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ADHESIVES IN DENTISTRY: PRESENT AND FUTURE; A LITERATURE REVIEW

Dentistry

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ABSTRACT

One of the challenges in restorative dentistry is to achieve an effective seal of the tooth-restoration interface. Advances in adhesive dentistry have steadily progressed over the past five decades. This article summarizes present status, and future of adhesive dentistry.

KEYWORDS

Dental Adhesive, Generations, Self – Etch, Universal Adhesives

INTRODUCTION

Adhesion has reformed restorative dentistry with many revolutionary researches like: dental surface modification by acid etching, development of methacrylate-based resin composite and hydrophilic resin chemistry. Today, adhesives are integral to many dental procedures like direct composites restorations, sealant placement, bonding of orthodontic brackets, intraradicular post, onlay, inlay, full-coverage all-ceramic crowns, bonded bridges cementation and root canal obturation.[1]

ADHESIVES; PRESENT

A dental adhesive should provide a high bond strength to enamel and dentin , provide an immediate bond and durable bond, prevent microleakage and decreasing the risk for post operative sensitivity, marginal staining and secondary caries.

Dentin bonding agents have evolved through different generations during the past few decades. Dentin bonding agents have been categorized into generations of products based on chemistry and the manner in which they treat the smear layer.

The Seventh-generation adhesives consists of single-component, one-step self-etch (SE) adhesives, or "all in one" adhesives combine conditioner, primer and adhesive resin. As a consequence, these adhesives are intricate mixes of hydrophilic and hydrophobic components. They have been made available since 2005.So far, a number of shortcomings of the seventh-generation adhesives have been documented but to the complex nature of the mixed solutions, they have attained consistently lower bond strengths than the fourth- and fifth generation adhesives.[2]

Self-etch adhesives can be further subdivided into 'Strong' (pH<1), 'Intermediary strong' (pH=1-2), 'Mild' (pH≈2) and 'Ultra -mild' (pH>2.5) self-etch adhesives.[2]

Strong self - etch adhesives failed on dentin as (1) collagen within the 3-4 µm was no longer supported by mineral, (2) no chemical bonding was involved, (3) the infiltrated resin did not adequately polymerize and remained highly hydrophilic, and (4) calcium phosphates embedded in the relatively deeply exposed collagen-fibril network were not hydrolytically stable, which destabilized the adhesive interface with time.[3]

The most favorable bonding performance to dentin was obtained with "Mild" self - etch adhesives that combine micromechanical interlocking with chemical bonding. A major drawback, remains the inferior bonding effectiveness of mild and especially ultra-mild SE adhesives to enamel.[4] This should most likely be attributed to a combination of factors, ie, (1) 6 lower micromechanical interlocking potential achieved by the lower etching effect of the acidic functional monomers contained in (ultra)mild self-etch adhesives; (2) the lower chemical reactivity of functional monomers (also lower 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP) nanolayering) with enamel hydroxyapatite crystals; (3) which are larger with (4) a higher crystallinity than dentinal hydroxyapatite crystals, making the targeted Calcium more difficult to reach; and finally (5) the parallel crystal organization in enamel rods as compared to the crisscross hydroxyapatite orientation in dentin, making Calcium easier to reach and interact with in dentin.[5]

Nevertheless, this drawback can clinically be compensated by selectively pre-etching enamel with phosphoric acid, then applying SE adhesive on the pre- etched enamel and unetched dentin. Thus, an etch and rinse procedure – so- called Selective enamel etching, a clinically popular combined E&R / SE bonding routine has resulted.[5]

Less common are "intermediary strong" SE adhesives that were developed as a compromise to bond more effectively to enamel through stronger etching, while not losing the chemical bonding potential to dentin. Two of the most successful adhesives in this class are the 1-SEa G-Bond (GC) that combines the functional monomers 10-DMP and 4-methacryloyloxyethyl trimellitic acid (4-MET) and the GPDM-based 2-SEa Optibond XTR (Kerr), for both of which good laboratory and clinical data have been published.[6]

The newest eighth-generation adhesives are universal adhesives (UAs) since 2011, combine the primer with the adhesive resin[7] that can be applied according to the dentist's personal choice in both full E&R or SE bonding modes, or the combined mode involving selective enamel E&R with a 1-SE bonding mode. They are offering application versatility with (claimed) bonding potential to glass-rich (via silane) and glass-poor zirconia (via 10-MDP) ceramics for indirect tooth-restorations.[8]

The universal SE bonding mode involves the use of monomers with an acidic functional (phosphate, carboxylate) group that in principle simultaneously etches (demineralizes) and infiltrates dentin up to about a 1-µm depth. In general, the SE bonding mode underperforms the E&R bonding mode on enamel, by which enamel remains to be selectively etched with phosphoric acid. SE bonding nevertheless possesses chemical bonding potential as an additional benefit to achieve durable bonding, which depends on the functional monomer contained. 10-MDP is the most effective monomer today; it is uniquely bi functional with a chemical bonding and polymerizing group at both monomer ends separated by a long hydrophobic spacer. 10-MDP (1) etches, thus releasing Calcium from dentin, (2) ionically bonds to hydroxyapatite's Calcium, and (3) self-assembles into stable nanolayered Calcium salts that spread three-dimensionally at the adhesive interface. 10-MDP's favorable bonding properties inspired most dental manufacturers to fabricate 10-MDP-based UAs.[5]

In terms of immediate performance (restoration retention, marginal sealing), many currently commercially available adhesives are clinically effective, although some product-dependency exists. However, the long-term bonding performance of this generation, in particular to dentin, is still insufficiently proven, and have already been associated with several shortcomings.[9]

First, their low film thickness, often below 10 µm, enables oxygen to inhibit polymerization for a significant fraction of its depth. Suboptimal polymerization insufficiently stabilizes the adhesive interface and may promote water sorption from the underlying dentin by osmosis. The thin adhesive layer is also thought to reduce the adhesive layer's ability to absorb stress (polymerization shrinkage) imposed onto the adhesive interface. Second, many UAs contain the mono-functional monomer (2-Hydroxyethyl methacrylate). HEMA makes the adhesive interface prone to hydrolytic degradation.

A third reason for potentially compromised bonding performance of UAs is related to the incorporated silane to chemically bond to glass-rich ceramics, by avoiding the need for a separate ceramic (silane) primer.[8] These UAs cannot be very acidic (pH>2.5), so as to ensure silane's stability in the acidic aqueous solution; a higher pH however decreases UAs' etching and thus bonding efficacy. Finally, although the 10-MDP is ionically bonds to hydroxyapatite, resulting in stable monomer-Calcium salt nanolayering, 10-MDP's esters, linking the hydrophobic spacer to the methacrylate and phosphate functional groups at both monomers ends, are sensitive to hydrolytic degradation.[5] Although most UAs contain 10-MDP, differences in performance among 10-MDP-based UAs may still exist, as the 10- MDP concentration and quality (purity) have been shown to significantly affect bonding effectiveness.[10]

Strategies to potentially improve Etch & Rinse and/or SE bonding in recent literature [5]

Insufficiently effective

1. Bonding following non-thermal atmospheric plasma treatment for both E&R and/or SE bonding.

Effective but impractical

2. Biomimetic repair of E&R hybrid layers by Remineralization for E&R bonding.
3. Ethanol wet bonding to improve resin infiltration/ interdiffusion for E&R bonding.

Bond degradation retarding

4.Inhibition of enzymatic bio- degradation for E&R adhesives in particular.

5.Biomodification of dentin by collagen cross-linking for E&R adhesives in particular.

Bond degradation retarding and practical

6. Effective polymerization conversion of adhesives for both E&R and/or SE bonding.
7. Extra hydrophobic resin sealing.
8. Primary ionic binding of the functional monomer with hydroxyapatite along with stable monomer Ca salt nanolayering for SE bonding.

Self- adhesive restorative materials

Self- adhesive restorative materials that no longer need a separate pre-application of an adhesive. Self- adhesive flowable composites were first developed. While the first self-adhering restorative composites were marketed several years ago, their documented inferior performance, both in laboratory and clinical research[11] did not lead to a true breakthrough.

ADHESIVES; FUTURE

Along with absence of anti-bacterial properties, lack of acid buffering may account for the higher susceptibility secondary caries around composite restorations, to prevent this adhesives and composites that contain anti-bacterial agents were developed.[12] For example, the anti-microbial monomer 12-methacryloyloxydodecyl pyridinium bromide (MDPB) was added to the commercial adhesive Clearfil SE Protect (Kuraray Noritake). Many in vitro studies have confirmed the contact anti-bacterial effect of MDPB, however the clinical suppression of secondary caries has so far not been proven.[5]

Besides quaternary ammonium methacrylate compounds immobilized into dental adhesives and composites without release potential, other anti-bacterial releasing agents like chlorhexidine and nano-silver particles have been investigated for their anti-caries properties, but they appeared less effective due to an uncontrolled, short-live burst release.[13]

Cetylpyridinium chloride (CPC) is a highly effective broad-spectrum anti-bacterial agent, and when incorporated into bonding resin, the anti-bacterial effect appeared to be confined to the area directly contacting the resin.Besides CPC release, this CPC - Mont technology is considered to have CPC rechargeability. A recent study demonstrated that adding 1 or 3wt% CPC - Mont into a 1-step SEa conferred anti-bacterial properties to the adhesive without reducing its bonding potential or increasing its cytotoxicity.[14]

CONCLUSION

Adhesive techniques, technologies, and clinical concepts are constantly being updated and improved, shaping the future of the dentistry. It is fair to say that the search for the “ideal” dental adhesive system is ongoing.

Based on the current literature, an adhesive should:

1) minimize phosphoric acid pretreatment of dentin and only require selective etching of enamel;
2) be a mild self-etch with a universal adhesive monomer such as MDP;
3) be solvent free;
and
4) have antibacterial properties.

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