“Bonding”: Foundation of Dentistry

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Abstract:
This review critically examines the clinical performance of various adhesives used in dentistry. An overview of currently available bonding systems is provided, along with categorization of these systems according to their clinical application procedure and their mechanism of adhesion. Bonding agents are most often used to bond restorative material to tooth. They are used as coupling resin sealants to enamel in young patients, as sealing agent on prepared dentinal surfaces or beneath amalgam restorations. Almost all restorative procedures involve a bonding step to ensure longevity of the restoration.

Key words: Alloys, Amalgam, Bonding agents, Ceramic, Fluorosed teeth.

Introduction:

Adhesion to tooth has been a subject of research interest for several decades. Because of poor adhesion of restorative materials to prepared tooth in early times, emphasis was placed on removal of sound tissue by preparing cavity to provide mechanical retention through features such as grooves, undercuts, dovetails etc. There has always been a strong desire to develop a dental adhesive that could provide a bonded and sealed interface. A major advancement in the field of direct adhesion to tissues without unnecessary sound tooth removal occurred with the discovery by Bunocore, that acid etching can significantly enhance bonding of restorations to enamel. However, dentin did not yield comparable results through acid etching technique. Now days, bonding agents are used routinely in various restorative and preventive procedures. Dental bonding is an excellent way to fix cosmetic and structural imperfections in teeth providing a more uniform smile. It is quick, affordable, and relatively painless, conserves tooth structure and is long lasting. This review focuses on science, systems and success of bonding systems for dental substrates and presents several valuable studies that have contributed to understanding of bonding to various substrates.

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Principles of adhesion:

Adhesion or bonding is the process of forming an adhesive joint. The initial substrate is called adherend and the material producing the interface is called the adhesive. The material which promotes adhesion between two different substances, or between material and tooth surface is called bonding agent[1].

Bonding of resins to tooth structure is a result of four possible mechanisms[2]:

1. Mechanical-penetration of resin and formation of resin tags within the tooth surface.

2. Diffusion-precipitation of substances on the tooth surfaces to which resin monomers can bond mechanically or chemically.

3. Adsorption-chemical bonding to the inorganic component (hydroxyapatite) or organic components (mainly Type I collagen) of tooth structure.

4. A combination of the previous three mechanisms

Steps in formation of good adhesion:[2]

1. The surface of the substrate should be clean. 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. The adhesive should wet the substrate well to remove smear layer, have a low contact angle and spread onto the surface.

3. Adaptation to substrate produces intimate approximation of the material without 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 recommended conditions.

Functions of bonding systems

1. Conditioning
2. Priming
3. Bonding

Application of bonding system

Sealant, Enamel bonding system, Dentin bonding system, Amalgam bonding system, Composite cement, Crown and Bridge Cement, Orthodontic bonding system, Maryland bridge cement, Porcelain veneers, PFM repairs.

Sealants:

Pit and fissure sealants are the low viscosity resins that readily penetrate pit and fissures of posterior teeth and seal these areas against oral bacteria and debris, thus preventing caries. Enamel conditioning prior to placement of resinous material remains an important task. To promote sealing capacity dentin bonding agent is applied. Dentin bonding system consists of bifunctional molecules consisting of a methacrylate group that bond to restorative resin by chemical interaction and a functional group that is able to penetrate wet dentin surface.

Askarizaden N, Norouzi N et al (2008) conducted a study on effect of bonding agent on microleakage of sealant following contamination with saliva and concluded that the use of dentin bonding agent between
tooth and fissure sealant can be beneficial for reducing microleakage\textsuperscript{[3]}.

**Enamel bonding system:**

The ability of clinician to bond restorative materials to enamel has been an important achievement of modern dentistry. One of the hallmark characteristics of tooth bonding is the strength with which it adheres to tooth enamel. Bonding to enamel occurs by micromechanical retention after acid etching is used to remove smear layer and preferentially dissolve hydroxyapatite crystals. Then primer and adhesive are flown into the surface irregularities such as prism peripheries and produce resin tags. These tags are called “macrotags” and several smaller tags “microtags”. Microtags contribute to most of micromechanical retention\textsuperscript{[1]}

**Dentin bonding system:**

**Historical development**

**First generation:**

Bunocore et al (1956) demonstrated that use of glycerophosphoric acid dimethacrylate containing resin would bond to acid etched dentin\textsuperscript{[4]}. These bonding agents were designed for ionic bonding to hydroxyapatite or for covalent bonding (hydrogen bonding) to collagen. Bowen RL (1965) addressed this issue using N-phenylglycine glycidyl methacrylate that acted as a primer or adhesion promoter between enamel / dentin and resin materials by chelating with surface calcium\textsuperscript{[5]} . Bond strength of these materials were in the range of 1-3 megapascals. These systems had very poor clinical results.

**Second generation:**

The 2nd generation of dentin adhesives primarily used polymerizable phosphates added to BIS-GMA resins to promote bonding to the calcium in mineralized tooth structure\textsuperscript{[6]} . Eg Clearfil Bond system F (Kuraray, Osaka Japan), Scotch Bond (3M ESPE, St.Paul, Minnesota). Bonding mechanism involves formation of ionic bond between calcium and chlorophosphate groups. In-vivo performance was found to be clinically unacceptable.

Bond strength: 4-6Mpa

**Third generation:**

A newer generation adhesive system have been developed that use a conditioning step on dentin in conjunction with a bonding agent. It includes dentin conditioner, dentin primers, bonding agent. With third generation system, the acid etching of dentin partially removes or modifies smear layer\textsuperscript{[7]} . According to Tao L et al (1988) bonding to smear layer covered dentin was not very successful\textsuperscript{[8]}.

**Fourth generation:**

With the fourth generation bonding system, complete removal of smear layer was achieved. Fusayama T et al (1979) tried to simplify bonding to enamel and dentin by etching them with 40% phosphoric acid\textsuperscript{[9]} . Nakabayashi N et al (1982) reported the formation of hybrid layer from polymerized methacrylate and dentin\textsuperscript{[10]} .

Concept of total etch and moist dentinal bonding are hallmarks of fourth generation materials\textsuperscript{[11, 12]} . Bond strength – 3to 25 MPa

**Fifth generation:**

The fifth generation consists of two different types of adhesive materials:

1. "One-bottle systems", 2. The self-etching primer bonding systems.

One bottle system:

“One bottle” systems combined the primer and adhesives into one solution to be applied after etching enamel and dentin simultaneously with 35 to 37 percent phosphoric acid for 15-20 sec. In this mechanical interlocking with etched dentin occurs by means of resin tags, adhesive
lateral branches and hybrid layer formation and show high bond strength both to enamel and dentin\[13\,14\].

Self etching Primer:

Watanabe I and Nakabayashi N (1993) developed a self etching primer that was an aqueous solution of 20% phenyl-P in 30% HEMA for bonding to enamel and dentin simultaneously\[15\].

**Sixth generation:**

This system eliminates the need for etching with phosphoric acid by use of an acidic primer.

Type I (Self-etching Primer + Adhesive) acidic primer applied to tooth first, followed by adhesive.

Type II (Self-etching Adhesive) Two bottles or unit dose containing acidic primer and adhesive; a drop of each liquid is mixed and applied to the tooth.

**Seventh generation:**

These are self etching adhesives that require no mixing.

**Eighth generation:**

These are dual cured, self etching, nano reinforced, produces bond strength of more than 30 MPa to dentin and enamel with no post operative sensitivity.

Munck JD, Landuyt KV, Peumans M et al (2005) concluded that ethanol based etch and rinse adhesive system remains the gold standard in terms of adhesion durability. Any simplification in clinical procedure results in loss of bonding.

Chopra V, Sharma H (2009) also concluded that multibottle system, sixth generation type - I performed better than single bottle system that is seventh generation system.

Bonding to fluorosed teeth

Fluorosed teeth have an altered structure, composition and appearance. With the increase in severity of fluorosis enamel becomes more porous and sub-surface lesion extends towards the inner enamel. Several studies have shown that composites can be bonded successfully to fluorosed enamel depending on the degree of fluorosis. It is always recommended to grind the enamel before bonding as it is seen that bond strength of composites to ground enamel of teeth with moderate fluorosis is similar to that of normal teeth.

Acid etching is good for enamel bonding but not for dentin bonding in fluorosed teeth. As a consequence a good choice of adhesive, it would be a two-step self etch adhesive with an additional acid etching step for the enamel.

**Amalgam bonding:**

Bonding of amalgam restoration to tooth is still a debatable topic. The use of adhesive systems beneath amalgam restoration reduces or prevents microleakage, makes cavosurface angle less susceptible to demineralization when compared to varnish. There is reduction in sensitivity and more conservative cavity preparation can be achieved when amalgam is bonded to tooth.

Staninec M (1989) showed that retention with amalgam bonding is equal to or superior to traditional means of mechanical retention.

Tig IA, Fodor O, Moldovan M et al (2005) noticed that at higher magnification, teeth restored with unbonded amalgam had more spaces and artifacts at the amalgam-tooth structure interface when compared with those that are filled with bonding agent in case of specimens with bonded amalgam.


Fedorowicz Z et al (2009) concluded that there is no evidence to claim difference in
survival between bonded and non-bonded amalgam.

Murad M (2009) conducted an evidence based study to assess the effectiveness of bonded amalgam. Two review authors screened papers, extracted trial details and concluded that there was lack of evidence on additional benefit of adhesively bonding amalgam compared to nonbonded amalgam.

**Bonding to alloys and ceramics:**

The nature of metal surface required for bonding plays an important role with regard to crown and bridge alloys. In base metal alloys naturally formed oxide layer on the alloy surface is thought to be involved in bonding process and the only preparation required is moderate roughening using sandblasting followed by steam cleaning. This can only be achieved using non-precious metal casting alloys. One final approach that has been developed, involves tribomechanical approach, silica coated corundum particles with a mean particle size of 30 µm are blasted against the surface to be bonded. This results in surface roughening and transfer of silica from surface of corundum to the substrate. This silicatized surface can be treated with silicane coupling agent before bonding with conventional resin composite. This technique can be used for all surfaces from composite resin through ceramics to metal.

**Discussion:**

The development and regular use of adhesive materials has begun to revolutionize many aspects of restorative and preventive dentistry. Attitude towards cavity preparation are altering since, with adhesive material, it is not necessary to produce large undercuts in order to retain the fillings. These techniques are therefore, responsible for conservation of large quantities of sound tooth structure. Microleakage, which is responsible for many cases of secondary caries may be reduced or eliminated. With the sealing effect of bonding systems on prepared dentinal surfaces or beneath amalgam restoration, newer forms of treatment such as sealing of pit and fissure on posterior teeth, the coverage of badly stained or deformed teeth in order to improve esthetics have all grown from the development of adhesive systems. Finally, bonding systems are essential for a proper bonding or luting procedure of any indirect restoration.

**Summary:**

In today’s era, numerous improvements in materials and procedures have been made to meet the growing esthetic demands of the patients. In all the esthetic restorations a bonding step is involved to ensure durability and reliability. Thus the ideal bonding system should be biocompatible, bond perfectly to enamel and dentin, have sufficient strength to resist to failure as a result of masticatory forces, have mechanical properties close to those of tooth, and be resistant to degradation in oral environment and easy to use.

**References:**


