

Comparison of light-curing time with the use of different led intensities devices in the bonding of metallic orthodontic brackets

Comparaç o do tempo de fotopolimerizaç o com o uso de aparelhos com diferentes intensidades de LED na colagem de br quetes ortod nticos met licos

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Abstract

Objective: to compare the shear bond strength of metallic brackets after orthodontic bonding using conventional and high-intensity light curing devices. **Methods:** eighty bovine central incisors were randomly divided into four groups according to curing time and LED devices: G1- Use of conventional LED LCU curing for 20 seconds (Emitter D – Wireless, Schuster, Brazil); G2- High Intensity LED LCU for 3 seconds (Valo Cordless, Ultradent Products, USA); G3- High Intensity LED LCU for 3 seconds (Flash Max P4 Ortho Pro, CMS Dental A / S, Denmark) and G4 – High Intensity LED LCU for 3 seconds (LEDX-T 2400 Orthometric, Brazil). Twenty-four hours after bonding, brackets were subjected to a universal testing machine with a shear bond strength (SBS) test. The Adhesive Remnant Index (ARI) visually evaluated the enamel surface. The one-way ANOVA was performed to compare the SBS between the different light-curing devices. The adhesive remnant index (ARI) was compared with the chi-square test. **Results:** there were no significant differences between the groups ($p = 0.767$). The analysis of the adhesive remnant index also showed no statistically significant differences between the groups. **Conclusion:** there was no difference in the shear bond strength and ARI index with a curing time of 3 seconds in high-intensity LCU and 20 seconds in conventional LCU.

Keywords: Light curing; Shear strength; Remnant Adhesive Index.

Resumo

Objetivo: comparar a fora de ades o de br quetes met licos ap s a colagem ortod ntica usando aparelhos fotopolimerizadores convencionais e de alta intensidade.

Metodologia: oitenta incisivos centrais bovinos foram divididos aleatoriamente em 4 grupos de acordo com o aparelho LED utilizado: G1 –Aparelho fotopolimerizador LED convencional por 20 segundos (Emitter D – Wirelles, Schuster, Brasil); G2: Aparelho fotopolimerizador LED de alta intensidade por 3 segundos (Valo Cordless, Ultradent Products, USA); G3: Aparelho fotopolimerizador LED de alta intensidade por 3 segundos (Flash Max P4 Ortho Pro, CMS Dental A / S, Dinamarca) e G4 – Aparelho fotopolimerizador LED de alta intensidade por 3 segundos (LEDX-T 2400 Orthometric, Brasil). Os esp cimes foram submetidos a uma m quina de ensaio universal ap s 24 hs para testar a fora de ades o. A superf cie do esmalte foi avaliada visualmente com o  ndice de Remanescente Adesivo (IRA). Para comparaç o a fora de ades o entre os diferentes tipos de aparelhos foi utilizado o teste ANOVA a um crit rio de seleç o. A comparaç o do IRA foi feita com o teste qui-quadrado. Resultados: n o houve diferena significativa entre os grupos ($p=0,767$). A an lise do  ndice de remanescente adesivo tamb m n o mostrou diferena significativa entre os grupos. Conclus o: n o houve diferena na fora de ades o e no IRA entre o tempo de fotopolimerizaç o de 3 segundos nos aparelhos de alta intensidade e 20 segundos nos aparelhos convencionais.

Palavras-chave: Fotopolimerizaç o; fora de cisalhamento;  ndice de adesivo remanescente

INTRODUCTION

With the advent of led light curing devices for orthodontic bonding, several different technologies of led light curing have been developed.¹ Recently, the high-power

LED light source ($\geq 3200\text{mW/cm}^2$) has been widely used by orthodontists. This device has a high-power light source, which enables more photons to be available for absorption by the photosensitizers.²⁻⁴ Consequently, it was possible to reduce the time for photopolymerization of orthodontic accessories, reducing the chair time.⁴

Advances in adhesive technology have led orthodontists to incorporate new adhesives, composite resins, light-curing devices, and bonding techniques into their

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clinical practices.⁵ All these advances aim to provide greater comfort to the patient and less chair time. Shorter curing times would save time for clinicians and patients and might also be associated with less likelihood of attachment failures by reducing moisture contamination.¹

Many factors can affect bond strength between the enamel and orthodontic brackets. The orthodontic adhesives, type, composition, and curing mode must be considered. Besides that, etching time, bracket material, loading mode, and oral environment are crucial in bonding techniques.⁵⁻⁷ In addition, many developments in orthodontics have occurred in the last decades, including new adhesives, sophisticated base designs, new bracket materials, self-etching primers, and faster or more efficient curing methods.⁸

The light-curing unit's (LCU) quality significantly influences the clinical performance of light-polymerized dental composites.⁹ On the other hand, there is no evidence to support the use of 1 light cure type over another based on the risk of attachment failure.¹ The choice of curing light system should be based on clinical preferences after analysis of other important factors, chiefly chair-side time considerations, purchase costs, and longevity.¹

In recent orthodontic literature, several studies have evaluated the clinical efficiency of LED as a curing unit for orthodontic bracket bonding.^{1-3,8,10-12} But none of them compared the shear bond strengths of brackets bonded with different LCU units and different photopolymerization times. Therefore, the objective of this study was to evaluate in vitro the effect of different LCU devices and different photopolymerization times on the shear bond strength of orthodontic brackets.

METHODOLOGY

The sample size calculation was performed based on an alpha significance level of 5% and a beta of 20% to detect a minimum difference of 1.85 Mpa with a standard deviation of 2.06 for the shear bond strength.¹³ The sample size calculation resulted in the need for 20 specimens in each group.

Eighty extracted bovine upper central incisors were collected and stored in distilled water under refrigeration at 4°C (ISO 11405).¹⁴ Only teeth with normal buccal surface morphology and no caries were included in the present study. The teeth were organized in individualized slides immersed in thermoplastic modelling plastic impression compound (Godiva Exata, Nova DFL, Rio de Janeiro, Brazil) (Figure 1A). After that, these specimens were cut on a precision cutting machine (Isomet 1000 Precision Saw, Buehler, Germany) with a standard size of 6mm² (Figure 1B).

These fragments were individually embedded in colorless auto-polymerizing acrylic resin (Dencor, Artigos Odontológicos Clássico LTDA, São Paulo, SP, Brazil). Polyvinylacrylic tubes with a height of 2.5 cm were used as forms (Figure 1C). The fragments were placed in the

center of the blocks and mounted for bracket bonding. The blocks were polished to remove the irregularities and flatten the buccal surface of the teeth. Polishing was done with sandpaper of different granulation (#600 and #1200), diamond polishing pastes, and felt discs in a metallographic polishing machine (Aropol-2V, São Paulo, SP, Brazil). After each sandpaper and felt, the samples were submitted to an ultrasonic tub for cleaning.

Figure 1(A-C) – A Tooth slide immersed in thermoplastic modelling plastic impression compound; B Bovine tooth fragment with 6mm² standard size; C Polyvinylacrylic used as forms.



The mounted specimens were randomly divided into four groups according to the type of curing light and polymerization times as follows:

Group 1: Conventional light-emitting diode (Emitter D – Wireless, Schuster, Santa Maria, RS, Brazil). Polymerization time: 20 seconds)

Group 2: High-power light-emitting diode Valo Cordless (Ultradent Products, USA). Polymerization time: 3 seconds

Group 3: High-power light-emitting diode Flash Max P4, Flash Max P4 Ortho Pro, CMS Dental A/S, Denmark). Polymerization time: 3 seconds

Group 4: High-power light-emitting diode LEDX-T 2400 (Orthometric, Marília, SP, Brazil). Polymerization time: 3 seconds

The light intensity of LED devices was measured before the commencement of the study with an RD-7 radiometer (Ecel, São Paulo, Brazil).

Mandibular incisors metallic brackets (Roth Prescription, Morelli, Sorocaba, SP, Brazil) with a 12.26mm² surface area were bonded in all the specimens.

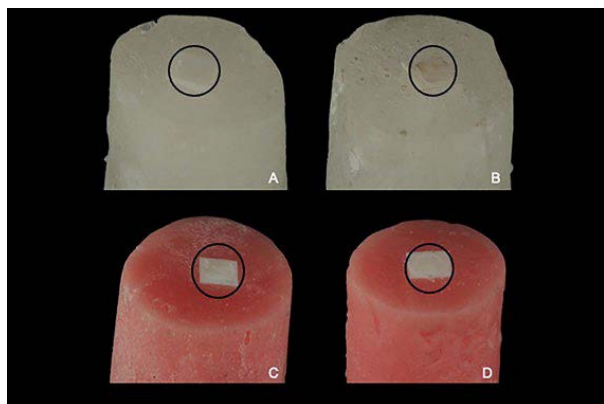
Each tooth was etched with 37% phosphoric acid gel (Ultra-Etch, Ultradent Products, USA) for 20 seconds. Afterwards, the surface was washed with a water/spray combination for 20 seconds and dried with hydrophilic cotton balls. A thin and uniform layer of Transbond XT adhesive primer (3M Unitek, USA) was applied on the etched enamel with a micro brush (KG Sorensen, Brazil) and cured according to the protocol of each group. The orthodontic adhesive was applied to the bracket base, positioned on the tooth, and then pressed lightly in the desired position. The excess adhesive was removed with an exploratory probe. The same operator in all samples performed bracket bonding. Each bracket was light-cured according to the protocol of each group. The light was positioned directly to the center of the bracket.¹⁵

Twenty-four hours after bonding, each specimen was loaded into a universal testing machine (Emic Equipamentos e Sistemas de Ensaio Ltda., São José dos Pinhais – PR, Brasil). A shear force was applied to all specimens by a shearing blade at a constant crosshead speed of 1 mm/min until the bracket was detached from the enamel. A 500 N load cell was connected to the computer to record the shear forces (in Newtons) using the TESC software. The forces (in Newtons) were converted to MpA by the formula $\text{MpA} = \text{N} / \text{mm}^2$.

The types of failure were analyzed by visual observation by a single trained operator and classified according to the ARI index (Figure 2A-D)). The adhesive remnant index (ARI)¹⁶. This index ranges from 0 to 3, as follows:

- 0 – No remaining adhesive on the bovine enamel
- 1 – Less than 50% remaining adhesive on bovine enamel
- 2 – More than 50% remaining adhesive on bovine enamel
- 3 – 100% remaining adhesive on bovine enamel, showing the impression of the bracket base

Figure 2- ARI scores. A:0 (no remaining); B:1(<50%); C:2(>50%); D:3 (100%)



Statistical analysis

The normal distribution of the data was checked using the Kolmogorov-Smirnov test. As the data presented a normal distribution, parametric tests were used.

The comparison of the shear bond strength between different light-curing devices was performed with a One-way analysis of variance (ANOVA).

The intergroup comparison of the adhesive remnant index (ARI) was performed with the chi-square test.

All statistical analyses were performed with Statistica software (Statistica for Windows, Version 10.0, StatSoft, Tulsa, Okla), with a significance level of 5% ($P < 0.05$).

RESULTS

The data showed normal distribution.

There was no difference in the shear strength between different light-curing units (Table 1).

Table 1– Results of the comparison of shear strength between different light-curing units (One-way ANOVA)

Variable	Schuster	Valo	LEDX T 2400	Flashmax P4	P
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	
Shear bond strength (Mpa)	13.79 (4.19)	12.94 (2.41)	12.82 (3.39)	12.93 (2.87)	0.7670

There was no difference in the adhesive remnant index among all light-curing units (Table 2).

Table 2 – Results of the intergroup comparison for the adhesive remnant index (ARI) (chi-square test).

ARI Group	0	1	2	3	Total
Schuster	0	0	2	18	20
VALO	1	2	4	13	20
Orthometric	1	1	3	15	20
Flashmax P4	1	1	3	15	20
Total	3	4	12	61	80

$\chi^2 = 4.50$ GL=9 $P = 0.875$

DISCUSSION

In the present study, four different brands of LED light-curing units (LCUs) were used. While one device had a recommended curing time of 20 seconds, the others had a curing time of 3 seconds. There is a belief that exaggerated acceleration of chemical reactions may increase polymerization stress and interfere with enamel bonding.¹⁷ So, this study aimed to check whether reducing photopolymerization time would increase the shear bond strength of orthodontic resins. Based on the main findings of this study, it was possible to achieve sufficient polymerization using shorter curing times because of the increased light intensity of the devices. In general, the

kind of LED unit did not affect the shear bond strength of orthodontic brackets.¹³ These claims agree with our results.

There was no difference in the shear strength between light-curing agents and curing times (Table 1). The mean values of bond strength were higher than those required for clinical routines in orthodontics, which vary between 5.9 and 7.9 Mpa.^{18,19} Pinto et al.²⁰ found similar results, which also overcame the values proposed by Reynolds.¹⁸ Although insignificant, the 20-second LCU showed a higher mean of shear bond strength (13.79 MPa) compared to the 3-second devices (Table 1). Sena et al.¹⁵ found similar results when applying 20 seconds of curing time. It could be explained that each additional second of light-curing increases bond strength by 0.077 MPa.²¹ However, their results for the 3-second photopolymerization time are different from those obtained in this study.¹⁵ They reported a mean of 5.81MPa for 3 seconds curing time, while we found a higher value, ranging from 12.82MPa to 12.94 MPa among the LCUs. It could be speculated that this difference is due to the previous storage of their specimens in distilled water for six months. They argued that water storage promotes a decrease in adhesion due to the degradation of the adhesive interface components. In the present study, we did not carry out prior storage on distilled water, which may have increased the shear bond strength. Our results agree with previous studies^{22,23}, which found higher shear bond strength, with tests carried out only 24 hours after bonding.

Table 2 shows the results for the ARI. These scores quantify the remaining material on enamel and assess where the fracture occurred during the shear bond strength test.²⁰ The chi-square test found no significant differences ($P=0.87$) among the groups, i.e., no difference in ARI scores between LED units and curing times. It means that changing the light-curing devices and their light intensities would not seem to influence the location of the weakest link in the enamel/composite bracket chain.²³ This result is in agreement with the current literature.^{10,13,20,23} According to Almeida, Martins, and Martins²²(2018), reductions in time did not affect the amount of adhesive remnant.

ARI score 3 (100% remaining adhesive on teeth) was the majority of fracture observed after tests (Table 2), and it is in accordance with Pinto et al.²⁰ It means that most of the adhesive remained adhered to the tooth after the bracket removal. This fracture type suggests that the adhesive chain's weakest link was between the bracket base and the composite. Therefore, it does not affect the dental surface at all, with cracks.²⁰ It is speculated that this happens due to an incomplete resin polymerization at the bracket base due to the reduced light exposure period.^{24,25} However, there are some contradictory results. While Almeida, Martins, and Martins²²(2018) found a majority of ARI score 1 (less than 50% of composite remained on the enamel), other authors^{23,26} reported a great majority of

ARI scores 1 and 2. A possible reason for this difference is that they used a light-curing time of 5 seconds, which may have influenced the results. It is important to emphasize that care must be taken when this result is extrapolated to orthodontic clinical practice. It is known that when the brackets are debonded at the finishing phase, part of the enamel is inevitably removed to eliminate adhesive remnants. So, the less adhesive left on the enamel after bracket debonding, the lower the possibility of causing lesions from cleaning procedures.²⁷

This study used bovine teeth instead of human teeth. The authors chose bovine teeth due to the difficulty of finding a sample of human teeth in the ideal conditions of this study.²⁸ One can say that the lower bond strength values of bovine teeth²⁹ (~35% and 44% below human teeth) could negatively influence the results. However, even considering this difference, it would still be within the acceptable values for orthodontic clinical routine.¹⁸ In addition, several studies used bovine teeth in their experiments.^{13,15,20,26,30} Therefore, bovine teeth can be used as a substitute for their human counterparts.^{28,31}

In vitro studies are a valuable screening tool. Still, clinical validation is necessary before any product or technique is universally accepted.¹¹ Orthodontic materials and methods that perform well in in-vitro experiments should always be tested in in-vivo RCTs. However, an accurate simulation is unrealistic because of the many conditions involved in the in-vivo situation.²¹ A meta-analysis²¹ conducted in 2010 found no RCTs in the topic of this present study. The authors suggested future in-vitro studies with a more careful evaluation of the factors affecting the shear bond strength of orthodontic brackets. Among the factors, the photopolymerization time has always been not adequately reported for its test conditions.

CONCLUSION

No differences existed between conventional and high-intensity LCU shear strength in metal brackets.

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