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Long-term adhesion and mechanism of bonding of a paste-liquid resin-modified glass-ionomer

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ABSTRACT

Objectives. The contribution of chemical bonding of the polycarboxylic acid in classical powder/liquid conventional glass ionomers (GI) and resin-modified glass-ionomers (RMGI) has been attributed to the excellent long-term bond strengths and clinical retention. RMGIs have been recently introduced as paste/liquid systems for convenience of clinical usage. The objective of this study was to investigate the long-term bond strengths and mechanism of adhesion of paste-liquid RMGI in order to ascertain whether similar characteristics are retained.

Methods. Long-term shear adhesion to dentin and enamel was measured on two paste-liquid RMGIs and one powder/liquid RMGI. Scanning electron microscopy (SEM), Fourier-transformed infrared spectroscopy (FTIR) and X-ray photoelectron spectroscopy (XPS) analyses were carried out on the paste-liquid RMGI Vitrebond Plus (VBP) and compared with the classical powder/liquid RMGI Vitrebond (VB).

Results. VBP maintains adhesion to dentin and enamel over long times; its long-term adhesive performance is equivalent to VB. FTIR data confirm that VBP exhibits the carboxylate crosslinking reaction of a true glass ionomer. SEM images show evidence of micromechanical bonding at the interface between VBP and the tooth. XPS and FTIR data show that the methacrylated copolyalkenoic acid component present in VB and VBP chemically bonds to the calcium in HAP.

Significance. The new paste-liquid RMGI liner, VBP, shows equivalent adhesion to its powder-liquid predecessor, VB. The adhesion mechanism was attributed to micromechanical and chemical bonding. This chemical bond is a significant factor in the excellent long-term adhesion of these materials.

1. Introduction

Several studies have shown that resin-modified glass-ionomer (RMGI) based materials exhibit superior and more predictable adhesion to tooth structure in comparison to other adhesive strategies (e.g. etch-and-rinse adhesives with three or two steps; self-etch adhesives with two or one steps) although their *in vitro* measured bond strengths may be lower than pure resin-based adhesives [1–4]. This is especially significant since in recent years much attention has been given to the

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technique-sensitivity of resin-based adhesives due to its influence on bond performance [2–4]. The self-etching approach has emerged as one of the main attempts to control the operator's influence [5]; it has been suggested that an additional prior conditioning step be used with self-etch resin-based adhesives to enamel [6] in order to obtain the same level of performance as conventional total-etch 3-step adhesives. On the other hand, glass ionomers have been recognized as self-adhesive materials for quite some time [7,8] due to chemical interactions of polyalkenoic acids with hydroxyapatite (HAP). Although it has been recognized that multiple bonding mechanisms exhibited by these materials may be responsible for the enhanced durability of these bonds, the adhesion mechanism of RMGI materials has not been completely elucidated. The chemical bonding of RMGI to HAP crystals in enamel and dentin has been demonstrated by X-ray photoelectron spectroscopy (XPS) [9], while the ability of these materials to bond micromechanically and form hybrid layers was demonstrated by confocal microscopy studies [10]. In addition the RMGI materials were found to be more tolerant to moisture contamination and provided a good seal to dentin under a broader range of conditions [11]. The stability of the RMGI/dentin bond under hydrostatic pressure was found to be superior to some resin adhesives in a study reported by Prati et al. [12]. One of the main reasons for the adoption of RMGI liners in clinical practice is the minimal incidence of post-operative sensitivity reported with these materials [13–18]. This is due to two features: first, these materials are self-adhesive and do not require the removal of dentinal smear layer prior to placement; second, the materials can act as a buffer against polymerization shrinkage stress of composites [19,20]. The combination of predictable bonding with the protection of high fluoride release [21–23], and minimal postoperative sensitivity make these materials attractive for use in long-term adhesive restorations.

The published studies have been conducted with RMGI materials that were available in powder-liquid formats. More recently paste-liquid versions RMGI liners have become available commercially supplied in convenient dual barrel delivery devices. However, not much information is available in the literature regarding their performance. In this study the long-term bond strengths of a new paste-liquid glass ionomer liner base (3M ESPE Vitrebond™ Plus Light Cure Glass Ionomer Liner/Base, VBP) were investigated and compared to a paste–paste glass ionomer liner base (GC Fuji™ Lining LC Paste-Pak (FPP) and to an established powder-liquid RMGI liner (3 M ESPE Vitrebond™ Light Cure Glass Ionomer Liner/Base, VB). The adhesion mechanism of VBP to HAP was studied by several techniques. By studying the interaction of the key components in RMGI to pure HAP, the effects of chemical bonding of RMGI to the HAP crystals in enamel and dentin can be isolated via eliminating the many confounding factors and biological variability in tooth structure [24]. The adhesion mechanism of VBP to HAP was evaluated by analyzing the reaction of the methacrylated copolyalkenoic acid component in VBP with HAP via FTIR and XPS; the interfacial microstructure was characterized via scanning electron microscopy (SEM).

2. Materials and methods

2.1. *Long-term shear adhesion test of RMGI liners to dentin and enamel*

Three RMGI liners were used in the long-term bond strength study. These are shown in Table 1 together with the manufacturers and batch numbers used. Extracted bovine teeth were mounted in epoxy, ground with 120 and 320 grit abrasive paper to expose either the dentin or the enamel. A spacer tape of thickness 0.3 mm and a central opening of 5.0 mm diameter was placed on the polished dentin or enamel surface. The RMGIs were dispensed according to the manufacturers' instructions and hand spatulated to form uniform mix. The mixed liners were transferred to the 5.0 mm diameter opening to ensure a reproducible uniform layer of the mixed RMGI on the tooth surface. The liner materials were then light-cured according to the manufacturers' instructions. Adper™ Single Bond Plus was applied on the liner, light-cured for 10 s following which the spacer was removed. Using a Teflon® mold as a template Filtek Z250 composite was placed on the cured liner-adhesive surface to form a cylinder 5 mm in diameter and 2 mm in height. The cured assembly was placed in distilled water and stored at 37 °C. Samples were removed at intervals of 24 h, 1 month, 3 months and 6 months. A sample size of 5 was used for each group. The Teflon molds were removed and adhesion strength measured using an Instron® Universal testing machine in the shear mode using a wire loop at a cross head speed of 1 mm/min. The data were analyzed via one-way ANOVA and compared with Tukey's *t*-test at $p = 0.05$.

2.2. *SEM of liner–dentin interface*

Two rectangular cavities (*ca.* 3 mm × 4 mm × 1.5 mm) were prepared side-by-side on the buccal surface of a three extracted human permanent molars. The occlusal margin was in

Table 1 – Glass-ionomer liners investigated.

Materials	Manufacturer	Type	Batch no.
Vitrebond™ Plus (VBP)	3M ESPE	Paste/liquid Hand mixed	L113
Vitrebond™ (VB)	3M ESPE	Powder/liquid Hand mixed	Powder: 5HB Liquid: 4FB
Fuji™ Lining LC Paste-Pak (FPP)	GC Dental	Paste/paste Hand mixed	0505101