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Shear strength of metal brackets using LED lamps with different wavelengths: An *in vitro* comparative study

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Abstract

AIM: To evaluate the shear strength of Orthocem and BracePaste polymerizable cement light-cured with light-emitting diode (LED) units with different wavelengths (Bluephase N) with their high power, low power, and soft start programs in the bonding of metal brackets.

MATERIALS AND METHODS: *In vitro* experimental research was performed. Mini Roth 0.022 metal brackets (Roth Orthometric brackets) were used. The adhesives were placed on the metal brackets with Orthocem and BracePaste resin cement. To compare the average strengths, the analysis of variance (ANOVA) test was used ($P < 0.05$).

RESULTS: The average shear strength was better with Bracepaste polymerizable cement compared to Orthocem cement in all its high power, low power, and soft star programs; the highest was Bracepaste with soft start of 26.52 MPa, and the lowest was Orthocem with soft start of 13.92 MPa. When evaluating the differences, it was found that these were statistically significant in all groups ($P < 0.05$).

CONCLUSIONS: Differences were found in the shear strength of light-curing Orthocem and Bracepaste light-curing cement cured with LED units with different wavelengths in bonding metal brackets to the tooth *in vitro*.

Keywords:

Bracket, shear bond, strength

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Introduction

Orthodontic treatments are presenting a great technological advance, especially since adhesion was discovered with the use of resins. Previously, brackets were soldered to metal bands, which were cemented on all teeth, which was unfavorable for patients and orthodontists in terms of dental esthetics and clinical consultation time. Over the years, biomaterials in orthodontics have been evolving to present better properties and reduce clinical times, for example, adhesion systems have changed from a first to a seventh generation, and the mesh of the bracket bases present a series of physical and chemical modifications to obtain better retention and guarantee the results of the treatments.[1-8]

Recently, some high-power (light-emitting diode [LED] polymerization sources can emit intense light radiation of 1600–2000 YmW/cm^2. This allows shorter exposure times, reportedly up to an average of 6 s to bond metal brackets to the enamel surface.[3]

Several generations of high-intensity LED units[2,8] that have larger emitting areas have been introduced to decrease the time required to bond orthodontic attachments and optimize the bonding procedure.[5-7] In addition, it has been suggested that free

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radicals occur when light and diffusion of free radicals take time to polymerize the composite at the base of the bracket. Because the polymerization light cannot pass through the metal alloy, the number of free radicals produced and the degree of conversion appear to be lower when bonded to the metal surface than to the enamel surface.[8,9]

Polymerization is initiated using visible light in the blue range of the electromagnetic spectrum to excite the outermost layer of camphorquinone, which has an absorption spectrum of 400 and 500 nm. For this reason, many light-curing options exist such as halogen, laser, and LED units. However, there are only two light sources, halogen and LED. Newer models of dental lamps have various settings that use the yellow spectrum instead of the blue during polymerization. This is a critical factor to avoid premature light curing of the composite.[10-13]

Therefore, the aim of this study was to evaluate *in vitro* the shear strength of Orthocem and BracePaste polymerizable cement light-cured with LED units with different wavelengths (Polywave Bluephase N) with their high power, low power, soft start programs in the bonding of metal brackets to the tooth.

Materials and Methods

Study design

The study was an *in vitro* experimental design. It was carried out at the High Technology Laboratory Certificate Laboratory, Lima-Peru. The Checklist for Reporting *In-vitro* Studies (CRIS) guidelines were used for the preparation of this manuscript. The unit of analysis consisted of each bovine mandibular incisor tooth. The sample size was calculated with the mean comparison formula and the Stata 17 software. Determining a sample of 90 specimens, 15 teeth per group were divided into the following groups:

With high intensity (high power) and its power of 1200 mW/cm^2

Group 1: Orthocem resin (high power).

Group 2: BracePaste resin (high power) with intermediate intensity (soft star) and its power of 650 to 1200 mW/cm^2.

Group 3: Orthocem resin (soft star).

Group 4: BracePaste resin (soft star)

with reduced intensity (low power) and its power of 650 mW/cm^2.

Group 5: Orthocem resin (low power).

Group 6: BracePaste resin (low power).

Storage and preparation of the teeth

Immediately after exodontia, the teeth were washed with distilled water, and blood and soft tissue debris were removed. They were then stored in physiological saline and stored in a refrigerator at 4°C. The surface was prepared with abrasive discs and distilled water; finally, it was verified that all surfaces of the teeth had been prepared to a similar depth and that they had a uniform surface.

Application of Orthocem and BracePaste adhesives

The adhesive material was applied with a thin film on the surface of the bovine tooth for 10 s of polymerization, and then mini Roth 0.022 metal brackets (Roth Orthometric brackets) were used. Resin adhesives were placed over the metal brackets with Orthocem and BracePaste resins. The light-curing time was 20 s in different directions.

After removing the excess resin, as the case may be, the tip of the LED Polywave N lamp, with its different programs of high power, low power, and a soft start, was placed on the bonding resin on the bovine parts.

Shear strength

The test specimens were carefully stored in simple distilled water at 37°C for 48 h until the appropriate time to perform the shear strength test bonded with Orthocem and BracePaste cement. Shear strength tests were performed on all bovine incisor teeth. During the tensile test, the tensile force was applied at 90 degrees to the surface plane of the substrate. A digital universal testing machine, LG model CMT-5L, was used following the standardized norms, the measurement was supervised by an engineering expert in the use of the machine, and a load force of 0/500 N with an accuracy of ± 0.001 N was used. Finally, the bond strength value is in MPa (Megapascals).

Statistical analysis

Summary measures (mean and standard deviation) were determined for each group. To compare tensile strength, the analysis of variance (ANOVA) test was used with a significance level of $P < 0.05$. Normal distribution was evaluated with the Shapiro–Wilk test for all groups. The analysis was performed with the Stata 17 program.

Results

The mean tensile strength was highest with Orthocem polymerizable cement with low power at 18.80 ± 2.30 Mpa, followed by high power at 17.39 ± 1.93 Mpa, and lastly soft start at 13.92 ± 1.63 Mpa. When the differences were evaluated, they were found to be significant ($P < 0.001$) [Table 1].

Table 1: *In vitro* comparison of shear strength of light-curing cement cured with different wavelength LED units

	High power		Soft start		Low power		*P**	*P***
	Mean	SD	Mean	SD	Mean	SD		
Orthocem	17.39	1.93	13.92	1.63	18.80	2.30	0.05	0.001
BracePaste®	19.58	3.34	26.52	3.54	21.18	2.92	0.05	0.001
*P***	0.001		0.001		0.001			

*Shapiro–Wilk's normality test. **ANOVA statistical test. All values were expressed in Mpa

The mean tensile strength was highest with the BracePaste polymerizable cement with a soft start at 26.52 ± 3.54 Mpa, followed by the low power at 21.18 ± 2.92 Mpa, and lastly the high power at 19.58 ± 3.34 Mpa. When the differences were evaluated, they were found to be significant ($P < 0.001$) [Table 1].

The mean tensile strength was better with BracePaste polymerizable cement compared to Orthocem™ cement in all groups (high, soft, and low powers). The differences were found to be statistically significant ($P < 0.001$) [Table 1].

Discussion

It is known that light sources for light curing have evolved from halogen light to LED lamps at different wavelengths. To optimize the time required for light curing, it should be kept in mind that the bonding strength achieved between the bracket and the tooth should be sufficient so that the detachment rate is as low as possible to avoid the patient returning frequently to the office for re-attachment of the brackets. There is a wide variety of LED lamps of different intensities, origins, and prices. These can be presented as a single lamp (monowave) or with different intensities or wavelengths (polywave) in the same model, depending on the manufacturers. They can require from 40 to only 3 s to achieve polymerization.[14-19] For this reason, the results obtained in the present study make it possible to identify the shear strength of Orthocem polymerizable cement and BracePaste light cured with LED units with different wavelengths (Bluephase N) with their high power, low power, and soft star programs in the bonding of metal brackets.

For example, according to the study by Swanson *et al*.,[14] which evaluated the association between the shear strength of metal brackets bonded to enamel under LED light vs. other curing devices with quartz, tungsten, and halogen light, the mean shear strength resistance in all test groups was higher than 8 MPa even at 10 s of light curing. Similarly, Almeida *et al*.[15] evaluated the effect of shortening the curing time of a high-power LED device (Valley, Ultradent; South Jordan, UT, USA) on the shear strength of metal brackets. They found that time and composition significantly affected bracket adhesion. In addition, they mentioned that decreasing the exposure time from 6 to 3 s significantly reduced the average shear strength values even when using a high-power LED unit.

However, De Abreu *et al*.[16] also evaluated the effect of different light sources, thermal cycling, and silane application on the bond strength of metal and ceramic brackets. They found that the bond strength of light sources with and without thermal cycling increased the bonding in silane groups. In summary, it can be stated that silane significantly improved the performance of ceramic brackets. Although Rachala *et al*.[17] mentioned that diode-curing units have recently been used to light-cure orthodontic brackets; however, they showed that the comparisons had no significant difference in shear strength scores among the groups evaluated.

Amer and Rayyan[18] evaluated the effect of many bonding techniques on the shear strength between brackets and other biomaterials. They concluded that the shear strength between zirconia crowns and metal brackets was highly dependent on the surface treatment used. Therefore, sandblasting increased the shear strength.

All this is very important during orthodontic treatment because bracket misalignments will directly impact the success of orthodontic treatment.[19] In our research work, it was found that the mean shear strength was highest with BracePaste soft star polymerizable cement with 26. 52 MPa and a standard deviation of 3.54, followed by low power with 21.18 MPa and a standard deviation of 2.92, and finally high power with 19.58 MPa and a standard deviation of 3.34. When evaluating the differences, it was found that these were significant ($P < 0.05$); thus, our findings are like those of some studies described in the literature.

Studies are limited on the shear force generated in the bonding of brackets with polymerizable cement using an LED with different wavelengths (Polywave N) with its programs (high power, low power, and soft start) that probably use less time polymerizing than conventional LED lamps, which could optimize the clinical procedure significantly, reducing labor time and providing greater comfort for the patient, and operator. Finally, an adequate adhesion of the brackets to the tooth will be achieved using polymerizable cement.

It is recommended to conduct future research to study the polymerization shrinkage of light-curing cementitious resins with stimuli such as light, heat, ultraviolet, and pressure to determine if these improve or worsen the properties of the resins. The success of clinical treatments involves other aspects besides strength such as proper planning and correct handling of the material according to the manufacturer's instructions.

Conclusions

Among the results of this *in vitro* study, significant differences were found in the tensile strength of Orthocem photopolymerizable cement and BracePaste cement light-cured with LED units of different wavelengths (Polywave Bluphase N) with their high power, low power, and soft star programs; therefore, it is important to consider these findings as parameters to be considered during the choice of biomaterials for bracket cementation.

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Author contributions

FM, JM, CMV, LV, RM, and FMT conceived the ideas. FM, JM, CMV, LV, RM, and FMT contributed to data collection. FM, JM, CMV, LV, RM, and FMT analyzed the data. FMT led the writing. FM, JM, CMV, LV, RM, and FMT critically revised the manuscript and gave final approval.

Ethical policy and institutional review board statement

Not applicable as this was a narrative review.

Patient declaration of consent

Not applicable.

Data availability statement

Data is available on appropriate request to the corresponding author.

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Conflicts of interest

There are no conflicts of interest.

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