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Current Concept in Adhesive Dentistry (Review Article)

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Abstract

Adhesive dentistry is based on the development of materials which establish an effective bond with the tooth tissues. In this context, adhesive systems have attracted considerable research interest in recent years. Successful adhesive bonding depends on the chemistry of the adhesive, on appropriate clinical handling of the material as well as on the knowledge of the morphological changes caused on dental tissue by different bonding procedures..

Introduction

Adhesion is the procedure of forming an adhesive joint. The initial substrate is termed adhered and the material producing the interface is termed the adhesive. The functions of dental adhesives is to promote conservation of tooth structure and enable minimally invasive dentistry, reinforcement of weakened dentin or enamel, reduce marginal staining, reduce micro leakage and may also reduce postoperative sensitivity when used appropriately.[1] The adhesive system should be non-toxic, provide adequate bond strength, resist wear, water sorption, provide sufficient wetting capacity and color stability.[2] The ultimate goal of a bonded restoration is to attain an intimate adaptation of the restorative material with the dental substrate. This task is difficult to achieve as the bonding process for enamel is different from that for dentin. That is, dentin is much humid and more organic content than enamel. This humid and organic nature of dentin makes bonding extremely difficult.[3] The purpose of this article is to review the main concepts regarding various adhesive systems.

Steps for good adhesion [3, 4]

1 Substrate surface should be cleaned. Once the surface is clean, its surface energy is high and it is more likely to adsorb material from environment such as moisture or saliva. Therefore surface must be protected and next step in bonding procedure should be proceeded.
2 Good wetting of adhesive to substrate by removal of smear layer to decrease the contact angle and increase their spread onto the surface.
3 Highly adaptation to substrate produces intimate approximation of the material to avoid air entrapment or other materials.
4 Intimate contact of adhesive to the substrate produces physical, chemical or mechanical bonding. For effective chemical bonding, distance between the adhesive and substrate must be less and a high density of new bonds must form along the interface. Because this is rarely seen, bonding of restorative materials involves mechanical bonding. Mechanical bonds (gross mechanical retention and micro mechanical retention) involve adhesive interlocking with surface irregularities
5 The adhesive be well cured under optional conditions.

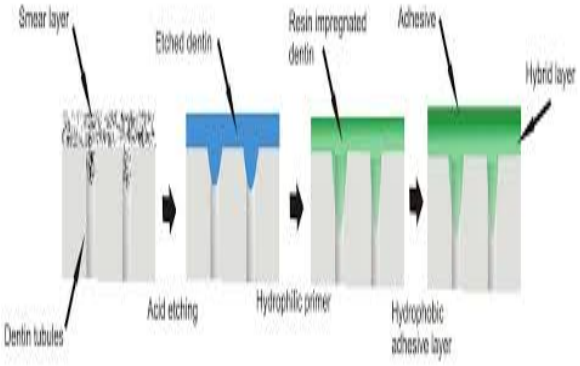
Application of bonding system

The bonding systems have a valuable application in dentistry such as: sealant, enamel and dentin bonding system, amalgam bonding system, resin-composite cement, crown and bridge cement and orthodontic bonding system [5].

Principles of adhesion

Bonding of resins to tooth structure is a result of four potential mechanisms [4, 5]

a) Mechanical-penetration of resin and creation of resin tags within the tooth surface.
b) Diffusion-precipitation of substances onto the tooth surfaces to which resin monomers can bond mechanically or chemically.
c) Adsorption-chemical bonding to the inorganic component (hydroxyapatite) or organic components (mainly Type I collagen) of tooth structure.
d) A combination of the previous three mechanisms usually responsible for bonding with modern adhesives.



Universal Adhesive System

One of the foremost recent novelties, in adhesive dentistry, was the introduction of universal adhesive that are used since 2011 in clinical practice. These new products are referred to as "multi-mode" or "multi-purpose" adhesives because they'll be used as self-etch (SE) adhesives, etch-and-rinse (ER) adhesives, or as SE adhesives on dentin and ER adhesives on enamel (a technique commonly mentioned as "selective enamel etching").[6] This versatile new adhesion philosophy advocates the utilization of the only option of every strategy, that is, onestep self-etch (SE) or two-step etch-and-rinse (ER) , using an equivalent single bottle of adhesive solution which is definitely far more challenging to dental substrates of various natures (i.e., sound, carious, sclerotic dentin, also as enamel. Beforehand etching enamel with orthophosphoric acid is usually recommended, especially when bonding to unground enamel. Indeed, the priming and bonding components are often separated or combined, leading to three steps or two steps for etch-and-rinse systems, and two steps or one step for self-etch adhesives. Contemplating these two bonding strategies, adequate bonding to dentin are often completely achieved with either etch-and-rinse or self-etch adhesives; however, at enamel, the etch-and-rinse approach using phosphoric acid remains the well-liked choice. In reference to the appliance mode, self-etch adhesive systems reduce the likelihood of iatrogenic induced clinical mis-manipulation during acid conditioning, rinsing and drying, which can occur when etch-and-rinse systems are used. On the opposite hand, some drawbacks could also be listed for these SE materials. Unfortunately, one among the most drawbacks from applying SE adhesives to dentin and enamel is their inability to etch enamel to an equivalent depth that phosphoric acid does, which is probably going liable for the upper rates of marginal discoloration within the enamel margins of cervical restoration thanks to their lower acidity. Thereby the degradation of SE was attributed to its acidic content, which increases the hydrophilicity of the adhesive layer and results in water uptake and plasticization. Therefore the long-term performance of simplified one-step adhesives is inferior in terms of bond durability, especially in comparison to the gold-standard three-step etch-and-rinse approach. to beat the weakness of previous generations of single-step self-etch adhesives, universal adhesives are developed that leave application of the adhesive with orthophosphoric acid pre-etching within the total etch or selective-etch approaches so as to realize a durable bond to enamel and has been accepted by showing good leads to vitro and in vivo studies Despite the similarities between adhesives, the composition of universal adhesive differs from the present SE systems by the incorporation of monomers that are capable of manufacturing chemical and micromechanical bond adhesion to the dental substrates. [6,7] Its composition is a crucial factor to be taken account, since most of those adhesive contain specific carboxylate and/or phosphate monomers that bond ionically to calcium found in hydroxyapatite (Ca10[PO4]6[OH]2).That could be influence the bonding effectiveness.For example, MethacryloyloxydecylDihydrogen phosphate (MDP) may be a functional monomer found in certain new adhesives, but not for older-generation bonding agents. This is often a hydrophilic monomer with mild-etching properties. MDP is one among the monomers that enable a universal adhesive to be used with any etching techniques. Stable MDP-calcium salts are formed during this reaction and deposited in self-assembled nano-layers of varying degrees and quality counting on the adhesive system. It also helps promote strong adhesion to the tooth surface via formation of non-soluble Ca2 salts. Furthermore, it contains biphenyl dimethacrylate (BPDM), dipentaerythritolpentaacrylate phosphoric acid ester (PENTA) and polyalkenoic acid copolymer may enhance adhesion to tooth structures and are a part of the composition of various materials for many years. this might be important in terms of durability, as water sorption and hydrolytic breakdown of the adhesive interface over time has been implicated together of the first causes of bond failure. Additionally, the matrix of universal is predicated on a mixture of monomers of hydrophilic (hydroxyethul methacrylate /HEMA) hydrophobic (decandioldimethacrylite /D3MA) and intermediate (bis-GMA) nature. this mix of properties allows universal adhesives to make a bridge over the gap between the hydrophilic tooth substrate and hydrophobic resin restorative, under a spread of surface conditions. Moreover, some universal adhesives may contain silane in their formulation,

potentially eliminating the silanization step when bonding to glass ceramics or resin composites, as an example .Nevertheless, it's known that simplified materials are related to lower in vitro bond strength result and poorer in vivo longevity of restorations. These findings are probably results of the complex formulation of simplified adhesives and their high content of solvents, which can impair complete solvent volatilization and consequently cause poorer adhesive polymerization. This multi-approach capability enables the clinician to use the adhesive with the so-called selective enamel etching technique that mixes the benefits of the etch-and-rinse technique on enamel, with the simplified self-etch approach on dentine with additional chemical bonding on remnant carbonated apatite crystallites in those bonding substrates. Therefore, the universal adhesives have much broader applications than 7thgeneration systems. Additionally, manufacturers typically state that universal adhesives are often used for the location of both direct and indirect restorations and are compatible with self-cure, light-cure and dual-cure resin-based cements and bonds to metals, zirconia, and porcelain and composite. While, the manufacturers of some universal adhesives still recommend the utilization of separate “activator” and dedicated primers to optimize bond strength to substrate like porcelain and zirconia. Thus, it appears , a minimum of in certain situations and with some products, that universal adhesive actually contains two bottles, or require the utilization of a further activator, or have chemistries that has got to be mixed before use, or bond most optimally to porcelain and zirconia with separately applied and dedicated primers, or aren't compatible with a total-etch protocol Further, there's a plus in having an adhesive which will operate these two procedures since it allows the dentist to settle on his procedure consistent with the clinical case so as to optimize the final result.For instance, when the restoration requires strong bonding to enamel or in case of sclerotic dentin, it may be advisable to apply prior etching. The etching step can be modulated according to the length of time the phosphoric acid gel is applied prior to rinsing. On the other hand, it may be preferable to benefit completely from the self-etch path way, when dealing with cases confronting difficult access, limited time or poor patient compliance in very young patients.[8]

Bonding strategy	Adhesive system name	Manufacturer
Three-step-etch-and-rinse adhesive systems - Acid etching with (usually) 37 % phosphoric acid - Rinsing; drying, with surface left slightly moist (shiny) - Application of primer - Evaporation of solvent - Application of adhesive resin - Air-thinning of adhesive resin - Light curing	Adper Scotchbond Multi-Purpose	3M ESPE, Seefeld, Germany
	All Bond 2/ All Bond 3	Bisco Inc., Schaumburg, IL, USA
	ProBond	Dentsply, Konstanz, Germany
	OptiBond/Optibond FL	Kerr, Orange, CA, USA
	Gluma Solid Bond	Heraeus Kulzer, Hanau, Germany
	Solobond Plus	VOCO, Cuxhaven, Germany
	Syntac	Ivoclar Vivadent, Schaan, Liechtenstein
	Clearfil Liner Bond	Kuraray Medical Inc., Tokyo, Japan
Two-step etch-and-rinse adhesive systems - Acid etching with (usually) 37 % phosphoric acid - Rinsing; drying, with surface left slightly moist (shiny) - Application of primer/adhesive resin - Evaporation of solvent - Light curing	Adper Scothcbond 1XT (Single Bond Plus)	3M ESPE
	One Step/ One Step Plus	Bisco
	Optibond Solo Plus/ Optibond Solo Plus Dual Cure	Kerr
	Gluma Comfort Bond	Heraeus Kulzer
	Prime and Bond NT/ Prime and Bond NT dual cure	Dentsply
	Solobond M	VOCO
	Clearfil New Bond	Kuraray
	HelioBond	Ivoclar
	Superbond C&B	Sun Medical Co., Shiga, Japan
Two-step self-etch adhesive systems - Application of an acidic primer - Evaporation of solvent	Adper Scothbond SE	3M ESPE
	All Bond SE	Bisco

- Application of adhesive resin - Evaporation of solvent - Light curing	OptiBond Solo Plus self-etch	Kerr
	Clearfil SE Bond/ Clearfil Protect Bond Clearfil Liner Bond 2	Kuraray
	Peak Self-etch	Ultradent Products, Inc., Salt Lake City, UT, USA
One-step self-etch adhesive systems - Application of the acidic/primer adhesive resin - Evaporation of solvent - Light curing	Adper EASY Bond/ Adper Prompt L-Pop	3M ESPE
	Adhe SE One	Ivoclar Vivadent
	Optibond All-in-one	Kerr
	FuturaBond NR	VOCO
	iBond	Heraeus Kulzer
	Xeno V	Dentsply
	Clearfil S3Bond	Kuraray

Table 1. Examples of currently available etch-and-rinse and self-etch adhesive systems. The bonding strategies are described on a general level, and differences may occur e.g. in the number of recommended applications of primer and/or adhesive resin.

Newly introduced components of dental adhesive:[9]

MDPB [e.g. Adper prompt L POP] MDPBis a singular monomer that was developed to supply resin-based materials with long-lasting antibacterial activity without releasing the antibacterial agent. After curing, MDPB is covalently bonded to the polymer network and acts as a contact inhibitor against the bacteria that comes in direct contact with the polymer.

Meth acrylamides (e.g. AdheSE): Meth acrylamides have an amide (–CO–NH– or –CO–N–) group rather than an ester group (– CO–O–R–) as in conventional acrylates and methacrylates, which promotes the formation of hydrogen bonds between the carboxyl and amide groups of the monomer with the carboxyl groups of collagen.[6]

Nano filled bonding agent (e.g. Nano-Bond) Nano-composites and nano-adhesives are one among the best contributions of nano dentistry which contain nano-sized fillers, which characterized by stable nano-filler which will not settle out of dispersion. Nano-particles prevent agglomeration thus producing high dentin and enamel bond strength, high stress absorption, longer time period, durable marginal seal, produce a low film thickness, show better penetration in dentine aside from generation.

PEM-F (e.g. Xeno IV) may be a monomer with a grafted fluoride functional group. The rationale for this monomer is that the release of fluoride upon admixture with water, which can scavenge calcium so as to accentuate the demineralization reaction.

NMSA (e.g. Clearfil Liner Bond) features a salicylic group that's intended to chelate with calcium so as to get a desensitizing effect.

Materials with adhesive properties

Restorative materials

• Glass ionomer or resin-modified glass ionomer bonds to tooth structure through a selected reaction combined with submicron hybridization.[10] Glass ionomers are acid-base reaction cements containing a reactive ion-leachable glass base and an solution of polyalkenoic acid, usually polyacrylic acid. to enhance the properties, resin-modified glass ionomers were developed with the addition of resin components into glass ionomer cements. Bonding of glass ionomer to tooth structure is especially supported the chemical bonding through natural process, and therefore the resin-modified version offers a further micromechanical interlocking of the cement into dentin tubules. The adhesion depends both on a limited demineralization of enamel and dentin by polyalkenoic acid and infiltration, and on chemical adhesion between hydroxyapatite calcium and polyalkenoic acid. This leads to a shallow hybrid layer formation (0.5-1µm). 7The application of polyacrylic acid as a cavity conditioner improves the bonding through smear layer removal, demineralization of the tooth structure and also by chemical bonding with residual hydroxyapatite. the discharge , uptake and rerelease of fluoride are

thought to be important caries protective properties of glass-ionomers by preventing demineralization and in assisting remineralisation. So far, studies have shown over 90 retentiveness rates for up to 5 years in non-carious cervical restorations, and over 75 % survival even in load-bearing class II cavities.

• Luting cements

Recently introduced luting cements with adhesive properties are considered as "self-adhesive materials". Self-adhesive luting cements are relatively new and knowledge on their compositions and adhesive properties are limited. they need multifunctional monomers and phosphoric acid groups to realize a simultaneous demineralization and infiltration of dentin and enamel. The reactions, (similar to those in glass-ionomer cements), of phosphoric acid with alkaline fillers end in a setting material. However, interaction with dentin is superficial and no hybrid layer formation is observed. While adhesion to dentin seems still acceptable, enamel adhesion seems to be the much less than within the conventional systems.

• Degradation of resin bond to dentin

The limited durability of resin-dentin bonds is caused partially by hydrolysis of the hydrophilic resin components as a result of water sorption and swelling, and possible esterase attacks from saliva, and partly by the degradation of exposed collagen fibrils by endogenous matrix metalloproteinase's (MMPs) derived from demineralised dentin. MMPs are a group of enzymes that collectively are ready to degrade extracellular proteins, including collagen, and dentin contains several members of MMP family. They're normally inactive within the mineralized dentin matrix but acid-etching or application of self-etch adhesive systems uncovers and activates MMPs. Both in vitro and in vivo studies have indicated that MMP inhibition within the hybrid layer with chlorhexidine may be a promising approach to enhance the durability of the resin-dentin bond with etch-and-rinse adhesives. However, clinical restoration survival data on the effect of such treatment isn't available. Currently, only limited data is out there on the future effect of CHX, however, studies treating acid-etched dentin for 30-60 sec with 0.2 to 2 chronicles chlorhexidine show around 1.9 amnesia in bond strength compared to five amnesia in no-treatment groups. CHX has also been ready to eliminate the reduction of bond strength in vivo: after 14 months in clinical service, bond strength of CHX-treated composite fillings reduced just one .5 %, while within the control group the reduction was 35 %. While chlorhexidine is already in clinical use, other approaches to inhibit dentinal MMPs have also been studied with promising results.

Clinical recommendations

Bonding to enamel remains best accomplished using the etch-and rinse approach. The in place polymerization of adhesive resins within the etched pits creates a durable micromechanical interlocking. The enamel bond not only effectively seals the restoration margin but also protects the vulnerable dentine bond against degradation. Bonds formed to enamel with etch-and-rinse systems are strong and sturdy because their ability to wet and impregnate etched enamel is efficient. In etch-and-rinse adhesive systems, evaporation of solvents may be a critical step. Ethanol-water based primers applied on blotted dry dentin, followed by proper evaporation of the solvent, could also be the safest approach. Both three-step etch-and-rinse adhesive systems and mild two step self-etch adhesive systems show a clinically reliable bonding to dentin. Generally the clinical performance of three-step etch and-rinse adhesive systems are superior than that of two-step, and two-step self-etch adhesive systems are superior than one-step (all-in-one) self-etch systems. One-step (all-in-one) self-etch adhesive systems show often an inadequate clinical performance.

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