LED vs Halogen Light-Curing of Adhesive-Precoated Brackets

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ABSTRACT

Objective: To test the hypothesis that bonding with a blue light-emitting diode (LED) curing unit produces no more failures in adhesive-precoated (APC) orthodontic brackets than bonding carried out by a conventional halogen lamp.

Materials and Methods: Sixty-five patients were selected for this randomized clinical trial, in which a total of 1152 stainless steel APC brackets were employed. In order to carry out a valid comparison of the bracket failure rate following use of each type of curing unit, each patient's mouth was divided into four quadrants. In 34 of the randomly selected patients, designated group A, the APC brackets of the right maxillary and left mandibular quadrants were bonded using a halogen light, while the remaining quadrants were treated with an LED curing unit. In the other 31 patients, designated group B, halogen light was used to cure the left maxillary and right mandibular quadrants, whereas the APC brackets in the remaining quadrants were bonded using an LED dental curing light. The bonding date, the type of light used for curing, and the date of any bracket failures over a mean period of 8.9 months were recorded for each bracket and, subsequently, the chi-square test, the Yates-corrected chi-square test, the Fisher exact test, Kaplan-Meier survival estimates, and the log-rank test were employed in statistical analyses of the results.

Results: No statistically significant difference in bond failure rate was found between APC brackets bonded with the halogen light-curing unit and those cured with LED light. However, significantly fewer bonding failures were noted in the maxillary arch (1.67%) than in the mandibular arch (4.35%) after each light-curing technique.

Conclusions: The hypothesis cannot be rejected since use of an LED curing unit produces similar APC bracket failure rates to use of conventional halogen light, with the advantage of a far shorter curing time (10 seconds).

KEY WORDS: LED; APC

INTRODUCTION

Blue light generated by conventional halogen light-curing units has typically constituted the most popular method of bonding orthodontic adhesives for many years despite its shortcomings.[1] These shortcomings include the narrow range of light produced by these delicate and high-maintenance devices. The conventional halogen light-curing unit is limited to visible wavelengths and represents only a small part of the entire electromagnetic spectrum. For example, the Ortholux XT curing light features a "blue filter," which only permits the passage of light and, therefore, emission of wave lengths from 455 nm to 492 nm. It also is not energy-efficient because its maximum light intensity is produced at 475 nm and only 1% of the total energy emitted is converted to light with the remainder generated as heat.[2–5]

Barghi et al[6] measured the light emitted by 209 conventional halogen curing units in 122 dental clinics and found that 45% emitted light with an intensity of less than 300 mW/cm², and 65% of these had a light emission of less than 200 mW/cm². On the other hand, a recent study has demonstrated that an intensity of 300 mW/cm² is necessary for adequate polymerization of

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dental composites.[7] Rueggeberg et al[8] recommend the use of lamps with a power of at least 400 mW/cm^2 for 60 seconds to completely polymerize a composite resin of thickness 1 mm.

In 1995, Mills et al[9] and Nakamura et al[10] proposed the LED (light-emitting-diode) as an alternative to the halogen curing light. This device, instead of using a heated tungsten filament, has two solid semiconductors joined together, and an electric charge is applied using a battery. When electrons and holes meet, energy is released in the form of light and therefore generates minimal heat. It also has a far superior life expectancy than the halogen bulb at over 10,000 hours, an insignificant level of intensity loss over time, a narrow spectrum of light (400 nm to 500 nm), and an emission intensity of 1370 mW/cm^2.[11,12]

Several studies have evaluated the clinical efficacy of LED light for bonding orthodontic brackets and have been unable to demonstrate a significant difference between the adhesion force obtained with an LED light-curing device as compared to that achieved using a halogen light.[13] However, other studies have reported a lower bond strength when the LED lamp was used for the limited period of 10 seconds, although all studies cited documented a clinically acceptable adhesion force of over 8 MPa.[14–16]

In addition to the aforementioned innovations in adhesion systems, the development of brackets precoated with adhesive (APC) has further improved the quality and accuracy of orthodontic bonding.[17,18] Among the advantages of APC brackets is the quality of adhesive available, the limited quantity of adhesive required, the reduced bonding time, better asepsis, less waste, and a better control of the inventory.[19] Thus far, studies which have compared the bond strength of APC brackets to that obtained using conventional means have yielded contradictory results. According to some in vitro studies, APC brackets have a bond strength similar to that of conventional ones,[20,21] whereas other studies maintain that their bond strength is lower.[22–24]

In vivo studies have also yielded contradictory results. Two of these have demonstrated that there are no statistically significant differences between the failure rates of conventional and APC brackets,[25,26] whereas Oliver and Dama[27] affirmed that APC brackets have a higher percentage of failure, and other authors have found that APC brackets performed better.[28]

Our study was aimed at evaluating the clinical performance of photopolymerized composite precoated brackets using two different light sources, ie, conventional blue halogen light and an LED light-curing unit.

Figure 1. Split-mouth design.

Table 1. Number of Patients and Brackets Light-Cured With Conventional Halogen and LED Lamps for Each Group

|	Patients, N	Attachments With Ortholux XT, N	Attachments With Ortholux LED, N
Group A	34	302	301
Group B	31	275	274
Total	65	577	575

MATERIALS AND METHODS

A total of 65 patients (34 female and 31 male patients of age 16.2 ± 3.4 years), treated with fixed orthodontic appliances, were included in this study carried out by one orthodontic operator. The only exclusion criterion was the presence of vestibular reconstruction. The split-mouth design was used and each patient's mouth was divided into four quadrants[19] (Figure 1). The patients were divided into two groups (A and B).

In group A, the APC brackets in the right maxillary quadrant and the left mandibular quadrant were polymerized with a blue halogen light-curing device (Ortholux XT, 3M Unitek, Monrovia, Calif), while the brackets in the remaining quadrants were polymerized with an LED lamp (Ortholux LED, 3M Unitek). The brackets in the quadrants of the patients in group B were polymerized in an equal and opposite fashion.

In the period between November 2004 and May 2005, the patients were assigned to either group A or group B and a total of 1152 adhesive precoated attachments (APC Victory Series, 3M Unitek) were fixed in place (Table 1).

The attachment procedures were carried out by one operator, according to the following protocol: each tooth was cleaned using a brush (Have Neos Dental, Bioggio, Switzerland) and pumice and water for at least 30 seconds and then dried with an oil-free air syringe. The enamel was then etched for 30 seconds with 37% orthophosphoric acid (3M Unitek etching gel), and the Primer Transbond XT (3M Unitek) was applied with a small brush and spread with compressed air. The composite precoated onto the brackets employed was a modified version of Transbond XT, which was altered to increase its viscosity. The difference with respect to Transbond XT was not in the chemical composition, but in the percentage of its various components; Transbond XT contains 14% Bis GMA, 9% Bis EMA, and 77% filler. In our APC brack-
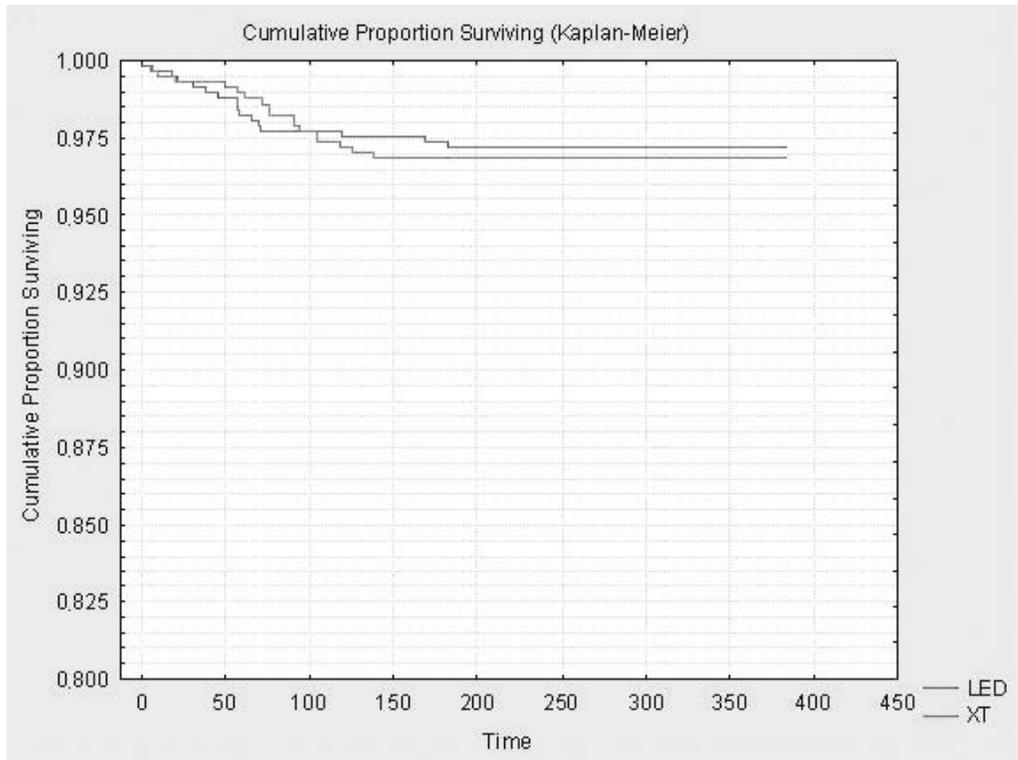
Figure 2. Survival plots for brackets bonded with each light-curing unit. LED Ortholux LED, (3M Unitek, Monrovia, Calif); XT, Ortholux XT (3M Unitek).

ets, the percentages were 12%, 8%, and 80%, respectively.[19] The excess of composite was removed with a probe before polymerization was initiated.

The composite was polymerized using a blue halogen curing light (Ortholux XT, 3M Unitek) for 20 seconds (10 seconds for each interproximal surface), as per the manufacturer's instructions. The LED lamp (Ortholux LED, 3M Unitek) was used on the remaining quadrants for 10 seconds (5 seconds for each interproximal surface), as per the manufacturer's instructions.

The patients were provided with oral and written instructions on maintenance of their fixed appliances and professional cleaning and checkups were carried out approximately every 4 weeks. The date of each attachment, the type of lamp used, and the date of any detachments were noted. The patients were instructed to inform their dentist immediately if they suspected a detachment, and the date of detachment was registered as the date in which the detachment was observed by the operator. The orthodontic treatment was carried out using a sequence of preformed archwires, commencing with a 0.016-inch thermoactive nickel-titanium wire (3M Unitek), followed by progressively thicker thermoactive nickel-titanium wires, and finally steel wires.

Statistical Analysis

In order to highlight any statistically significant differences in the percentage of detachment after treatment with each curing unit and to discover whether there was a statistically significant difference between the number of detachments in the upper jaw as compared to the lower, we employed Pearson's chi-square test (Table 2), Yates-corrected chi-square test (Table 3), and the Fisher's exact test (Table 4). Furthermore, we carried out Kaplan-Meier survival analysis (Figure 2) to verify whether, irrespective of the group, there were any significant differences in terms of detachment for each type of light. The software STATISTICA 7 (StatSoft, Tulsa, Okla) was used for all statistical analyses.

RESULTS

A total of 1152 APC brackets were fixed in place, and a conventional halogen curing light was used to cure 577 attachments, while the remaining 575 were treated with LED-generated light (Table 1).

During a mean observation period of approximately 8.9 months, 34 of the 1152 attachments were registered as detached (2.951%); 19 (3.293%) had been bonded using a halogen lamp, while the remaining 15

Table 2. Number and Percentage of Failed Brackets Light-Cured With Conventional Halogen and LED Lamps

Light-Curing Unit	Bonded, N	Failed, N	Failed, % (2)	P Value
Halogen light	577	19	3.293	.4927*
LED	575	15	2.609	
Total	1152	34	2.951	

* P value is not significant.
N = number.

Table 3. Number and Percentage of Failed Brackets of Maxillary vs Mandibular Arch

	Bonded, N	Failed, N	Failed, %	P Value
Maxillary arch	600	10	1.667	
Mandibular arch	552	24	4.348	.012*
Total	1152	34		

* P value is significant.

Table 4. Relationship Between the Different Arches and the Different Lamps Used

	Bonded, N	Failed, N	Failed, %	P Value
Maxillary arch	600			NS*
1. Halogen light		4	0.67	
2. LED		6	1.0	
Mandibular arch	552			
1. Halogen light		15	2.71	
2. LED		9	1.63	
Total	1152	34	6.01	

* NS indicates not significant.

Table 5. Number and Percentage of Failed Brackets of Anterior vs Posterior Segments of the Maxillary Arch
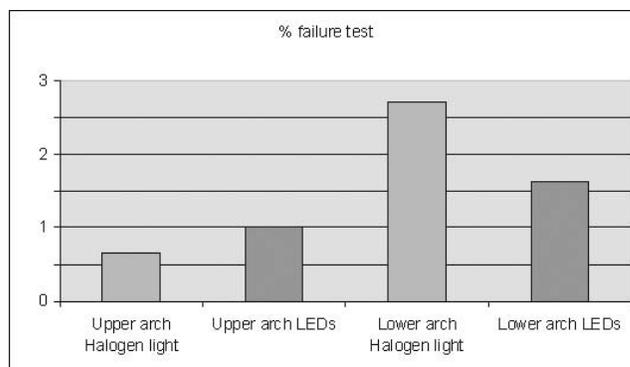
Maxillary Arch	Bonded, N	Failed, N	Failed, %	P Value
Anterior 3–3	363	10	2.755	.0244
Posterior 4–5	237	0	0	

Table 6. Number and Percentage of Failed Brackets of Anterior vs Posterior Segments of the Mandibular Arch

Mandibular Arch	Bonded, N	Failed, N	Failed, %	P Value
Anterior 3–3	317	7	2.16	.0052
Posterior 4–5	211	7	7.456	

Figure 3. Graphic of the percentages of failed brackets of maxillary vs mandibular arch cured with conventional halogen and LED lights.

LED light-curing (2.609%) or in the percentage of failure after using the conventional halogen lamp (3.293%).

Results of the Yates-corrected chi-square test ($P = .012$) permitted us to affirm that the number of detachments in the upper arch (1.667%) was significantly lower than in the mandibular arch (4.348%) (Table 3).

Fisher's exact test ($P = .2764, >.05$) confirmed that the percentage of detachment was higher in the mandibular arch than in the maxillary arch (Figure 3). There was no significant relationship found between the type of lamp used and the number of detachments occurring per arch (Table 4).

We also decided to subdivide both the upper and lower jaws into an anterior section (including canines and incisors) and a posterior section (including the premolars). The data obtained from this analysis are reported in Table 5 for the maxillary arch and Table 6 for the mandibular arch.

According to the Yates-corrected chi-square test, the percentage of detachments in the anterior part of the maxillary arch (2.755%) was significantly higher than the percentage of detachments in the posterior part of the same arch (0%). The percentage of detachments in the anterior part of the mandibular arch (2.16%) was significantly lower than the percentage of detachments at the premolars (7.456%).

The use of the Ortholux LED lamp seems to confer APC brackets with a slightly higher probability of survival with respect to that obtained with the Ortholux XT lamp (Kaplan-Meier survival analysis) (Figure 2). Nevertheless, the differences are minimal, and this was confirmed by the log-rank test ($P = .72465$), which indicated that there were no significant differences be-

(2.609%) had been fixed in place using an LED lamp (Table 2).

Pearson's chi-square test revealed a P value of .49 ($>.05$), and thus we found no significant difference between the number of registered detachments after

Table 7. Log-Rank Test Results

	WW = −1.027	Sum = 33.958	Var = 8.4967
Survival	Test statistic = −.352254	P = .72465	

tween the probability of survival relative to the two types of curing light (Table 7).

DISCUSSION

Analysis of the data presented showed that an LED curing light produces a quality of adhesion comparable to that of a conventional halogen curing unit. Indeed, no statistically significant differences could be found between the percentages of detachment occurring following use of each type of lamp.

Furthermore, no significant relationship was found between type of lamp used and survival in the maxillary arch or in the mandibular arch, in accordance with existing literature.[25,29,30] The only statistically significant results obtained were a smaller percentage of detachments in the maxillary arch with respect to the mandibular arch and a difference between the number of detachments in the anterior part (incisors and canines) with respect to the posterior section (premolars) of each arch. In particular, in the maxillary arch, the percentage of detachments in the anterior zones was greater than that recorded in the posterior sectors. This is in contrast to the existing literature, in which a larger percentage of detachments have been observed at the premolars with respect to the canines and incisors. This is probably due to the fact that the posterior sectors are subjected to higher occlusal loads, they are more difficult to isolate, and there is a large quantity of aprismatic enamel.[22,26,29,31]

Indeed, in our study, the number of detachments in the posterior sections was higher than that in the anterior zones. Cacciafesta et al[32,33] however, did not find any difference between anterior and posterior sections, and this variability may be due to the type of adhesive used, the light employed or the exposure time or the ability of the operator.

A Kaplan-Meier survival analysis was also carried out in this study, taking into account the fact that not all attachments became detached during the average observation time. The analysis also highlighted no significant difference in the survival curve relative to use of the halogen lamp and the LED lamp, respectively, during the average period of observation (approximately 8.9 months). O'Brien et al[29] found that 82% of detachments occur in the first 6 months of treatment. Our average observation time (approximately 8.9 months), which far exceeded 6 months, should therefore be sufficient time to carry out a comparison of the performances of the two lamps.

The incidence of detachment observed in our sample (3.29% for the halogen lamp and 2.61% for the LED) was very similar to that reported in previous studies conducted with APC attachments,[25,28] but lower with respect to that observed by O'Brien et al[29] and

Millett et al[31] who documented a detachment percentage of 6% and 4.7%, respectively. Other clinical studies,[30,34] however, have reported much higher percentages of detachment (23%–24%). We believe that this may be due to the differing methods of adhesion, the type of attachments used, the operator, and the characteristics of the composite filler.

In this study, variables such as age, gender and type of malocclusion were not considered, as previous studies in which these analyses were carried out have given contradictory results.[31,35–37]

CONCLUSIONS

- There are no significant differences in percentage of detachment recorded when using an LED light-curing unit with respect to conventional halogen light.
- The clinical application of LED curing lights associated with APC attachments is a clinically valid procedure which may reduce the time necessary to carry out bonding without leading to an increasing number of detachments over time.

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