Effect of different curing protocols of various dual-cure one-step self-etching adhesives on shear bond strength to dentin

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INTRODUCTION

Advances in dental adhesive technology have extensively influenced modern restorative dentistry. The rapidly rising demand for simplification resulted in development of one-step (all-in-one) self-etching adhesives that combine all the bonding procedures in a single step.(1) All-in-one self-etching adhesives gained their appeal among other adhesive systems because of their user-friendliness, reduced application time(2,3) and less incidence of post-operative sensitivity.(4) They chiefly rely on acidic monomers that simultaneously demineralize and infiltrate into the tooth substrate, eliminating the need of a separate etching step, hence forming a strong micromechanical bond.(5,6)

From a clinical perspective, it is generally accepted that the adhesive material should be preferably light activated before the application of the composite,(7,8) to obtain a proper degree of conversion and good mechanical strength of the adhesive layer.(9-11) A low degree of conversion of the adhesive layer may result in unpolymerized, potentially leachable monomers,(12) which act as plasticizers(13) deteriorating the mechanical properties of the adhesives(9,10) and subsequently compromising bond strength values.(14) One of the main factors influencing light intensity is the distance of the light guide tip from the surface of the resin to be exposed.(15) Clinically, placing the light tip in close vicinity of the resin surface is often difficult to achieve. So, it can be expected that the power density of the light would decline by increasing the distance of the light source.(16)

Self-cure composites, as core foundation materials and resin cements, are still frequently used in dental practice especially in areas not readily accessible to light.(17) However, an incompatibility between self-etching adhesives and self-/dual-cure composites has been reported.(18-20) The presence of unreacted acidic monomers in the oxygen-inhibited layer has been found to inactivate the tertiary amines of these resin composites, so adversely affecting the bonding complex.(16,19)

In response to the issues raised, dual-cure adhesives have been developed in attempt to compensate for such situations where light exposure is ultimately compromised. They have been traditionally recommended to be used in association with dual- or self-cure core build-up resin composites, or when bonding fiber posts and indirect coronal restorations. There is also a general trend toward application of the dual-cure adhesives in the self-cure mode, mainly when used with dual- or self-cure resin cements.(21,22) In this context, ternary catalysts or chemical co-initiators have been included in these adhesive systems in order to overcome the inevitable drawbacks of the dark cure.(23-25)

On the basis of these considerations, studying the effect of different curing protocols of dual-cure self-etching adhesives on bonding performance of self-cure resin composite to dentin might be of great value.

REVIEW OF LITERATURE

Nowadays, the so-called ‘extension for prevention’ concept adopted by GV Black(26) in 1917 has been reappraised and replaced by the modern approach of ‘minimally-invasive dentistry’.(27) This approach is solidly based on the achievement of a more conservative cavity design to preserve the health of the tooth over a lifetime.(28) The succeeding emergence of adhesive restorative materials placed less reliance on macro-mechanical retention.(29) Bonding agents are adjunctively paired with resin composites in attempt to seal the interface between the cavity and the restorative material, thus reducing the risk of interfacial gap formation, marginal leakage, postoperative sensitivity, and recurrent caries.(30) Hence, a strong and durable adhesion to tooth substrate is required for clinical long-term success of resin-bonded direct and indirect restorations.(30)

The fundamental mechanism of bonding to tooth substrate is based on an exchange process. Inorganic minerals —calcium phosphates— are removed from the dental hard tissues, creating microporosities which will subsequently allow the penetration of resin monomers to form resin tags that provide micromechanical interlocking upon polymerization.(31,32) In 1955, the introduction of acid etching by Buonocore(33) was a major breakthrough in adhesive dentistry. He was the first to demonstrate that the application of a weak acid could alter the enamel surface and increase its microscopic surface area through selective dissolution of the enamel rods, thereby creating micropores that would be readily infiltrated by a hydrophobic bonding agent.(34) This new structure was a hybridization of both enamel and resin(35) that is still proven to provide the best achievable bond to the dental substrate.(31) In 1982, Nakabayashi, et al.(36) proposed that the formation of a hybrid layer is the main bonding mechanism of dentin bonding agents. They showed that resin could infiltrate into acid-etched dentin to form a structure comprised of a resin matrix reinforced by collagen fibers.(36)

Despite the reliability of adhesion to enamel, bonding to dentin has been considered far more intricate and less predictable. Enamel is almost homogenous in structure, consisting of 95% mineral by weight. In contrast, dentin is morphologically heterogeneous; containing 70% mineralized structure by weight and a relatively high organic content.(32) Numerous fluid-filled tubules radiate from the pulp throughout the dentin thickness, which render the exposed dentin surface naturally moist and thus intrinsically hydrophilic.(37) This hydrophilic nature definitely represents one of the main issues restricting the interaction of different adhesive systems to dentin. The presence of tenacious smear layer and smear plugs retained on instrumented dentin surface and obstructing the dentinal tubules is also a critical factor that should not be overlooked.(38)

Contemporary adhesive systems can be classified according to the adhesive strategy employed into ‘etch-and-rinse’, ‘self-etching’ (or etch-and-dry) or ‘glass ionomer’ adhesives.(1,39) Up to the present time, the multi-step etch-and-rinse dental adhesives can be deemed as the ‘gold-standard’ adhesive systems.(28) However, this multi-step technique is extremely technique-sensitive with the minor error in the application procedure would provoke early marginal degradation or even premature debonding.(5)

SELF-ETCHING ADHESIVES (SEAs)

The market-driven demand for simplified adhesive procedures has urged the manufacturers to introduce the ‘self-etching’ adhesive system as an alternative to the etch-and-rinse approach. In the past years, self-etching adhesives have been steadily growing in popularity in dental practices.(5) They offer many favorable features over their predecessors. Regarding time-saving and user-friendliness, this approach seems clinically most promising.(2,3) It is based on the use of non-rinse acidic monomers that simultaneously etch and prime dentin, hence eliminating the rinsing phase.(5,6) It also reduces the technique sensitivity associated with the conventional etch-and-rinse adhesives.(30) By the omission of the separate etching step, the risk of over-etching is minimized, as these acidic monomers do not etch very far into the dentin beneath the smear layer, which theoretically ensures good resin infiltration.(5,40) The self-etching system provides fewer procedural steps which may translate into fewer operator errors during application and manipulation.(1) Another important clinical benefit of self-etch adhesives is the lower incidence of post-operative sensitivity experienced by patients.(41,42) To a great extent, this could be attributed to the preservation of smear plugs, owing to their less aggressiveness compared to phosphoric-acid etching; thus limiting fluid movement within dentinal tubules.(5)

The morphological features of the adhesive/tooth interface produced by self-etching adhesives partly depend on their pH or their demineralization intensity.(5) Following De Munck's classification,(43) the interaction depth may differ from: (i) a few hundreds of nanometers following an ‘ultra-mild’ self etch approach ($pH > 2.5$), which is referred to as ‘nano-interaction’,(44) (ii) an interaction depth of around 1 um for a ‘mild’ self-etch approach ($pH \approx 2$), (iii) an interaction depth of 1-2 um for an ‘intermediately strong’ self-etch approach (pH= 1-2), and (iv) to an interaction of several micrometers deep for a ‘strong’ self-etch approach ($pH \leq 1$).

Besides micro-mechanical hybridization, the residual hydroxyapatite may serve as a receptor for chemical interaction with carboxyl/phosphate groups of the functional monomers.(45,46) So, the bonding performance attained by self-etch adhesives does not only depend on the actual class of self-etch adhesives, but also on the composition and particularly on the