EFFECT OF CURING TIMES ON SHEAR BOND STRENGTHS OF DIFFERENT ADHESIVE SYSTEMS: AN IN-VITRO STUDY

ABSTRACT

Background and Aims: The aim of this in-vitro study is to determine the immediate shear bond strength of two different adhesive systems after direct bonding.

Materials and Methods: 120 extracted human premolars without caries were used in the study. Teeth were separated into two groups randomly (n = 60). Transbond XT (3M Unitek) and Grengloo (Ormco) adhesive systems were used for direct bonding. Each group was divided into three sub-groups and different adhesive curing times were applied for each of these groups (10, 15 and 25 seconds). After brackets were bonded, the samples were stored in distilled water at 37°C for one minute in order to simulate the oral temperature and then the brackets were debonded. The bonding strength values were measured by a universal testing machine.

Results: Both adhesive groups exhibit adequate bonding strength, however, bonding strengths of the 25 seconds light-cured sub-groups were increased significantly. There were no significant differences between 10 and 15 seconds light-cured subgroups.

Conclusions: When high amount of force activation is needed immediately after bracket bonding, using increased light curing time is an easy and reliable way to achieve adequate bond strength.

Key words: Curing Time, Immediate Shear Bond Strength

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INTRODUCTION

After Buonocore first introduced acid etching in 1955, dental resin materials showed significant improvement. In the area of orthodontics, Newman, Silverman and Thomas showed the brackets could be directly bonded on teeth by using Buonocore’s technique. The factors affected the bonding force between the bracket surface and enamel was modified to find the ideal bonding conditions. The bond strength between enamel surface and bracket base can be affected by several factors, such as, the type of the adhesive used, acid concentration, acid etching duration, bracket’s base design, bracket material, intraoral conditions and the clinical experience of the orthodontist. Another important factor affecting the resistance to bracket failure is the time between the bonding and the force application. 15 seconds of acid etching for routine clinical usage, 30 seconds of acid etching, if the force application was planned to be applied in 5 minutes after bracket bonding, were suggested by some investigators. For both chemical and light cured bonding systems, the highest bonding strength values were measured, at least 24 hours after the bracket bonding was performed in vitro tests. Polymerization took place during whole this period. Shear bonding strength of both chemical cured and light cured bonding systems increased proportionally with time.

The single failure of the brackets during the clinical applications are caused mostly by the patient related factors, although, sometimes could be caused by the forces applied immediately after bonding. The resistance of adhesive should be high enough to withstand the forces applied by the arch-wires, the chewing muscles and the other additional factors. A resistive force of 6-8 Mpa was found to be adequate for orthodontic use, if the forces and the bracket base area are taken into account. After their introduction to dental usage, a light-cured restorative material has gained popularity in the orthodontic applications. There are several light source types being used for polymerization. For both chemical and light cured bonding systems, the highest bonding strength values were measured, at least 24 hours after the bracket bonding was performed in vitro tests. Polymerization took place during whole this period. Shear bonding strength of both chemical cured and light cured bonding systems increased proportionally with time.

Therefore the aim of this study was compare the in-vitro effect of different light curing times on shear bond strengths of two different adhesive systems when the force was loaded immediately after bonding.

MATERIALS AND METHODS

120 human premolars were used in the study. These teeth were collected from patients aged between 13 and 17 who were undergone extraction therapy. The selection criterion was not having any visible enamel defects on the buccal surface. Teeth were stored in distilled water and cleaned once in two weeks. The samples were placed in casts with their buccal surfaces uncovered. Special care was taken to place the teeth with their bonding surfaces parallel to ground. Before placing, their roots were cut from a point under the enamel-cement junction. Stainless steel wires were placed into the root canals and pulp chambers in order to fix the teeth on wax bases in position during filling plaster into the casts (Figure 1).

The samples were randomly divided into two groups after cleaning and pumicing. Transbond XT (3M-Unitek) and Grengloo (Ormco) adhesive systems were used for bonding of the first and second groups respectively. Each group was then divided into three sub-groups randomly. These subgroups had light application times of 10, 15 and 25 seconds separately. SmartClip (3M-Unitek) metal brackets with a surface area of 9.08 mm² were bonded on all samples. The enamel surfaces of the teeth were acid etched for 15 seconds then the acid was thoroughly removed by 10 seconds application of water-air combination. After etching, both adhesive systems were applied according to their prescriptions. Light activation times were set to 10, 15 and 25 seconds and a LED light source was used for activation. The samples were placed into distilled water at 37°C for one minute in order to simulate the intra-oral temperature during debonding tests. Samples were tested by a Lloyd LRX testing machine (Lloyd Instruments Plc, Fareham, Hampshire, England) with a cross-head speed of 1 mm/minute (Figure 2). Testing apparatus was modified in order to test pull and shear forces. The measurements were made in Newtons, and converted into megapascals (MPa) with the following equation: shear force (MPa)= debonding force (N) / (w*l) (mm²), where w= width of the bracket base, l= height of the bracket base, and 1 MPa= 1 N/mm². The remaining adhesive on both bracket and tooth surface was measured using adhesive remnant index (ARI) after debonding tests for more detailed examination of the bond failures.
Curing Times Effect

Statistical analysis

ANOVA using factorial design was performed in a completely randomized design: 
\[ \hat{Y}_{ijk} = \mu + \alpha_i + \beta_j + \alpha \beta_{ij} + e_{ijk} \]
where \( \hat{Y}_{ijk} \) is observation values (bonding, ari...), \( \mu \) is the overall mean, \( \alpha_i \) is the effect of the Transbond XT, Greengloo bond strength, \( \beta_j \) is the effect of time (10, 15, 25 s), \( \alpha \beta_{ij} \) is the effect of interaction and \( e_{ijk} = \) residual error. TUKEY Multiple Range Test was then utilized to distinguish these differences. In addition to this analysis, ANOVA using factorial design was not performed for ARI scores, so Kruskal Wallis Test, a nonparametric test, was performed to test whether there were any differences among the times for ARI scores. All the computational work was performed by means of MINITAB (Minitab V. 13.20, 2000) (MINITAB, 2000. MINITAB Statistical Software, Release 13.20, Minitab Inc. State College, PA, USA).

RESULTS

Descriptive statistical analysis of every group was summarized in Table 1. ANOVA showed that there was a significant difference between the groups (p<0.001), but, there were no significant differences among the different bond systems’ sub-groups, regarding the light activation times, which means that the shear bond strengths of two different systems were similar when same time is used for light activation. Regarding the differences between effects of light activation times, shear bond strength was significantly higher in the 25 second light activated systems. When 10 seconds of activation was used Transbond showed 8.9 ± 2.6 Mpa, Grengloo showed 8.3±3.1 Mpa, with 15 seconds of activation, Transbond showed 8.7±1.9 Mpa, Grengloo showed 10.1±2.4 Mpa, with 25 seconds of activation, Transbond showed 12.8±3.5 Mpa, and Grengloo showed 11.5±2.8 Mpa of shear bond strengths. There were also no significant differences between ARI scores of the groups and sub-groups (Table 2).

DISCUSSION

The forces applied on rebonded brackets, which were debonded by mostly patient-related factors, could be high because of the more activation needed for the arch-wire. In this circumstance, the easiest ways of avoiding high forces are mounting the arch-wire passively into the bracket slot or arch-wire could be entirely changed with a more flexible one, however these solutions could have a negative effect on total treatment time. For this reason, higher shear bond strength of the brackets are needed immediately after bonding. This study evaluated the shear bond strength immediately after bonding to see if these materials could overcome these forces.

Brackets were placed in distilled water at 37°C in order to stimulate the oral environment before the debonding tests; the temperatures of the teeth were checked by a digital thermometer.
Bovine teeth were used in many studies testing shear bond strengths, because of their close similarity to human teeth. One more reason for choosing bovine teeth is they are easy to find and enamel irregularities were seen fewer than human teeth, which may affect the bonding strength. Although human teeth showed varying amounts of enamel irregularities caused by the different saliva contents of different individuals, human premolars were used in this study in order to stimulate the natural oral environment. In addition, according to some studies, bovine teeth showed lower shear bond strengths than human teeth. Another reason which affects the bond strength is acid etching duration. A study showed that the shear bond strength increased when enamel was etched for 60 seconds, however, acid etching the enamel surface during 15 seconds with 37% orthophosphoric acid can provide adequate bond strength for clinical use. Bond strength more than adequate can lead to enamel fractures during debonding. Debonding forces of 8 MPa are considered adequate for orthodontic use. However, forces applied along the long axis of the enamel prisms must exceed 25 to 30 MPa to induce fractures. The continuing polymerization progress under the bracket causes the bond strength to increase with time. According to the previous studies, the bonding strength was found to be lower right after the bonding was performed, when chemical cure bonding systems were used. Braem and Coworkers found that the polymerization reaction of light

| Table 1. Descriptive statistics (in MPa) and the results of the Analysis of Variance (ANOVA) comparing the shear bond strengths of the groups tested. |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Adhesive type   | LED application times | Mean(Mpa) | Std* | Range | Test** |
| Transbond (3M Unitek) 10 s | 8.9 | 2.6 | 7.7-10.1 | A |
| Transbond (3M Unitek) 15 s | 8.7 | 1.9 | 7.8-9.6 | A |
| Transbond (3M Unitek) 25 s | 12.8 | 3.5 | 11.1-14.4 | B |
| Grengloo (Ormco) 10 s | 8.3 | 3.1 | 6.9-9.8 | A |
| Grengloo (Ormco) 15 s | 10.1 | 2.4 | 8.9-11.2 | A |
| Grengloo (Ormco) 25 s | 11.5 | 2.8 | 10.1-12.8 | B |

*Std= Standard deviation. ** Different letters show significant difference between the groups (p<0.001).

| Table 2. Frequency distribution of the Adhesive Remnant Index (ARI) scores. |
|-----------------|-----------------|-----------------|-----------------|
| Adhesive type   | LED application times | ARI SCORES | Median Values |
| Transbond (3M Unitek) 10 s | 0 1 2 3 | 4 |
| Transbond (3M Unitek) 15 s | 1 7 8 4 | 6 2 |
| Transbond (3M Unitek) 25 s | 1 6 9 4 | 2 |
| Grengloo (Ormco) 10 s | 1 7 7 5 | 2 |
| Grengloo (Ormco) 15 s | 2 7 8 3 | 2 |
| Grengloo (Ormco) 25 s | 1 8 6 5 | 2 |

ARI SCORES: 0= No adhesive remaining on teeth surface 1= Less than 50% of the adhesive is on the tooth surface 2= More than 50% of the adhesive is on the tooth surface 3= No adhesive remaining on the tooth surface.
cured composite was faster than the chemical cured and the bond strength at the first several minutes after bonding was higher as well. Light cured adhesive resins are widely used in orthodontic practice, these resins are chosen because of their ease of use, to be able to control the polymerization during bracket positioning and providing adequate bond strength in a short time. The light sources used in activation of these resins are; conventional, halogen, fast halogen (as an alternative to halogen), argon laser, plasma-arch and LEDs. Polymerization time varies depending on the type of light source used. Shear bond strengths with different light activation times were evaluated in our study. According to its manufacturer, Grengloo had a faster polymerization reaction than the other systems on the market, so, it could reach to a bonding strength strong enough for clinical use in only 5 seconds of light activation. In this study, this characteristic of the material was tested comparatively with another system which was widely used in orthodontic practice. A recent study showed that curing time can be reduced to 6 seconds when the high power halogen light (3000 mW/cm²) was used. The same investigation emphasized that 10 seconds with high-intensity LED (1200 mW/cm²) also exhibit adequate bond strength. In an in-vitro study in 2004, Üşümez and coworkers found significantly higher bond strength for the samples light cured for 40 seconds, among the samples which were light cured for 10, 20 and 40 seconds. The samples were stored in water at 37°C for 24 hours after debonding tests. These findings seem to be similar with ours, since, different light activation times were used and debonding tests was performed immediately after bonding in our study. Applying the LED light for 25 seconds led to significantly higher shear bond strength, which means increasing the light activation time, could be useful when higher forces were applied. ARI scores showed that, most of the composite remains on teeth after debonding, regardless of the composite type or light cure duration. This finding showed the bonding strength at the bracket base-composite interface was lower than the strength at the enamel-composite interface. The adherence could be weak if composite could not reach the grooves under the bracket base, but, there were similar scores in all groups in the study and there were no significant differences.

CONCLUSION

The shear bond strengths of two different bonding systems immediately after bonding were evaluated. Light activation times of 10, 15 and 25 seconds were used for each system. It is suggested to apply increased light activation time when higher bond strength was needed immediately after bracket bonding. Despite the limitations of the study, an increase in shear bond strength was observed in both materials when the light activation time was increased especially to 25 seconds.

REFERENCES


