and IIIa were bonded with metal brackets; Groups Ib, IIb, and IIIb were bonded with ceramic brackets; and Groups Ic, IIc, and IIIc were bonded with composite brackets. Representative sample brackets used are shown in Figure 11. The bracket base areas used were 9.81 mm² (metal bracket),
13.74 mm² (ceramic bracket), and 11.67 mm² (composite bracket) as provided by the manufacturer.

Bonding was done using light-cured adhesive Transbond XT Light Cure Adhesive System. Before the bonding teeth are pumiced, they were washed for 30 s with water and dried for 10 s with oil-free air. 37% phosphoric acid (Dtech) was then applied on the buccal surface of the teeth for 30 s. Then, the teeth were rinsed using running water, dried, and are now ready for bonding. The etched enamel surface showed a frosted appearance. A thin coat of bonding agent was applied on the tooth surface using the applicator tip, air blown, and light cured using Woodpecker light-emitting diode (LED) D Light cure unit, DC-5.0V for 20 s. The adhesive (Transbond XT) was...
applied under the bracket and the bracket was placed at the required position and excess adhesive was removed from the bracket periphery. The adhesive was cured using Woodpecker LED D light cure unit for 40 s for each tooth.

After completion of bonding protocols, the specimens were then subjected to SBS test using universal testing machine (Instron machine, 3345) at a crosshead speed of 1 mm/min as shown in Figure 12. The force required to shear the bracket causing bonding failure was recorded in Newton and the bond strengths were calculated in Mega Pascals.

**Results**

Descriptive statistics, including the mean, standard deviation (SD), and minimum and maximum values, were calculated for each group. The data are expressed in mean ± SD. Statistical Package for Social Sciences (version 16.0; Chicago Inc., IL, USA) was used for statistical analysis. One-way ANOVA was applied for analysis. Post hoc test followed by Dunnett’s t-test was used to find statistical significance between and within the groups. $P < 0.05$ was considered statistically significant at 95% confidence interval.

The mean SBS of metal brackets in control group (Ia) was found to be 16.03 ± 0.87 MPa. It decreased to 14.68 ± 1.67 MPa in the at-home bleached (IIa) group and reduced further to 10.95 ± 2.61 MPa in the in-office bleached group (IIIa). The mean SBS of ceramic brackets in control group (Ib) was found to be 20.21 ± 0.94 MPa. It decreased to 18.31 ± 1.23 MPa in the at-home bleached (IIb) group and reduced further to 16.13 ± 2.67 MPa in the in-office bleached group (IIIb). The mean SBS of composite brackets in control group (Ic) was found to be 9.81 ± 0.61 MPa. It decreased to 8.06 ± 1.88 MPa in the at-home bleached (IIc) group and reduced further to 7.22 ± 2.15 MPa in the in-office bleached group (IIIc).

There was a significant difference ($P < 0.05$) in the bond strengths of Group I (control) and Group III (in-office bleached). No statistically significant differences ($P > 0.05$) were found between Group I (control) and Group II (at-home bleached). There was a significant difference ($P < 0.05$) between Group II (at-home bleached) and Group III (in-office bleached) except in case of use of composite brackets. In addition, there was intragroup statistical significance ($P < 0.05$) in the mean SBS values among metal, ceramic, and composite brackets in Groups I, II, and III. The highest values for SBS were measured in Group Ib (20.21 ± 0.94 MPa). The lowest values for SBS were measured in Group IIIc (7.22 ± 2.15 MPa). Mean values of SBSs of different group are given in Table 2. Multiple comparisons of mean value of SBS (MPa) of different groups are illustrated in Figures 13-15.

**Scanning electron microscopic study**

Specimen 1 (normal enamel): sound enamel surface indicating no alterations; specimen 2 (etched with 37% phosphoric acid for 30 s): type I etching pattern with honeycomb appearance; specimen 3 (bleached with at-home bleach): showed alterations on surface smoothness and presented different levels of surface changes. Minor changes of the enamel surface occurred in samples treated with 10% carbamide peroxide for 8 h daily for 14 days. This aspect suggested an insignificant increase in the
Table 2: Mean values of shear bond strength of different group

| Group | Type of bracket | Shear bond strength (MPa), mean±SD |
|-------|----------------|-----------------------------------|
| Group Ia | Metal | 16.03±0.87 |
| Group Ib | Ceramic | 20.21±0.94 |
| Group Ic | Composite | 9.81±0.61 |
| Group IIa | Metal | 14.68±1.67 |
| Group IIb | Ceramic | 18.31±1.23 |
| Group IIc | Composite | 8.06±1.88 |
| Group IIIa | Metal | 10.95±2.61 |
| Group IIIb | Ceramic | 16.13±2.67 |
| Group IIIc | Composite | 7.22±2.15 |

SD=Standard deviation

Figure 15: Multiple comparisons of mean value of shear bond strength (MPa) of different groups. Group Ic – Control group, Group IIc – At-home bleached group, Group IIIc – In-office bleached group (composite brackets)

Discussion

Although the process of in-office bleaching and at-home bleaching is different, it is based on hydrogen peroxide as an active agent for bleaching. However, concentrations of hydrogen peroxide in in-home bleaching and in-office bleaching are different. While a 10% carbamide peroxide bleaching product contains 7% urea and 3% hydrogen peroxide, an in-office bleaching product contains about 35% hydrogen peroxide. The mechanism of the action of bleaching agents is thought to be due to the ability of hydrogen peroxide to form oxygen-free radicals that interact with colored organic molecules and oxidize these macromolecules and pigment stains, which produce dental discoloration into smaller and lighter molecules.

Many studies have shown that the various bleaching methods have adversely affected the SBS of orthodontic brackets to enamel. The present study was done to find the effect of at-home and in-office bleaching procedures on the SBS of metal, ceramic, and composite brackets to enamel.

In the present study, the effect of at-home and in-office bleach on the enamel surface morphology was studied using SEM. It was found that at-home bleaching resulted in an insignificant increase in the enamel porosity, as compared to the control samples. Mild surface erosion, depressions, and increased depth of enamel grooves were some of the other noted alterations. This was in agreement with other studies. In the present study, there was a significant difference ($P < 0.05$) in the bond strengths of Group I (control) and Group III (in-office bleached). SEM analysis revealed that in-office bleaching resulted in surface alterations and intense surface deposits. Morphologic surface alterations became much more pronounced after in-office bleaching. Intermittent depressions of various depths were present; craters and shallow erosions could also be observed. These observations were in agreement with other studies.

The SEM images obtained in this study have the same etching pattern as the unbleached etched enamel, but the honeycomb appearance is not uniform. This effect is more apparent after in-office bleaching than the at-home procedure. This variation in the etching pattern might explain the large SDs in the SBS values obtained in the in-office bleached enamel. Furthermore, there is more clogging of pores in the case of in-office bleaching compared to at-home bleached samples after etching. This could be due to the higher concentration (40%) of hydrogen peroxide used. In addition, due to its low molecular weight, hydrogen peroxide can penetrate the coronal walls of teeth and enter the pulp chamber. Hence, the oxygen can accumulate in dentin, since dentin and dentinal fluid can act as a peroxide and oxygen reservoir.

There are a few studies which have demonstrated that neither at-home nor in-office bleaching affect the SBS of orthodontic brackets to enamel. In another study, they used high concentrations of hydrogen peroxide for tooth bleaching and they found out that under maximum peroxide exposure, it failed to show any evidence of deleterious effects on enamel or dentin. It was suggested that the changes in enamel morphology may be due to the pH of formulation used.
There are some studies which show that use of at-home bleach (10% carbamide peroxide) has resulted in decrease in SBS,\(^1\)[11,17,18,20,31] while some studies have mentioned that in-office bleaching results in poor SBS.\(^1\)[32,33] However, most of the studies are in agreement that the effect of dental bleaching wears off with time. Although remarkable variations exist among the recommended postbleaching time periods in different studies (24 h to 4 weeks), many authors have suggested that it is safe for orthodontic bonding after a period of about 1 week after bleaching.\(^1\)[11,20,21]

One of the aims of the present study was to determine whether adequate SBS is present without waiting for a week after dental bleaching. Hence, bonding of brackets was done 24 h after completion of bleaching process.

It was found that the SBS of Group I (control) and Group II (at-home bleach) was not statistically significant \((P > 0.05)\). In case of samples that were treated with at-home bleach, even though there was a reduction in SBS in metal, ceramic, and composite brackets, it was not statistically significant. However, when the SBS of Group I and Group III was compared, it was statistically significant and there was a significant reduction in SBS of metal, ceramic, and composite brackets in the samples treated with in-office bleach. These results were in agreement with the study conducted by Patusco \textit{et al.}\(^2\)[32]

A study by Gungor \textit{et al.} also suggests that at-home bleaching adversely affects the SBS more than in-office bleach. They relate this finding to longer application periods associated with the home bleaching method because alterations in the organic substance and the loss of calcium could be increased with time.\(^3\)[24]

The normal SBS values attained in the at-home bleaching group of this study were probably attributable to the lower concentration of the peroxide (10%) and mainly because, after each daily bleaching, the teeth were stored in distilled water. This might have eliminated the residual peroxide absorbed by the enamel. We could have had better SBS values in the hydrogen peroxide-bleached group if the teeth had been stored in distilled water for at least 1 week before bonding the brackets.\(^3\)[22]

Even though manufacturers have introduced several methods for retention, plastic brackets still show lower bond strengths than conventional metal and ceramic brackets.\(^4\)[34,35] In a study conducted by Ali \textit{et al.}, Silkon Plus™ brackets showed a SBS of 9.89 MPa, which is approximately similar to the value obtained in the present study.\(^5\)[36] Manufacturer claims that the Silkon Plus™ bracket has particle mechanical lock for superior bond strength and therefore there is no need for silane or special adhesive.

In the present study, there was intragroup statistical significance \((P < 0.05)\) in the mean SBS values among metal, ceramic, and composite brackets in Groups I, II, and III. The SBS of composite brackets in all the three groups was found to be significantly less compared to metal and ceramic brackets. After bleaching, the bond strength decreased even further. Hence, it is preferable to use metal or ceramic brackets for bonding after bleaching than using composite brackets. All bond strength values of the composites used in this study were greater than this minimum requirement and fell within the clinically acceptable ranges; even after bleaching with the two methods.

**Conclusions**

Within the limitations of this study, the following conclusions were drawn:

1. Using 10% carbamide peroxide at-home bleaching 24 h before bonding does not significantly alter SBS values of metal, ceramic, and composite brackets to enamel.
2. Using 40% hydrogen peroxide in-office bleaching 24 h before bonding significantly reduces SBS values of metal, ceramic, and composite brackets to enamel.
3. If bleaching before orthodontic bonding is mandatory, home bleaching is preferable.
4. It is preferable to use metal or ceramic brackets than composite brackets for bonding 24 h after bleaching.

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**Conflicts of interest**

There are no conflicts of interest.

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