Original Research Article

COMPARISON OF SHEAR STRENGTH AFTER BONDING OF ORTHODONTIC BRACKETS WITH IMMEDIATE AND LATE LIGHT CURING

ABSTRACT

Objective: This study aimed to compare the shear bond strength of brackets bonded to tooth enamel with immediate and late light curing of different orthodontic resins. **Material and methods:** 108 bovine teeth were used, divided into three groups according to the type of resin used for bonding, and each group was subdivided into three subgroups of 12. The mandibular incisor brackets were bonded to the teeth and, after 24 hours, subjected to the shear test in a universal testing machine with a 500N load cell and a constant speed of 1mm/min. Intergroup comparisons were performed using the ANOVA and Tukey tests. **Results:** The Transbond XT resin showed significantly higher shear strength at times T5 and T10. There was a significant difference for the Transbond XT resin and all resins together, being significantly higher than at T0. **Conclusion:** The delay in photopolymerization tends to increase the adhesion strength of orthodontic resins.

KEYWORDS: Shear Strength; Light-Curing of Dental Adhesives; Orthodontic Brackets.

INTRODUCTION

In the early days of orthodontics, accessories were affixed to the teeth using metal bands. Each tooth was fitted with a band, and a tube or bracket was attached to it. This hindered cleaning, compromised aesthetics, and made the clinical implementation of orthodontics more complex and time-consuming.[1,2]

The advent of acid etching of dental enamel in the 1970s opened up the possibility of increased adhesion of resin materials to the tooth structure, which revolutionized orthodontics. This enabled direct bonding of orthodontic accessories to the dental crown, reducing working time for the procedure, facilitating cleaning and caries detection, and resulting in more pleasing aesthetics.[3] However, the failure to adhere brackets to dental structures is a frustrating and inherent aspect of orthodontic practice, often resulting in additional work, treatment delays, and increased costs.[4] One advantage of using light-curing materials is the flexibility it offers orthodontic professionals to position brackets on enamel surfaces since polymerization only begins when the operator exposes the material to visible light from a light-curing device.[5] In the clinic, some professionals cure the adhesive system immediately after placing the brackets. In contrast, others prefer to position all the brackets of a semi-arch or complete arch. However, it is unknown whether delayed light curing could affect the bond strength of these orthodontic accessories

Taubock *et al*.[6] investigated the influence of time delay and duration of photoactivation on the microhardness of a dual-cure resin composite. Results showed that delay in light exposure did not influence microhardness, regardless of depth. Additionally, photoactivation of the tested resin composite did not provide clinically relevant benefits compared to self-curing regarding the degree of hardening.

Thomas *et al*.[7] examined the effect of light-curing initiation time on orthodontic bond strength in a resin-modified glass ionomer cement. They found that a delay in light curing may reduce curing efficiency and alter the structure of the material, but shear strength was not affected. However, to date, no studies have examined the effect of time delay for light curing of orthodontic resins on the shear strength of orthodontic accessories bonded to tooth enamel.

Therefore, the present study aims to compare the shear strength of brackets bonded to dental enamel with immediate and delayed light curing of various orthodontic resins.

MATERIAL AND METHODS

The sample calculation determined the minimum number of specimens in each group. It was considered α=5% (type I error), β=20% (type II error), and a standard deviation of 1.2[8] to detect a minimum difference of 1.45 MPa for the shear strength. The results showed the need for a minimum number of 36 specimens in each group (12 specimens in each subgroup).

Laboratory research was carried out using 108 bovine incisor teeth, divided into three groups of 36 teeth, one for each type of resin used. The groups of each of the resins were subdivided into three subgroups, with immediate light curing (T0), with a delay of 5 minutes (T5), and with a delay of 10 minutes (T10). Thus, 12 teeth were used for each time of each resin, divided according to a draw for randomization of the sample.

> Group 1 was bonded with Transbond XT Resin (3M Unitek, Maplewood, USA) and subdivided into three subgroups: Subgroup 1A for time T0, Subgroup 1B for time T5, and Subgroup 1C for time T10.
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> Group 2 used Orthocem Resin (FGM, Joinville, Brazil) and was subdivided into Subgroup 2A for Time T0, Subgroup 2B for Time T5, and Subgroup 2C for Time T10.
>
> Group 3 was bonded with Ortho Natural Resin (DFL, Rio de Janeiro, Brazil), subdivided into Subgroup 3A for time T0, Subgroup 3B for time T5, and Subgroup 3C for time T10.

Bovine teeth were stored in a saline solution under refrigeration. The specimens were analyzed with a magnifying glass, and those with cracks, grooves, cracks, or fractures were discarded. The teeth had their crowns wrapped in self-curing acrylic resin to expose an enamel window, allowing the orthodontic bracket to be glued onto it, using a glass plate to create a tangent plane to the enamel surface.

These teeth subsequently had their root portion inserted into an acrylic base in a PVC ring using a glass device, which allowed the bracket to be positioned perpendicularly to the PVC base.

All teeth wrapped in acrylic resin were polished with silicon carbide sandpaper with decreasing grain (#600 and #1200) in a metallographic polisher (Aropol-2V, São Paulo, Brazil). After polishing, the specimens were treated with felts (TOP, RAM, SUPRA – Arotec, Cotia-SP) associated with diamond pastes (1, ½, and 1/4µ).

The samples were washed in an ultrasonic vat between each polishing step for cleaning. They were submitted to prophylaxis with a Robinson brush and pumice stone paste and water for 10 seconds, with each Robinson brush being used in only four specimens; the surface was washed with a jet of air and distilled water for 10 seconds and dried with a tissue.

After prophylaxis, the brackets were bonded, respecting the manufacturer's specifications for each orthodontic resin. Roth Max metal brackets were used for lower incisors (Morelli, São José do Rio Preto, São Paulo – Brazil – ref. 10.10.410), whose base area is 9.94 mm^2.

To bond the brackets, the enamel surface was etched with Condac 37, 37% phosphoric acid (FGM, Joinville, Brazil) for 15 seconds, then washed in water for 10 seconds and dried with an air jet for 10 seconds. A micro brush was used to apply the specific adhesive made from Transbond XT resin, as recommended by the manufacturer. According to the manufacturer's instructions, Orthocem and Natural Ortho resins do not use adhesives.

After positioning the brackets with the resin, the excess was removed with an exploratory probe, and the times for light-curing were observed according to the subgroups.

For light-curing, the DBA iLed CE light-curing device (Guangxi, China) was used for 12 seconds, divided into 3 seconds for each side of the bracket: mesial, distal, upper, and lower, at a distance of 3mm between the light beam and the bracket, according to the manufacturer's instructions.

Twenty-four hours after bonding the brackets, the specimens were taken to the laboratory and subjected to shear in an EMIC® DL 500 Universal Assay Machine (Emic Equipamentos e Sistemas de Assay Ltda., São José dos Pinhais, Brazil) (Figs. 1 and 2) at a constant speed of 1mm/min. A 500N load cell was connected to the computer so the Newtons' shear forces could be registered by the TESC Emic software (InterMetric, Mogi das Cruzes, Brazil). Forces in Newtons were converted to MPa by the formula MPa =N/mm².

After bracket debonding, the enamel surface and brackets were examined with a stereoscopic magnifying glass to verify the Adhesive Remnant Index (ARI).[9] The remaining adhesive was evaluated with scores ranging from 0 to 3. A score of zero (0) indicates that there is no resin adhered to the enamel surface of the tooth; (1) indicates that less than half of the resin has adhered to the tooth's enamel surface; (2) indicates that more than half of the resin has adhered to the tooth enamel surface; (3) indicates that all the resin has adhered to the tooth enamel.

Statistical analysis

Data normality was verified with the Shapiro-Wilk test, demonstrating normal distribution, and parametric tests are recommended.

The two-ANOVA was used to analyze the time to light curing and resin type.

To compare the groups of different resins at each time for light curing and between the different times for light curing of each type of resin, the ANOVA test was used with a selection criterion and the Tukey test when necessary.

To verify intergroup differences in the ARI, the chi-square test was used.

Tests were performed with Statistica for Windows software version 10.0 (StatSoft, Tulsa, Okla, USA), and data were considered significant for $p<0.05$.

RESULTS

There was a difference regarding the variables: type of resin, time for light curing, and the interaction between them (Table 1).

In the comparison between the resins at times 5 and 10 minutes, there was a significant difference between them (Table 2). At T5, Transbond XT resin had the highest bond strength, followed by Natural Ortho resin and Orthocem resin, which had the lowest bond strength, with a significant difference between them all (Table 2). At T10, Transbond XT resin had significantly higher bond strength than Orthocem resin (Table 2).

Regarding the comparison between times, there was a statistically significant difference between the Transbond XT resin and all of them together (Table 3), with the bond strength at T10 being significantly higher than at T0 (Table 3).

The Remaining Adhesive Index evaluation showed no statistically significant difference between the groups (Table 4).

DISCUSSION

In the present study, bovine teeth were used. Several studies support using bovine teeth as an alternative to human teeth for adhesion tests.[10-12] In the study by Nakamichi, Iwaku, and Fusayama[13], no significant differences were found in adhesion to human and bovine dental enamel in all materials tested, enabling the use of bovine enamel in different adhesion tests. Bovine teeth have structural similarities to human teeth and are easy to acquire and manipulate.[14]

After bonding the brackets, the specimens were stored until the moment of shearing, which was 24 hours, based on the study by Bishara *et al*.[15], who found that the highest bond strengths were obtained after 24 hours of storage. The Orthocem and Natural Ortho resins were selected because they are widely used in the local market and have an affordable value when compared to the Transbond XT resin, which, in addition to being one of the most used by orthodontists, is considered the gold standard in terms of adhesion.[16-19]

The orthodontic bracket must have an adhesive strength sufficient to withstand masticatory forces and activate the mechanics used.[20] The force transmitted to the bracket during mastication ranges from 40 to 120N; thus, a bracket should have an adhesion strength to tooth enamel greater than 120N.[21] Reynolds[22] previously described that the minimum ideal bond strength between the enamel and the bracket should be 5.9 to 7.8 MPa. Several studies have verified that the clinically verified orthodontic forces generated during treatment can vary between 5 and 20 MPa.[23-26] Therefore, the shear strength values for all resins and evaluated times were suitable for use in orthodontic bonding. The mean values found in this research ranged from 9.83 MPa (Orthocem at T0) to 19.36 MPa (Transbond XT at T10) (Table 2).[16] The bond strength does not need to exceed the mean value to be considered sufficient, as these brackets will be removed and should not cause damage to tooth enamel.[27]

The Transbond XT resin showed better results than the others, confirming its gold-standard status in the orthodontic literature.[28] The Natural Ortho resin presented superior results to the Orthocem resin. Still, they all demonstrated adequate adhesion to withstand orthodontic forces and satisfy clinical requirements for bracket bonding, with sufficient adhesion to resist them.[29]

Regarding the comparison between the different times of light-curing, it is observed that all resins alone showed increasing shear strength as the delay in light-curing increased; however, only with a significant difference between the times immediately after bracket placement and 10 minutes after (Table 3).

Although we are unaware of studies evaluating the effect of delayed light curing on the bond strength of orthodontic resins, a few studies with resinous glass ionomers indicated this tendency towards increased adhesiveness[30,31]. In contrast, others stated that there was no change, and another still showed decreased adhesiveness.[7]

Regarding the results of the Adhesive Remnant Index (ARI), there was no statistically significant difference between the groups, and the vast majority of specimens from all groups presented the absence of adhesive material on the enamel after shear, evaluated as a score of 0 (Table 4).

The fact that the ARI values were higher can be considered positive, as it indicates that the rupture occurred at the bracket/resin interface, and this gives the orthodontist more confidence by preventing enamel fractures, which helps to maintain its integrity.[32]

Objectively, in our study, lower scores were obtained, mostly scores 0 (zero) in all groups, showing that the breakage of adhesion occurred at the enamel/resin interface but without damage to the enamel surface; these results were confirmed by another study, including for the Transbond XT resin.[29]

Unlike our clinical speculation that adhesiveness would decrease, increasing bracket loosening during orthodontic treatment, the results of the present study showed the opposite, increasing bond strength with a more significant delay in light curing. Guimarães *et al*.[33] state that reducing irradiance at the beginning of the photoactivation process can extend the pre-gel phase of the resin composite, in which the material can flow and undergo molecular rearrangement, compensating for the shrinkage forces. Therefore, it is speculated that the increase in adhesion strength with the most significant delay in light curing may occur by exposing the resin to ambient light, starting a natural and continuous light activation, which is then completed by the light-curing device.

Some studies demonstrate that different light-curing techniques involving immediate and late polymerization of composite resins can change the hardness and strength of the composite due to the prolongation of the pre-gel phase. Silva *et al*.[34], evaluated the micro tensile strength and microhardness of different composite resins using the conventional polymerization technique, the “soft-start” technique in which an initial polymerization with low intensity and a final polymerization with high intensity, and the “pulse delay” technique, performing an initial polymerization with low intensity and a final with high intensity after 3 minutes. The method that generated greater resistance to micro tensile and microhardness was the “pulse delay”, apparently due to the prolongation of the pre-gel phase, which allows greater flow of the composite resin before its complete polymerization, reducing the shrinkage stress and consequently increases the strength of the composite.

Although the results show an increase in the bond strength of the brackets on tooth enamel when using late light curing, clinical studies are needed since laboratory studies do not reproduce the same conditions as in the oral cavity.

CONCLUSION

The delay in light-curing tends to increase the bond strength of orthodontic resins since there was a significant difference between immediate curing and a 10-minute delay when comparing all resins.

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Table 1. Two-way ANOVA test results. Interaction between different resins and light curing times.

	DF	SS	MS	F	p
Intercept	1	19778.02	19778.02	1654.68	**0.000***
RESIN	2	602.55	301.28	25.20	**0.000***
TIME	2	150.05	75.02	6.27	**0.002***
RESIN*TIME	4	175.26	43.82	3.66	**0.007***
Error	99	1183.32	11.95		
Total	107	2111.18			

* Statistically significant for p<0.05.

Table 2. Analysis of shear strength between different orthodontic resins (N=12).

Shear bond strength (Mpa)	**TRANSBOND**	**ORTHOCEM**	**NATURAL**	**p**
	Mean (s.d.)	**Mean (s.d.)**	**Mean (s.d.)**	
T0	12.80 (3.96)	9.83 (2.27)	12.96 (4.28)	0.071
T5	16.22 (3.17) A	10.27 (1.59) B	13.38 (3.00) C	**0.000***
T10	19.36 (4.33) A	11.13 (3.77) B	15.80 (3.70) AB	**0.000***

One-way ANOVA and Tukey test

* Statistically significant for p<0.05.

Different letters on the same row indicate the presence of a statistically significant difference.

Table 3. Analysis of variance of shear force (Mpa) between light curing times (N=12).

Shear bond strength (Mpa)	T0	T5	T10	P
	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	
TRANSBOND	12.80 (3.96) A	16.22 (3.17) AB	19.36 (4.33) B	**0.000***
ORTHOCEM	9.83 (2.27)	10.27 (1.59)	11.13 (3.77)	0.493
NATURAL	12.96 (4.28)	13.38 (3.00)	15.80 (3.70)	0.142
ALL	11.86 (3.80) A	13.29 (3.58) AB	15.43 (5.13) B	**0.002***

One-way ANOVA and Tukey test

* Statistically significant for p<0.05.

Different letters on the same row indicate the presence of a statistically significant difference.

Table 4. Comparison of adhesive remnant index (ARI) between groups (N=12) (chi-square test).

ARI Group	0	1	2	3
TRANSBOND XT T0	11	1	0	0
TRANSBOND XT T5	9	1	0	2
TRANSBOND XT T10	10	2	0	0
ORTHOCEM T0	9	3	0	0
ORTHOCEM T5	10	2	0	0
ORTHOCEM T10	11	1	0	0

NATURAL ORTHO T0	12	0	0	0
NATURAL ORTHO T5	12	0	0	0
NATURAL ORTHO T10	11	1	0	0
X^2=23.15	**DF=16**		**P=0.109**	