Original Article

Long-term Failure Rate of Brackets Bonded with Plasma and High-intensity Light-emitting Diode Curing Lights

A Clinical Assessment

Nikolaos Pandis[a]; Sophia Strigou[b]; Theodore Eliades[c]

ABSTRACT

Objective: To comparatively assess the long-term failure rate of brackets bonded with a plasma or a high-intensity light-emitting diode (LED) curing light.

Materials and Methods: Twenty-five patients with complete permanent dentitions with similar treatment planning and mechanotherapy were selected for the study. Brackets were bonded according to a split-mouth design with the 3M Ortholite Plasma or the high-power Satelec mini LED Ortho curing light. Irradiation with the two curing lights was performed for 9 seconds at an alternate quadrant sequence so that the bonded brackets cured with either light were equally distributed on the maxillary and mandibular right and left quadrants. First-time bracket failures were recorded for a mean period of 15 months (range 13–18 months) and the results were analyzed with the chi-square test and binary logistic regression.

Results: The failure rate for brackets was 2.8% for the plasma light and 6.7% for the LED light source. Although significantly more failures were found for the mandibular arch, no difference was identified in failure rate between anterior and posterior teeth.

Conclusions: High-intensity LED curing lights present a 2.5 times higher failure rate relative to plasma lamps for nominally identical irradiation time. Mandibular teeth show almost 150% higher failure incidence compared with maxillary teeth. No effect from the arch side (right vs left) and location (anterior vs posterior) was identified in this study.

KEY WORDS: LED; Plasma; Bonding

INTRODUCTION

The introduction of alternative light-curing devices in orthodontic bonding during the past few years has revolutionized the application of light-cured adhesives, eliminating the requirement of increased chair time. The wide array of new light-curing sources includes plasma arc, laser, and light-emitting diode (LED) lights, which were integrated in the profession to facilitate short irradiation times.[1,2] Plasma lamps present very high intensity compared with halogen lights (1600–2100 mW/cm^2), an effective spectrum of 450–500 nm, and a significantly higher cost, which nevertheless is counterweighed by their increased lifespan of 5000 hours compared with 40–100 hours for halogen. Orthodontic bonding with these light sources can be achieved with only 6 seconds of irradiation for stainless steel brackets[3–8] or 3 seconds for ceramic brackets.[9]

Laser lights show an intensity of 700–1000 mW/cm^2, have a basically monochromatic spectrum of variable wavelength (454, 458, 466, 472, 477, 488, 497 nm), and are costly but have an almost infinite lifespan. Application of these light sources to orthodontic bonding has shown that 5 seconds of irradiation provided bond-strength values comparable with those found for halogen.[10]

LED light-curing units yield a maximum intensity of 1100 mW/cm^2 at a spectrum of 420–600 nm, have a cost comparable with that of conventional halogen lights, and have a nearly infinite lifespan. The results of bond-strength studies show contradicting evidence on the performance of these lights, with most investi-

[a] Private practice, Corfu, Greece.
[b] Scientific Researcher of Sectoral Institute of Education INEGSEE/OIELE, Athens, Greece.
[c] Associate Professor, Department of Orthodontics, School of Dentistry, Aristotle University of Thessaloniki, Athens, Greece.
Corresponding author: Dr Theodore Eliades, 57 Agnoston Hiroon Street, Nea Ionia GR-1423, Athens, Greece
(e-mail: teliades@ath.forthnet.gr)

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gations demonstrating bond strength comparable with halogen lights at same irradiation duration. However, reduced strength resulted when shorter time frames were applied.[11–13]

Recently, a novel type of LED light became available with significantly higher intensity, which would supposedly reduce the requirement for longer irradiation time down to the range found for plasma lights. Whereas favorable results have been published by investigators using laboratory assessment of this light source,[14,15] no clinical evidence has been presented on its performance.

The purpose of this study was to comparatively assess the failure rate of brackets bonded with either a plasma or a high-intensity LED curing light over a treatment period of at least 13 months.

MATERIALS AND METHODS

The curing lights included in the study were the Ortholite Plasma (3M Unitek, St Paul, Minn) and the Satelec mini Ortho LED with the 5.5-mm Ortho booster tip (Satelec Acteon Group, Mérignac-cedex, France). Informed consent was obtained from 25 patients (15 girls and 10 boys) of an average age of 14 years (range 12–16 years). Participants were selected from a large pool of patients according to the following inclusion criteria: complete permanent dentition, nonextraction treatment, absence of buccal or labial restorations, similarity in the projected mechanotherapy with respect to the use of treatment utilities or auxiliaries (elastics), absence of intra- or extraoral appliances (lip bumpers, headgears), and no oral habits. A total of 494 edgewise brackets (Microarch, GAC, Bohemia, NY) of 0.022-inch slot were bonded with Orthosolo primer and Enlight adhesive paste (ORMCO, Glendora, CA). The teeth were pumiced, rinsed, etched with 37% liquid phosphoric acid, and air dried before adhesive application.

Bonding involved a split-mouth design, and for every participating patient light units were alternated so that they were equally distributed on maxillary and mandibular left and right quadrants. Polymerization was initiated with either the plasma or the high-intensity LED light in the following manner: each bond was irradiated for 9 seconds (3 seconds from the gingival, 3 seconds from the occlusal, and 3 seconds interproximally at the maximum intensity). Light intensity for the two lights included in the study was approximately 2000 mW/cm^2 for the plasma light and 2000 mW/cm^2 $\pm$ 10% for the LED light.

The initial wire placed in all cases immediately after bonding was 0.016-inch nickel-titanium (NiTi). Various combinations of round and rectangular NiTi followed, and stainless steel wires were used as the treatment progressed for all patients. Recording of failed brackets involved only first-time failures for an observation period of at least 13 months (range 13–18 months). All bonding and clinical procedures were performed by the first author.

Descriptive statistics and univariate and multivariate statistical analyses were used to explore the effect of light-source irradiation and tooth characteristics on failure. Statistical analysis relied on logistic regression modeling with treatment outcome (survival or failure of bonds) serving as the dichotomous dependent variable, whereas light source (plasma or LED), arch (maxillary or mandibular), side (left or right), and region (anterior or posterior) were investigated as independent variables separately or simultaneously by using a univariate or a multivariate model, respectively.[16]

RESULTS

Table 1 shows the results of the statistical analysis of failure incidence per light-irradiation source, arch, side, and location. A significantly higher failure rate was observed for the LED light, which failed 2.5 times more often compared with the plasma curing light source ($P < .05$). Similarly, mandibular teeth showed an almost 150% increase in failed bonds compared with maxillary teeth. Overall, the light source and arch remained significant predictors of failure in multivariate analysis after accounting for arch and side location. On the contrary, arch side (left or right) and region (anterior or posterior) did not affect failure.

DISCUSSION

Despite the fact that most in vitro studies have reported bond-strength values that largely exceed the supposedly minimum threshold set 30 years ago,[17] clinical trials have shown increased bond failure that often reaches 8%–10%. The validity of introducing a minimum required bond strength has been criticized on the basis of (1) a lack of similarity among the materials, utilities, and treatment mechanotherapeutical trends of the time of proposition of this value relative to those currently used; (2) the absence of any consideration for material aging patterns, which have been found to induce potent degradation in adhesive resins, such as the presence of esterases, which cause enzymatic degradation of polymeric adhesives[18]; and (3) a lack of simulation of masticatory forces, which may explain the increased frequency of bond failure in the mandibular arch relative to maxillary teeth, as verified in this study.[19] Thus, apart from the necessity to introduce more clinically relevant methodological approaches,[20,21] in vitro protocols may depart from the commonly followed notion to compare

Table 1. Descriptive Statistics and Statistical Analysis of Failure Incidence by Light Source, Dental Arch, Arch Side, and Arch Location

					Univariate Analysis[a]		Multivariate Analysis[a]	
	n	Success	Failure	Failure Incidence	Relative Risk for Failure	*P*-value	Relative Risk for Failure	*P*-value
Light source								
Light-emitting diode	247	230	17	0.067	2.429	<.05	2.429	<.05
Plasma	247	240	7	0.028	Reference			
Arch								
Maxiallary	246	239	7	0.028	0.415	<.05	0.415	<.05
Mandibular	248	231	17	0.069	Reference			
Side								
Right	248	237	11	0.044	0.839	NS	0.839	NS
Left	246	233	13	0.053	Reference			
Location								
Anterior	299	284	15	0.05	1.087	NS	1.087	NS
Posterior	195	186	9	0.046	Reference			
Total	494	470	24	0.049				

[a] Based on logistic regression. NS indicates nonsignificant.

the obtained bond-strength values with an unsubstantiated standard.

The results of this study, which is the first long-term trial to show the clinical performance of high-intensity LED, demonstrate that these lamps are incapable of reaching the success rates observed for plasma lamps, implying that an increase in irradiation should be utilized. In general, the introduction of novel light sources such as plasma and LED lamps in orthodontic bonding sought to drastically reduce the time required for the polymerization of light-cured adhesive, a factor that was considered the main disadvantage of such bonding systems.

The halogen light units provide 1100 mW/cm^2 of energy, whereas high-intensity LED output may reach 2000 mW/cm^2. However, with the former, an irradiation time of 20 seconds per bracket is suggested, which yields an energy value substantially higher when compared with the corresponding energy provided to the adhesive with LED lights at 5–6 seconds. This is supported by studies that indicated that LED lights showed strength comparable with halogen units at similar time frames but reduced bond strength at decreased irradiation duration.[15] It seems that high-intensity LED did not cure this deficiency in spite of in vitro reports suggesting that these new products provided strength comparable with conventional lamps at reduced times.[14] This may be partially assigned to the clinical irrelevance of laboratory investigations, which may also show a large variation of values obtained for nominally identical materials.[22]

A fundamental issue of photo-polymerization relates to the peak wavelength at which the maximum intensity is recorded. Two main initiator systems are used in light-cured dental composite resins: camphoroquinone, which is the typical photo-initiator in the majority of products, presents a peak absorbance at 468 nm, whereas 1-phenyl-1,2-propanedione shows a peak absorbance at 390 nm.[23] Therefore, light sources that emit high energy at wavelengths outside these specific areas may not be efficient. According to manufacturers, the plasma emission spectrum emits at a peak intensity of 468 nm range; however, the high-intensity LED tested in this study presents a peak at the 450–460 nm area, and its output at 468 nm may be a fraction of the reported peak intensity.[24] This variation may also provide a basis for the explanation of the inferior performance of bonds irradiated with the LED light.

In the broader adhesive-materials literature, high polymerization rates have been shown to induce two undesirable effects. First, high stresses develop because of the polymerization shrinkage in the tooth cavity.[23] However, there is a lack of data on this issue for orthodontic bonding, and it seems that this should not constitute a concern because of the relaxation of these stresses in the bracket-adhesive interface owing to the lack of margins and cavity walls. Second, an exceedingly high light intensity above 2000 mW/cm^2 may cause material structural defects. It has been suggested that very high rates of excitation of radicals may induce such a high polymerization rate and that encapsulation of unreacted monomer species may take place, leading to an inhomogeneous material.[25] This is attributed to the development of prematurely terminated chains, which do not achieve the required chain length and are of insufficient cross-linking. Although this effect may not be reflected in the immediate bond-strength results of the adhesive, it is known that nonhomogeneously polymerized materials are susceptible to dissolution and degradation and present increased monomer leaching.

CONCLUSIONS

- High-intensity LED curing lights present a 2.5 times higher failure rate relative to plasma lamps for nominally identical irradiation time.
- Mandibular teeth show an almost 150% higher failure incidence compared with maxillary teeth.
- No effect from the arch side (right vs left) and location (anterior vs posterior) was identified in this study.

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