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SLER® (Soft Light Energy Release)-A Novel Curing Technology for Orthodontic Bracket Bonding

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Abstract

Bracket bonding procedures with composite photo-cured materials are commonly used in orthodontics to improve clinical performance and reduce treatment time.

Ceramic brackets are frequently applied in combination with composite photo-cured materials to improve aesthetics.

Since bond strength depends on the light curing process, in dentistry a new technology named Soft Light Energy Release (SLER®) has been introduced to allow thermal control of the curing process by softly decreasing light energy in the final step of the irradiation period.

The aim of this study was to test the SLER® technology in orthodontics.

Eighty ceramic brackets were bonded on the enamel facial surface of freshly extracted central lower bovine incisors with light cured composite materials. They were randomly divided into two groups: one using standard light curing (group A) and the other SLER® curing technology (group B), both providing the same energy dose. An Instron digital torsiometer determined the bonding strength.

Statistical analysis showed a significant difference between the two groups. Group B with the SLER® showed a greater bonding strength compared to the Group A with standard light curing. The findings suggested that SLER® improves the bonding strength of orthodontic brackets when using light cured composite materials.

Keywords: Bracket; Bonding strength; Composite materials; Photo-polymerization; SLER® curing technology

Introduction

Direct bonding with resin-based adhesives and composite materials is the most popular method to apply orthodontic brackets to teeth [1] reducing chair and treatment times. In the last few years new orthodontic biomaterials were developed for clinical applications. Ceramic brackets are, thus, commonly used in combination with composite photo-cured materials to improve aesthetics.

However, the efficiency of orthodontic fixed appliances depends on bond strength [2]. Accidental bracket debonding is still one of the most frequent problems during orthodontic treatment.

The bonding strength is closely related to bracket base characteristics and to the adhesive and mechanical properties of the bonding material.

The mechanical properties and, consequently, the long-term clinical performance of the bonding materials are directly influenced by the light curing process (LCP). An inadequate degree of light cure may result in a higher *in vivo* wear and marginal breakdown [3,4], in an increased material cytotoxicity [5-7], and in poor mechanical properties (i.e. elastic modulus and strength) [8-10].

A novel light curing process, named Soft Light Energy Release (SLER®), has recently been introduced in dentistry for the photo-polymerization of composite restorative materials to improve mechanical properties and, consequently, clinical results [11]. This technology allows a thermal control of the curing process by softly decreasing the light energy in the final step of the irradiation period resulting in a more relaxed and homogeneous internal material stress distribution.

The aim of this study was to investigate the influence of the SLER® on the bonding strength of orthodontic ceramic brackets compared with a standard curing modality.

Materials and Methods

Eighty central lower incisors were extracted from 2-year-old bovine [12,13]. Teeth damaged by the extraction procedures were excluded using visual analysis with ×4 magnification loupes.

Teeth were stored in 10% thymol solution at 37°C during preparation and prior mechanical testing. Optical microscopy identified the smooth and flat vestibular surface for bracket bonding within 1 week after extraction.

Enamel surfaces were cleaned with pumice [14] and sectioned with an Isomet microtome (Buehler Ltd, Lake Bluff, Illinois, USA), fitted with a diamond saw (0.3 mm thick and 100 mm diameter) and cooled by water at a speed of 125 mm/s (150 rpm). The sections were then placed on an adhesive tape and embedded into steel cylinders filled with a self-curing, methyl methacrylate based resin (Formatray, Kerr Corp., Orange, California, USA). Finally, the specimens were re-examined by visual analysis. The teeth were randomly divided into two groups: Group A and Group B of forty samples each.

Sample preparation

Ceramic adhesive pre-coated upper central incisors brackets (APC™ Plus, 3M Unitek, USA) (Figure 1) were bonded in combination

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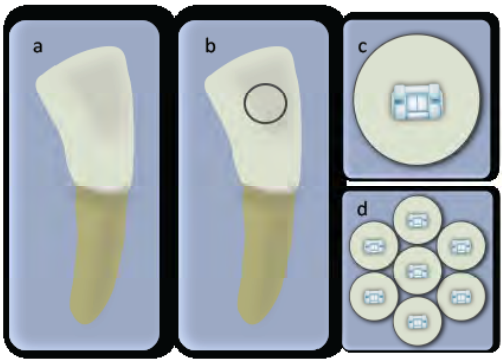

Figure 1: Samples preparation steps: (a) bovine teeth selection; (b) recognition and marking of an almost flat surface on the vestibular aspect; (c) tooth sectioning and bracket bonding; (d) selected samples storage prior mechanical testing.

Figure 2: Experimental LED light curing unit used for sample preparation and custom made support for optical tip positioning.

with a moisture insensitive primer/adhesive system (Transbond MIP Primer, 3M Unitek, USA), on the enamel selected surfaces following the manufacturer's instructions. Air dried enamel surfaces where etched with a 35% *w/w* phosphoric acid gel (Unitek™ Etching Gel, 3M Unitek, CA, USA) for 15 s, washed with physiologic solution for 15s, gently dried with a oil-free air flushing, and firmly brushed with the Transbond MIP priming solution for 10s. After an additional 4s air burst, bracket light-protective blisters were opened and brackets were applied to tooth enamel surfaces. A force of 300g (Correx force gauge, Bern, Switzerland) was uniformly applied on each bracket for 10s to ensure the same adhesive and composite thickness between the bracket and the enamel. Adhesive flash was removed from the teeth with a sharp probe and, then, finally, two different modalities "Standard" or a "SLER®" where used to light cure bonding procedures in each Group.

In Group A, "Standard" light curing was utilized.

In Group B, experimental light curing prototype unit, developed by Mectron (Mectron Spa, Genova, Italy), incorporating the SLER® process, was used (Figure 2).

The lamp power output was measured by a radiometer (LED Demetron, Kerr Corporation, USA) and the maximum output was 1200 mW/cm^2.

The "Standard" power curve was constant at the maximum intensity level, while the "SLER®" power curve (Group B) consisted of a constant step at the maximum power followed by a soft light energy release. As reported in Table 1, both light curing procedures provided the same energy dose. The resin transparent optical fiber tip (diameter 12mm) of the experimental unit was placed 1mm away from the superior border of the brackets.

The bonded teeth were left undisturbed for 30min to ensure complete polymerization of the adhesive/composite and stored in distilled water at 37°C for a 24 hour period prior testing.

Torsional mechanical tests

Mechanical testing was performed using a digital torsiometer (IMAD 5Nm) (Figure 3). The torsion was carried out controlling the angular position and with the angular speed set at 0.5 degrees/min. Torque was applied through a flat (1.7 mm thick) screwdriver placed in the vertical groove between the wings of the bonded brackets and the testing tool remained perpendicular to the tooth surface.

Results

Bonding strength (BS) of each group was summarized in Figure 4. Group A (n=40) presented a BS of 202 ± 24 (N*mm ± SD), while Group B (n=40) presented a BS of 243 ± 18 (N*mm ± SD). One-way ANOVA statistical analysis showed significant differences between the two light curing conditions (P<0.01). The comparison of mean values of torsion failure loads showed an increase of almost 30% in BS when SLER® curing modality was adopted.

Statistical analysis of results obtained from mechanical testing showed a significant difference between the two groups of samples

Curing modality	Power (mW/cm^2)	Exposure time (s)	SLER® time (s)	Energy dose (J/cm^2)
"Standard"	1200	10	-	12
SLER®	1200	9	2	12

Table 1: Light curing modalities used to polymerize the adhesive/composite brackets bonding material.

Figure 3: Torsiometer device and experimental set-up tools used for mechanical debonding test.

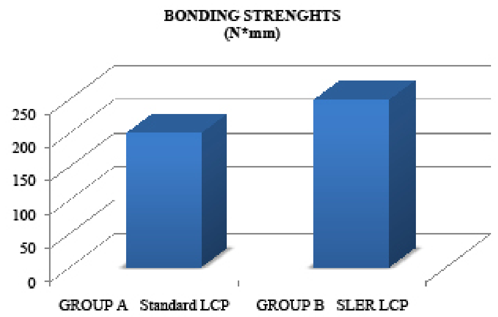

Figure 4: Mechanical testing results (Bonding Strength): Group A (n=40) 202 ± 24 (N×mm ± SD), Group B (n=40) 243 ± 18 (N×mm ± SD).

(Figure 4). Samples prepared using the SLER® technology curing modality showed an increase in the mean values of bonding strength when compared to those prepared with the Standard curing modality.

Discussion

Bracket bonding is commonly performed using adhesive systems and composite light-activated materials. These materials combine high adhesion values with easy handling, virtually unlimited positioning time, and, therefore, high positioning accuracy. In clinical practice, the choice of a bonding system is mainly based upon the adhesion capability of the material as well as the handling procedure [15].

The mechanical properties, stability and, consequently, the clinical performances of the "bracket– composite/material–tooth" system is directly related to the involved interfaces strength and stability and to the mechanical "bulk" properties of the different involved materials. The reliability of the enamel-adhesive and composite-bracket interfaces is assured, respectively, by the acid etching technique and by the improved retention design of the bracket bases. The retentive characteristics of bracket bases have evolved to such a level that, usually, a fracture at the composite–bracket interface is uncommon in clinical trials [16]. Rather, such fractures tend to occur at the enamel–composite interface and are almost always caused by errors in operating procedures or in the manipulation of the adhesive materials [17]. Indeed, when these materials are used correctly, the adhesion values attained are so high that they may cause enamel lesions during debonding.

On the other hand, the mechanical properties of the composite bonding material is strictly dependant on the light curing process and related to the particular geometrical boundary conditions during the polymerization process.

The polymerization process forms covalent bonds between monomer, molecules that were originally subject to inter-action through weaker Vander Waals forces. Average intermolecular distances are therefore reduced [18], causing a reduction in free volume [19] that is non-homogeneously distributed through the developing cross-linked network. These effects macroscopically translate into volumetric shrinkage.

In clinical practice, the amount of stress building up in the composite depends on boundary conditions. In particular, the ratio between bonded and un-bonded surfaces, the stiffness of the surrounding tissues or materials and the photo-polymerization kinetics of the composite material in relation to its chemistry together all determine the amount of shrinkage or contraction stress developing into the material. On the base of these preliminary considerations, the bracket bonding procedures, using light-activated composite materials, presents many different critical aspects: the composite bonding material is constrained by the enamel surface and the bracket base with a unfavorable bonded and un-bonded surfaces ratio, light transmission is strongly decreased by the shield effect of the bracket material and thickness, polymerization activation starts from the external perimeter of the composite material resulting in a unfavorable shrinkage stress internal distribution. As highlighted by Fox et al. [20] and confirmed by Eliades and Brantley [21], the protocols used by researchers differ widely. Consequently, comparison of the heterogeneous data is impossible, and clinical inference becomes unreliable. Eliades and Brantley [21] also emphasized the need for a research protocol that standardized a series of parameters and considered all of the variables linked to the operating methodology. In particular, those authors focussed on the influence of the type of substrate used, on the structures of the coupled surfaces, and on the debonding stress methods. In order to investigate adhesive materials for orthodontic bracket bonding, it is necessary to analyse their performance in relation to the stress involved in the bracket–adhesive–tooth system. As suggested by Valletta et al. [22], the application of a torsional moment resulted in a similar type of fracture, regardless of the adhesive material used. Furthermore, analysis of the fracture surfaces by optical microscopy confirmed the absence of enamel lesions in all of the samples debonded by torsion.

Conclusions

Mechanical properties of composite and adhesive materials used for bonding orthodontic brackets can be improved by adopting the soft light energy release curing process SLER®. As the power unit of conventional light curing devices is turned off, a fast temperature decrease is observed into the composite bonding material. Consequently, a fast thermal shrinkage occurs and the filler-matrix interface, as well as the resin-dentin interface, can be damaged. The SLER® process allows smoothing this thermal shrinkage thus allows relaxing the stress. This novel light curing process, based on a soft light energy release, enhances mechanical properties of dental composite and bonding materials in orthodontics clinical procedures.

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