An effective application of dental restorative adhesives

Philip Millstein¹, Apa Juntavee², Behrouz Abedian *³
¹ Department of Restorative Dentistry and Biomedical Sciences, Harvard University, Boston MA 02115
² Department of Preventive Dentistry, Faculty of Dentistry, Khon Kaen University, Khon Kaen 40002, Thailand
³ Department of Mechanical Engineering, Tufts University, Medford Ma 02155
*Corresponding author: Behrouz Abedian, Department of Mechanical Engineering, Tufts University, Medford Ma 02155, E-mail: Behrouz.abedian@tufts.edu; Tel: +86-28-85503671/13688339355; Fax: +86-28-85503671

Introduction

Contemporary dental adhesives, with decades of improvements, have revolutionized preventive and restorative dentistry and are widely used in dental practice [1]. Their applications cover a significant portion of US population [2] resulting in reduced incidence of caries both in children and adolescents [3-7] and reduced restorations involving toxic metals [1]. In application of dental adhesives, despite their strong interfacial properties, from an operational standpoint, there are still too many failed restorations using adhesives and extending restoration’s durability is critically needed [8].

Factors such as the patient and the operator can play important roles on the restoration longevity, but a treatment failure incident, in most instances, involves physical debonding between the cured material and its tooth substrate. Even when a dental application is successful initially, debonding can eventually be caused by repeated physical, thermal and mechanical loads at the interface that a normal tooth experiences. To prevent early restoration replacement, effective interfacial bonding should be promoted. Interfacial bonding can be strengthened by a more robust adhesive with a higher bonding energy and a higher operational efficacy. The technique can be a better way to apply the adhesive on any surface.

A successful dental operation of an adhesive will be a long lasting treatment with strong interfacial bonding that is evenly distributed on the interior of the cavity. To this end, the adhesive is required to be fully resting in contact with the inner walls, both macroscopically as well as microscopically. When applying a dental adhesive, adsorbed and trapped air on irregular and rough inner surfaces and existence of areas hard to reach can facilitate interfacial air gaps that mitigate secondary caries [9].

In practice, commercial dental adhesives are delivered and applied with a syringe. Optimizing shaping and spreading of the adhesive in proximity of treatment area is often required and can influence the treatment longevity. Subsequent to placement, the adhesive may further be shaped and spread around with a commercial stylus applicator for better control and adaptability, prior to light curing.

Use of a conventional dental applicator to form the adhesive on any surface will have two outright practical challenges. First, upon the insertion of the stylus to the adhesive, the submerged tip get wetted and will stuck by the adhesive. With tack, removing the stylus from the adhesive pile to untack it will require a negative disjoining pressure to the adhesive pile producing undesired deformations and increasing the chances of debonding and treatment failure. Secondly, the tack greatly limits the

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spreading ability by the dental operator resulting in an uneven application of adhesive on the surface. Unevenness of the adhesive layer can compromise its mechanical strength and uniform light curing of the layer. Existence of these two challenges increases operational sensitivity and errors.

A collaborative effort between two authors of this report has provided dental practitioners with a tool to circumvent the tack effect in compaction and forming of dental adhesives [10]. The concept is to use a vibrating tip at a proper frequency to manipulate the adhesive to deform without adhesion of the tip. With continuous pressure using a conventional dental stylus, the submerged portion of the tip is always wetted irreversibly and permanently due to a strong interfacial energy of the adhesive.

With a positive vibrational pressure at the adhesive interface, interactions between the tool and the material interface are transitory and nearly reversible, rendering no permanent tack and no negative pressure in a pull-out act when vibrations are at a prescribed frequency range [11]. Interfacial vibrations can be induced by using a non-axisymmetric rotating bur with different geometries on a dental drill. A primitive non-axisymmetric geometry for the bur is shown schematically in Figure 1. The bit, rotating axially, will induce oscillations at the adhesive interface. The pull-out effect for two cases of rotating and non-rotating bur is descriptively provided in Figure 2. This figure depicts that the rotating bur has no permanent adhesive attached to it while manipulating the adhesive. Without any wetting effect, a vibrating bur can provide a more controllable adjustment of the adhesive shape with less operational errors.

Preliminary studies comparing the placement outcome using vibrating and non-vibrating bids have been performed [12-13]. One study has also demonstrated that a needle vibrating tool was effective in cleansing and etching occlusal pits and fissures [14].

In our studies [11], two resin-based restorative flowable composites, Esthet XFlow (Dentsply International, Milford DE) and Revolution (Kerr Company, Romulus, MI), were attempted to form a lining on the inner wall of a square cavity, in vitro. A dental explorer and a specially designed smooth, off-center bur rotating in the range 300-600 rpm were used by the same dental operator. A total of 20 attempts for each composite were conducted and after each attempt the geometrical characteristic of the adhesive lining for each attempt were measured and statistically analyzed. Figure 3 shows the physical shapes of the adhesive (Esthet Xflow), in the square molds after three operations, syringe loading, shaping with a dental explorer and shaping with rotating bit. The adhesive layer formed by the rotating bur is thin and uniform, even around the corners that can be particularly challenging for a dental practitioner because of trapped air. With all the experiments, it was demonstrated that use of a rotating bur can provide a more consistent thin uniform layer with a much better success covering the inner walls of 90-angle corners and a better macroscopic marginal adaptation.

The two placement techniques have also been compared on effective sealant bondage to occlusal areas [13]. Figure 4 depicts two images of microleakage tests utilizing these two methods of placement. It is shown that dental sealant placement technique can have a decisive effect on occlusal adhesion and penetration. A set of flow-burs with identical tip geometry as used previously for lining of flowable composites were constructed and used to manipulate the sealant in the occlusal area of extracted healthy teeth. The results were compared with similar data using a conventional dental applicator. The comparisons indicate that use of flow-burs resulted in 50% reduction in microleakage on average for filling a tight area and 66% reduction of unfilled voids inside the treated fissures. It is concluded that the rotating bur has provided better macroscopic and microscopic adaption and a more consistent outcome, making a treatment potentially longer lasting with less operational errors.

Based on their adhesion mechanism, there are different types of dental adhesives, etch and rinse, self-etch and glass-ionomers [15]. Aging effects and adhesion degradation are observed for all categories of dental adhesives. While some dental adhesives such as etch and rinse adhesive might be preferable to other categories [8], all adhesives can benefit from use of vibrating bur for their placement for a longer lasting treatment. Future patient-based clinical studies should evaluate potential extend of benefits or advantages of this method.

Factors that influence this placement technique includes the size and shape of bur, the material the bur is made of and the frequency of rotation. In many laboratory-based studies, any bur with a cross-sectional size 1-3 mm and having any kind of axial asymmetry has been effective. The bur material is also recommended to have a hydrophobic surface such as plastics to reduce interfacial energies.

The effective rotational frequency of the bur should be within a range. Rotating too slowly, polymer strands on the interface will rotate and move due to thermal motion resulting in irreversible interfacial interactions and bonding as the adhesive wets the tip. On the other hand, when the bur vibrates or spins too fast, the adhesive can get splashed around and disintegrate due to excessive inertial effects. Accordingly, an effective rotating bur will have lower and upper bounds of frequency that needs to be specified for a working adhesive. In general, this frequency range is dependent on physicochemical properties of the adhesive and lighter adhesives will require a higher frequency[10]. For present dental adhesives, we
Figure 1. (a) Cross sectional view; (b) Side view.

Figure 2. Bit in the extraction phase (a) Non-rotating (b) Rotating at 600rpm

Figure 3. Esthet Xflow in the square mold after each placement: (a) loading with a syringe nozzle; (b) use of a dental explorer; (c) use of the rotating bur. Final form of composite in dark shade.

Figure 4. Images of microleakage tests for the two placement techniques using: A – Flow-bur; B- conventional applicator.
anticipate that the frequencies that we have used in our studies (300-1200 rpm) should be the range that make this technique effective.

References


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