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АДГЕЗИВНЫЕ СИСТЕМЫ В РЕСТАВРАЦИОННОЙ СТОМАТОЛОГИИ

ADHESIVE SYSTEMS IN RESTORATIVE DENTISTRY

Учебно-методическое пособие

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Освещены терминология, классификация, состав, свойства, требования к современным адгезивным системам, представлены современные подходы в использовании адгезивных систем, особенности работы с адгезивными системами разных поколений.

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INTRODUCTION

Adhesive dentistry has achieved great progress in the last decades. Every dental restoration requires retention by some system of connection and attachment. Nowadays there is no composite material used without an adhesive system. Due to achievements in the field of dental material science, adhesive systems have been separated into an independent class of materials.

Adhesive technique has been widely used in dental practice, because these bonding systems isolate pulp from the irritants and allow long-term and secure adhesion of dental materials with enamel and dentin.

Advantages of bonding techniques. They

1) provide adhesion of restorations to enamel and dentin;
2) minimize removal of sound tooth structure;
3) reduce microleakage in restorations;
4) serve as part of resin cements for bonding cast restorations;
5) expand the range of esthetic possibilities;
6) reinforce weakened tooth structure;
7) reduce marginal staining;
8) serve as bonding agents for many types of restorations.

The assortment of adhesive systems is wide and is constantly replenished. They significantly differ from each other in their characteristics and work techniques. Hence, the doctor should always update his knowledge and improve his qualification in adhesive dentistry.

Dentists often have to choose an optimal material and work technique. Even today there is no universal adhesive system that could be used in any situation.

USE OF BONDING IN DENTISTRY

There are two main factors of using adhesive technique in dental practice - retention of restorations and reduction of microleakage.

1. Retention of restorations. Adhesion is commonly used to keep restorations in place, including minimally invasive restorations. Bonding systems make it possible to attach orthodontic brackets, porcelain veneers, crowns, inlays or onlays, prefabricated and cast posts, periodontal splints and other appliances to teeth.

2. Reduction of microleakage. Microleakage (Fig. 1) is the seeping and leaking of fluids and bacteria between the tooth/restoration junction or interface. Microleakage may cause recurrent caries and postoperative sensitivity. If the pulp is irritated by fluid movement or bacterial metabolic wastes (acids), pain occurs. If the coefficient of thermal expansion for a restorative material does not match that of the tooth, it expands and contracts at different rates. Repeated expansion and contraction of teeth and restorations at different rates results in fluids being sucked in and pushed out at the margins of a restoration. This process is called percolation.

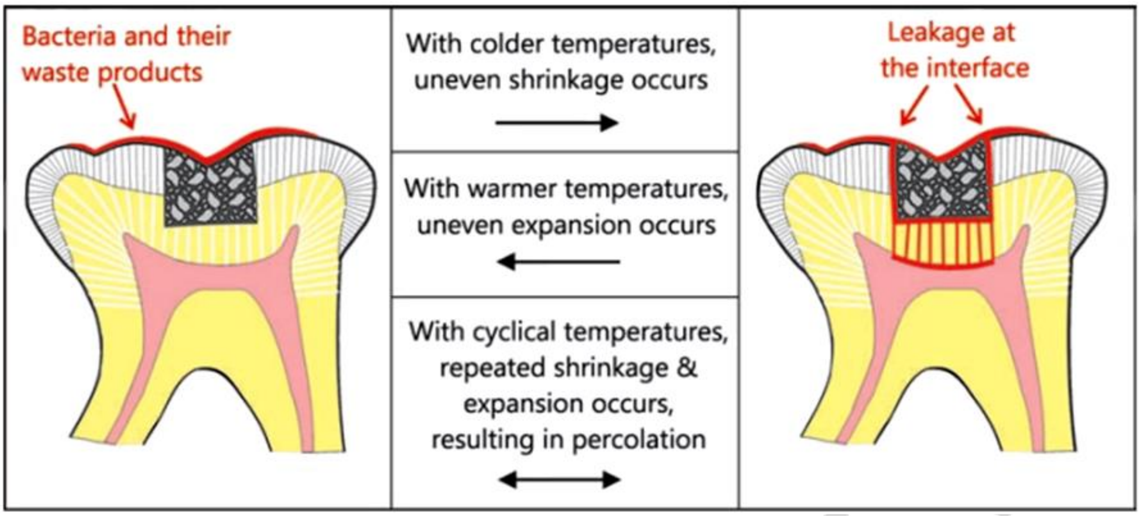

Fig. 1. Illustration of the effects of temperature changes and microleakage (from Clinical aspects of Dental materials)

Microleakage also leads to visible margins (Fig. 2) that become dark, stained, and unaesthetic.

Fig. 2. Visible margins (photo by Monaldo Saracinelli)

TERMINOLOGY IN ADHESIVE DENTISTRY

It is important to know the terminology in adhesive dentistry to understand the bonding process.

Adhesion is the establishment of molecular interactions between the adherend and adhesive.

Adherend is the surface or substrate that is adhered.

Adhesive technique — the modifying process of hard tooth tissues in the defect zone in order to ensure a strong connection of dental materials with enamel, dentin and cement. The three main stages of adhesive process are etching, priming and bonding.

Adhesive system is a material that includes the main components (etchant, primer, bond) in various combinations, and provides micromechanical and chemical bond of dental materials to hard tooth tissues.

Primers are hydrophilic monomers usually carried in a solvent. The solvents used in primers are acetone, ethanol-water, or primarily water. In some primers, the solvent levels can be as high as 90 %. Therefore, primers have different evaporation rates, drying patterns, and penetration characteristics, all of which can influence the resulting bond strength. Because of their hydrophilic nature, they are able to penetrate the moist tooth structure especially the dentin and its collagen mesh thus improving the bond. As a result, they serve as a bridge connecting the tooth structure to the adhesive. Primer mixtures have a wide pH range because of variations in the functional groups of the corresponding monomers.

Hydrophilic monomers are low molecular weight methacrylates (4-META, HEMA, BPDM, PENTA, GPDM, PMDM, PMGDM) which are polar organic molecules with low pH and have hydrophilic properties. These properties, in combination with a solvent, allow hydrophilic monomers to penetrate deep into structures of the etched dentin and promote the formation of ionic connections with hydroxyapatites.

Adhesive (adherent) is a material that can bind substances. Adhesives are generally hydrophobic monomers. Being hydrophobic, they do not wet the tooth leading to air entrapment, air inhibition and thereby poor bonding.

Hydrophobic monomer is a high molecular weight methacrylate with high viscosity (Bis-GMA, UDMA, TEGDMA, PEG-DMA, etc.). During the polymerization process, these molecules are cross-linked and form an organic matrix. Hydrophobic monomers differ from each other according to the degree of shrinkage, layer thickness of the material, stability. Therefore, there is usually a combination of hydrophobic methacrylates in the adhesive.

Initiator is a chemical substance, which triggers formation of free radicals. Free radicals are able to bind low- and high-molecular methacrylates in a single organic matrix. Light-cured bonding agents contain an activator such as camphoroquinone or phenylpropanediol. Chemoactivated bonding agents are tertiary amines or benzoyl peroxide.

Stabilizer is a chemical substance that prevents spontaneous interaction of bonding system's monomers and their premature polymerization. Stabilizer determines shelf-life of the bonding system.

Filler includes particles of inorganic matter (SiO_2, acrosil) of various size (micrometers or nanometers) contained in a certain amount in a primer and a bond. The filler improves the strength and stability of the hybrid layer.

Accelerator is an additional component for some total-etching adhesive systems. It provides self-cure of the bonding system. It is mixed with primer and bond.

Solvent is a chemical substance (acetone, alcohol, and water, or their combination), which keeps the liquid consistency of the primer and the bond. Solvents promote penetration of the adhesive system into the tooth tissues.

Other ingredients: fluoride, antimicrobial agents, desensitizer (glutaraldehyde).

Nanoleakage is a specific type of leakage within the dentin margins of restorations, with fluid transport through some of resin bonding layers and is detectable only by electron microscopy techniques. Here the paths of transport are not related to bulk partition of material, but to hydrolytic degradation. Nanoleakage may be related to the acid etching procedure, by allowing the penetration of pulpal and oral fluids such as acids into porosities within or adjacent to the hybrid layer. Nanoleakage is independent from microleakage. The amount of such penetration depends on the type of the bonding agent used, on the hydrophilic nature of the monomers within the adhesive and on different parameters of the application technique such as dentin moisture and etching time. Nanoleakage is less extensive than microleakage, and has probably no immediate clinical relevance. However, the long-term stability of the adhesive bond between dentin and the restorative material may be adversely affected by the degradation phenomenon.

Rewetting agent is an aqueous solution of hydrophilic monomer, for example, HEMA, with substances stabilizing collagen fibers (glutaraldehyde, salicylic acid derivatives). Rewetting agent is used with total-etch technique, when dentin is overdried. This process prevents postoperative sensitivity.

Contact angle is an angle of intersection between a liquid and a surface of a solid that is measured from the solid surface through the liquid to the liquid-vapor tangent line originating at the terminus of the liquid-solid interface. The contact angle is used as a measure of wettability, whereby absolutely no wetting occurs at a contact angle of 180 degrees; complete wetting occurs at an angle of 0 degrees.

Resin tag is extension of resin that has penetrated into the etched enamel or dentin.

Surface energy is the excess energy of molecules at the surfaces of the materials above that of the molecules found in the interior of a material.

Surface tension is the tension at the surfaces of liquids that results from the physical driving force to minimize the total energy of a system. This tension causes a liquid to minimize its surface by forming a spherical drop or a droplet with a contact angle against a solid surface.

Wettability is a relative affinity of a liquid for the surface of a solid.

Wetting is a relative interfacial tension between a liquid and a solid substrate that results in a contact angle of less than 90 degrees.

ADHESIVES REQUIREMENTS

Adhesives should:

– be universal and compatible with most dental materials;

– provide an immediate, load-resistant, long-term bonding effect to the tooth tissues;

– compensate the stress resulting from polymerization shrinkage of composite materials;

– have similar bond strength to both dentin and enamel;

– provide sufficient adhesion to moist dentin;

– be biocompatible (not cause immediate or delayed irritation and pulp necrosis);

– not get dissolved in oral or dentin fluids;
– be convenient and easy to use;
– have long shelf-life;
– not have a sensitizing effect on both the patient and the doctor.

CLASSIFICATION OF BONDING SYSTEMS

On the dental market a large assortment of adhesive systems is presented. It makes it difficult for the dentist to select the material. One of the reasons is insufficient systematization of information on adhesive systems.

There are some main principles of classification:

1) According to the generations:
– 1^{st} generation;
– 2^{nd} generation;
– 3^{rd} generation;
– 4^{th} generation;
– 5^{th} generation;
– 6^{th} generation;
– 7^{th} generation.

2) According to the filler level:
– unfilled;
– filled;
– nanofilled.

3) According to the solvent type:
– Water-based;
– Acetone-based;
– Ethanol-based;
– Combined.

4) According to their intended purpose:
– Enamel-dentinal;
– Universal;
– Multifunctional.

5) According to the polymerization type:
– Light-cured;
– Self-cured;
– Dual-cured.

6) According to the mechanism of action:
– Self-etch bonding systems;
– Total-etch bonding systems.

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INDICATIONS AND CONTRAINDICATIONS TO USING ADHESIVE SYSTEMS

Modern adhesive systems have a wide range of indications, which makes it possible for the dentist to work with most dental materials.

Indications to using adhesives:

1) classes 1–6 restorations including amalgam restorations;
2) non-caries decays (for example, erosion, abrasion, abfraction);
3) minimally invasive treatment;
4) correction of contours, positions, dimensions, or shades of teeth;
5) treatment of dentinal hypersensitivity;
6) pulp protection after preparation before fixing prosthetic restorations and dentures;
7) to seal pits and fissures;
8) to repair fractured porcelain, amalgam, resin restorations, porcelain-fused-to-metal crowns, metal acrylic crowns, acrylic crowns;
9) to bond orthodontic brackets;
10) to prepare teeth before fixing indirect restorations (crowns, bridges, inlays, onlays, canal posts).

Contraindications to using adhesives:

1) allergy to any component of the adhesive system;
2) inability to isolate the operative field from saliva and gingival crevicular fluid;
3) direct pulp capping;
4) poor oral hygiene.

DEFINITION OF SMEAR LAYER

The smear layer is created on hard tissues. While cutting dentin, the heat and shear forces produced by the rotary movement of the bur cause dentin debris to compact and aggregate.

The smear layer is responsible for:

– acting as a physical barrier for bacteria and bacterial products;

– restricting the surface area available for diffusion of both small and large molecules;

– resistance to fluid movement. In vital teeth, the smear layer restricts the dentinal fluid from flushing the dentin surface. It also hinders the chemical process that produces the marginal seal.

The smear layer may be deterrent to the bonding process since it may serve as a barrier to the penetration of resin to the underlying dentin substrate.

The smear layer has an amorphous, irregular and granular appearance. Cameron (1983) and Mader (1984) described the smear layer as consisting of two separate parts (Fig. 3):

1. One superficial and loosely attached to the underlying dentin;

2. The other one consisting of plugs of dentinal debris in the orifices of dentinal tubules.

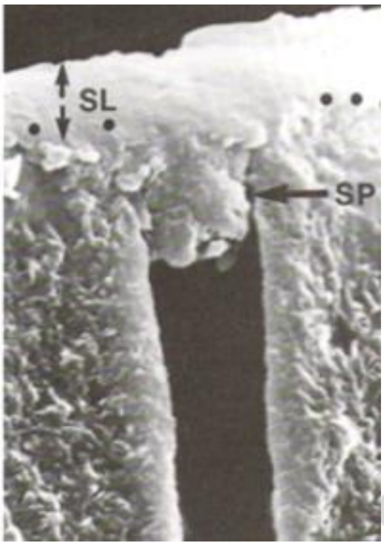

Fig. 3. Smear layer (SL) and smear plugs (SP) (from Pashley D.H., et al.)

The smear layer has an average depth of 1 to 5 μm but in the dentinal tubules it may go up to 40 μm. The depth of the smear layer depends on the following factors:

- dry or wet-cutting of the dentin;
- type of the instrument used.

The smear layer consists of both organic and inorganic components. The inorganic material in the smear layer is made-up of tooth structure and some non-specific inorganic contaminants. The organic components may consist of heated coagulated proteins (gelatin formed by the deterioration of collagen heated by cutting temperature), necrotic or viable pulp tissue and odontoblastic processes, saliva, blood cells and microorganisms.

The smear layer on deep dentin contains more organic material than superficial dentin because of a greater number of proteoglycans lining the tubules and a greater number of odontoblastic processes near the pulp. The dentin smear layers consist of globular particles approximately 0.05–0.1 mm in diameter that are separated by water-filled channels. These globular particulates probably represent fractured apatite crystallite aggregates that are burnished together by the denatured collagen remnants.

The smear layer cannot be rinsed off with water.

Dentin bonding agents can:

- remove smear layer;
- dissolve smear layer;
- modify smear layer.

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DEFINITION OF HYBRID LAYER

Hybrid layer is an artificial structure formed after etching (demineralization) and subsequent infiltration of the tooth hard tissue components of the adhesive system which is completely polymerized.

When a bonding agent is applied, part of it penetrates into the collagen network, known as intertubular penetration; the rest of it penetrates into dentinal tubules called intratubular penetration. In intertubular penetration, it polymerizes with primer monomers forming a hybrid layer/resin reinforced layer.

The process of formation of a hybrid layer is **hybridization**.

The hybrid layer is responsible for micromechanical bonding between tooth and resin. Micro-mechanical retention is thought to provide resistance to 'acute' de-bonding stresses; the relevance of additional chemical bonding is suggested to lie in durability and survival of adhesion.

The hybrid layer has shown to have three different zones:

1. *Top layer:* It consists of loosely arranged collagen fibrils and interfibrillar spaces filled with resin.

2. *Middle layer:* It consists of interfibrillar spaces in which hydroxyapatite crystals have been replaced by resin monomer because of the hybridization process.

3. *Bottom layer:* It consists of almost unaffected dentin with a partly demineralized zone of dentin.

The hybridoid layer is an area of demineralized dentin into which resin fails to penetrate.

INTERFACE FORMATION FOR ADHESION

Formation of an optimally bonded interface (formation of the hybrid layer) requires (Fig. 4):

– clean surface;
– wet surface;
– adaptation to the substrate without entrapped air or other intervening materials;
– well-cured adhesive.

Dental surfaces exposed to the oral environment contain a pellicle of adsorbed materials from saliva or smear layer after preparation. In case a surface is cleaned, its surface energy is higher. Good wetting is evidenced by a small contact angle and spreading of the adhesive onto the substrate. Clean dentin is hydrophilic and will be wet best by an adhesive that is also hydrophilic. Once good wetting is achieved, the adhesive should intimately contact the substrate to produce physical (covalent bond, ionic bond, metallic bond), chemical (Van der Waals interactions, dispersion forces, hydrogen forces), or mechanical bonding. The final practical consideration for bonding is the method of curing (polymerizing) the adhesive. If curing does not continue to a sufficient degree, the under-cured adhesive may not provide good retention and sealing.

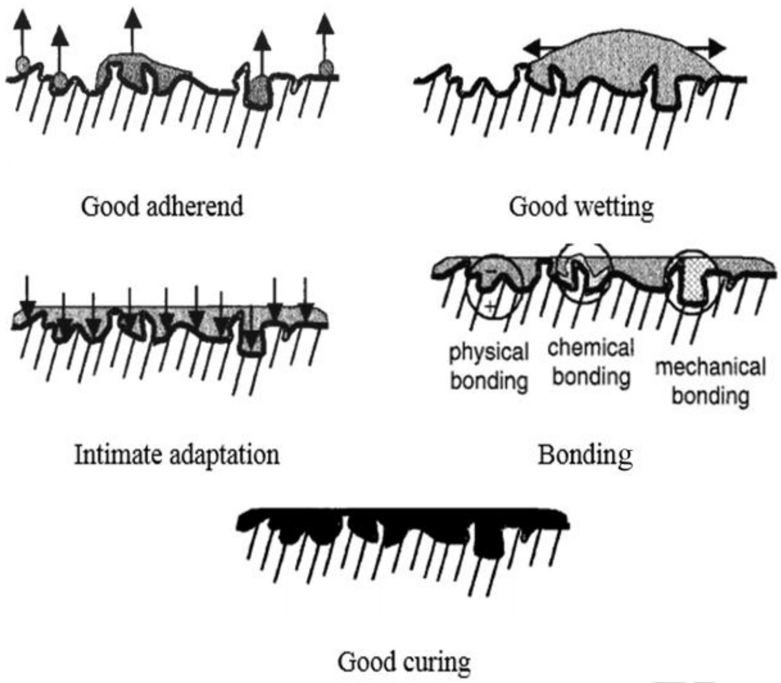

Fig. 4. Steps involved in the formation of an adhesive joint (from Restorative dental materials)

Interfacial debonding. Debonding of dental joints occurs through a process of crack formation and propagation and subsequent joint failure.

Debonding defects include:

– areas of interfacial contamination;
– excess moisture;
– areas of poor wetting;
– trapped air bubbles;
– voids formed during the solvent evaporation;
– bubbles within the adhesive;
– curing shrinkage pores;

These defects decrease the bond strength between the tooth and filling material.

ENAMEL BONDING

Enamel is the hardest tissue in the human body. It contains by weight 95 % of inorganic hydroxyapatite crystals, and the other 5 % are organic matrix and water. The first step of the bonding process is to etch the enamel.

In 1954, Buonocore conducted successfully his first experiments on adhesion to enamel through acid etching. ***Acid etching*** was the first successful technique for bonding dental materials to the tooth structure. He used 85 % phosphoric acid for etching. The mechanism of acid-etch enhanced adhesion was not published until 1968, when Buonocore, Matsui and Gwinnett discussed the effect of phosphoric acid conditioning, which produced “prism-like” tags of resin materials that penetrated enamel surfaces.

Goals of enamel etching:

– to clean the enamel of the surface organic pellicle in uncut enamel;

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– to remove the enamel smear layer in cut enamel (Fig. 5);

– to partially dissolve the mineral crystallites to create retentive patterns for the infiltration and retention of resinous materials.

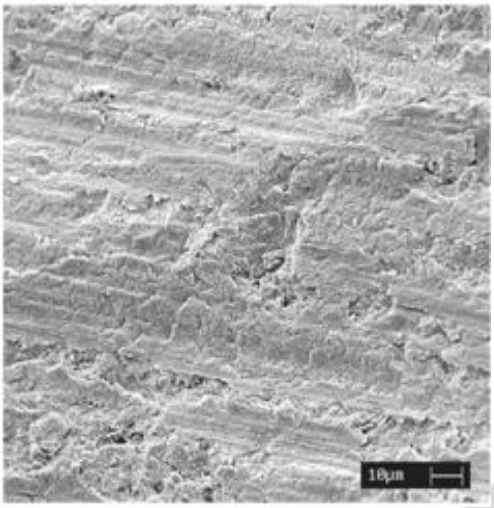

Fig. 5. A smear layer after cutting enamel with a diamond bur (from G. Eliades, D. C. Watts, T. Eliades)

Enamel etching creates microporosities by discrete etching of the enamel, i.e. by selective dissolution of enamel rod centers, or peripheries, or both. Etching increases the surface area. One can overetch, however, and crystals can form (precipitate) from the calcium and phosphate ions initially dissolved. Such precipitated crystals can *inhibit* bonding. The recommended time for etching enamel is typically ***15 to 30 seconds*** depending on the manufacturer or the product. If etched enamel becomes contaminated by saliva, it should be re-etched with the same acid, but only a 5–10-second etch is necessary.

Factors affecting the effects of acid etching on enamel:

– type of acid used in either gel or liquid form;

– concentration of acid used and time of etching;

– type of acid used;

– chemical nature of enamel;

– whether enamel is fluoridated or demineralized;

– type of dentition, i.e. primary or permanent.

Acid etching increases the surface energy and lowers the contact angle of resins to enamel. However, there is poor correlation between the length of resin tag formation or the depth of resin penetration and the strength of resin–enamel bonds.

There are several agents used to modify the smear layer:

– ***Acids***. As for enamel, we can use phosphoric acid; it **removes** a smear layer and creates a microporous collagen network into which resin monomer penetrates. Nitric acid, maleic acid, citric acid, oxalic, 10–15 % phosphoric acid and hydrochloric acid can be used to modify the smear layer. Citric acid (50 %) needs 5 min exposure time to give a satisfied etching pattern. This length of time is impractical.

– ***Calcium chelates.*** These are used to modify or remove the smear layer. For example, ethylenediaminetetraacetic acid (EDTA).

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Concentration of phosphoric acid in the etchant ranges from 20 % to 40 %. The most useful is ***37 % phosphoric acid***, pH 0,7–0,8. The concentration more than 40 % leads to complete dissolution of the surface layer of the enamel. As a result, there are no microporosities. Using etching acid with concentration lower than 20 % leads to insufficient dissolution.

After etching, we can see three types of patterns:

– ***Type 1*** (Fig. 6). Preferential demineralization of enamel prism core leaves the prism peripheries intact. Its corresponding tags are cone shaped. The average diameter of the hollowed regions is 3 μm.

– ***Type 2*** (Fig. 7). Preferential removal of interprismatic enamel leaves the prism core intact. The corresponding enamel tags are cup shaped.

– ***Type 3*** (Fig. 8). In this, the pattern is less distinct, including areas that resemble type 1 and 2 patterns as well as areas which bear no resemblance to the enamel prism.

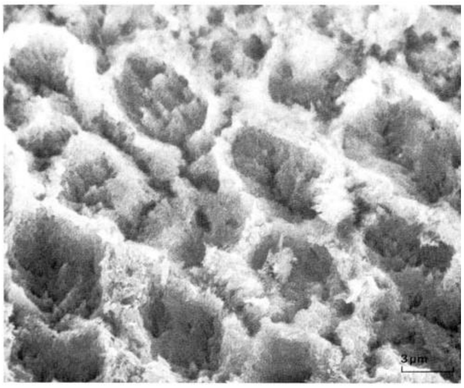

Fig. 6. Type 1 etching pattern

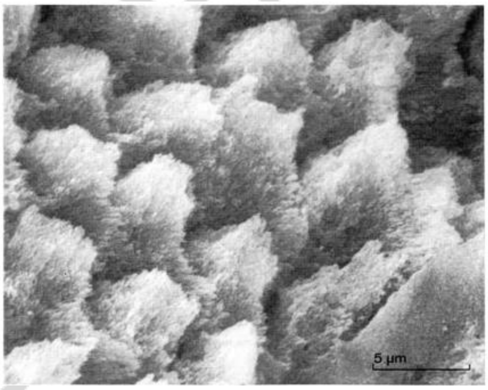

Fig. 7. Type 2 etching pattern

(Fig. 6 and Fig. 7, from L. M. Silverstone, C. A. Saxton)

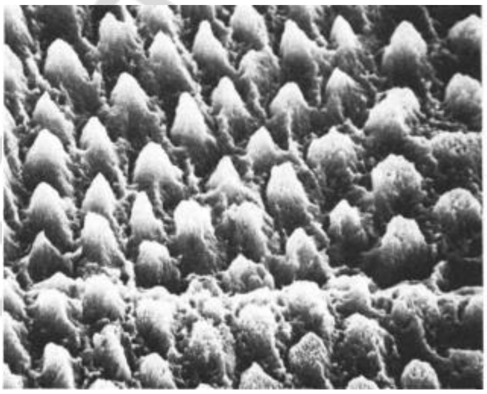

Fig. 8. Type 3 etching pattern. (from Khadry A. Galil, Gerald Z. Wright)

The etchant can be as a gel or liquid (Fig. 9). Etching solutions are free-flowing liquids and are difficult to control during placement. Gel etchants were developed by adding small amounts of microfiller or cellulose thickening agents. These gels flow under slight pressure but do not flow under their own weight. Thus, the most convenient to use is a dye gel. It allows an effective control of the etchant's application and removal.

Fig. 9. Different types of etching agents (from Kerr, 3M ESPE)

Steps for enamel bonding:

1) Provide oral prophylaxis procedures using ***non-fluoride and free-oil*** pastes.
2) Wear rubber dam to prevent any contamination from saliva and gingival crevicular fluid.
3) Apply acid etchant (according to instructions).
4) Wash off the etchant (min. 15 seconds).
5) Dry the surface. We should give a chalky or a frosty white appearance.
6) Apply bonding agent.

After etching, bonding agent must be applied (Fig. 10).

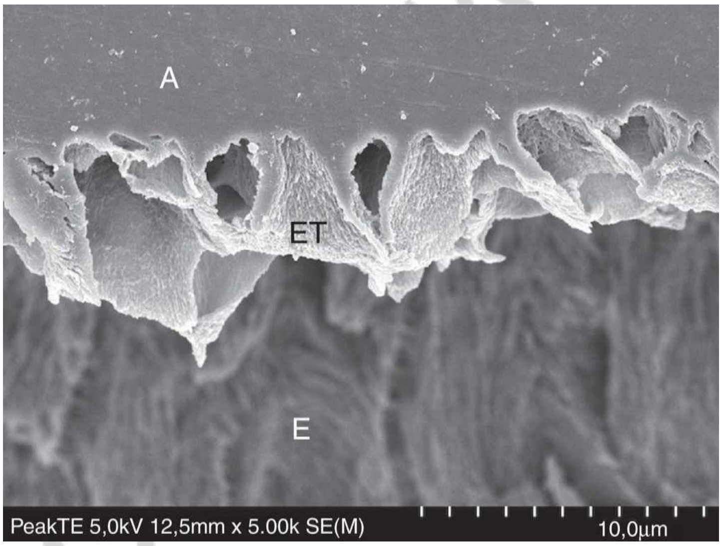

Fig. 10. Hybrid layer in enamel (A — adhesive, ET — enamel tags, E — enamel) (from J. Perdigao)

DENTIN BONDING

Dentin is a crystalline material, which is less hard than enamel. It is about 70 % inorganic hydroxyapatite crystal, 20 % organic material, 10 % water. Dentin comprises dentinal tubules with processes of odontoblasts, peritubular dentin and intertubular dentin.

Mechanism of bonding. The dentin adhesive molecule has a bifunctional structure: M-R-X (Fig. 11). The component M is the double bond of methacrylate, which copolymerizes with composite resin. R is the spacer, which makes the molecule large. X is a functional group for bonding which bonds to inorganic or organic portion of dentin. Ideally, a dentin-bonding agent should have both hydrophilic and hydrophobic ends. The hydrophilic end displaces the dentinal fluid to wet the surface. The hydrophobic end bonds to the composite resin. Bonding to the inorganic part of dentin involves ionic interaction among the negatively charged group on X (for example, phosphates, amino acids and amino alcohols, or dicarboxylates) and the positively charged calcium ions. Commonly applied bonding systems use phosphates. Bonding to the organic part of dentin involves interaction with Amino (-NH), Hydroxyl (-OH), Carboxylate (-COOH), Amide (-CONH) groups present in dentinal collagen.

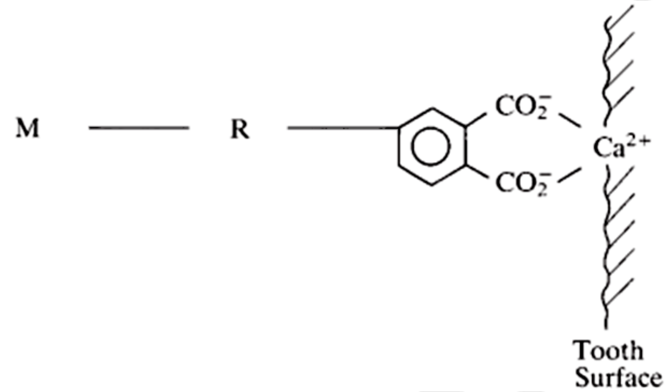

Fig. 11. 4-META bound to calcium in tooth substance (from Applied dental materials)

Bonding to dentin has been proven to be more difficult and predictable than bonding to enamel because of:

1) dentinal fluid which flows constantly outwards; thus, the surface of the dentin never dries up;

2) dentin contains 10 % water, but many resins are hydrophobic;

3) dentin contains dentinal tubules with vital processes of the pulp, odontoblasts, thus, this is a living sensitive structure

4) different amounts of dentinal tubules on different levels; the dentinal tubule openings occupy only about 5 % of the cut dentin surface in superficial dentin (near the amelodentinal junction) and this rises to near 20 % in deep dentin;

5) various diameter of the dentinal tubules (Fig. 12);

6) thick smear layer after preparation (Fig. 13);

7) dentin, which is a dynamic tissue that shows changes due to aging, caries or operative procedures.

After etching dentin (15 seconds), collagen fibers get exposed (Fig. 14). Three-dimensional system of collagen network is filled with water. This fiber system has a large contact area due to free spaces among the fibers. Water keeps collagen network in an expanded soft state. Thus, it is preferred to keep the dentin surface moist, otherwise, collagen fibers get ***collapsed*** (Fig. 15) in dry condition resisting the entry for primer and adhesive resin. Once this happens, the collagen mesh readily excludes the penetration of primer, and bonding will fail. However, excess moisture tends to dilute the primer and interfere with resin interpenetration. Thus, excess moisture should be removed with a gentle stream of air or by blotting.

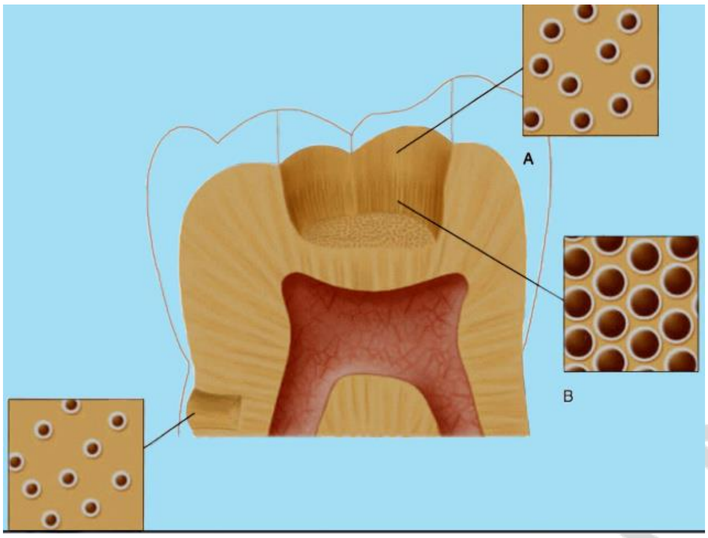

Fig. 12. Regional variation in the permeability characteristics of dentin (from V.Taduri)

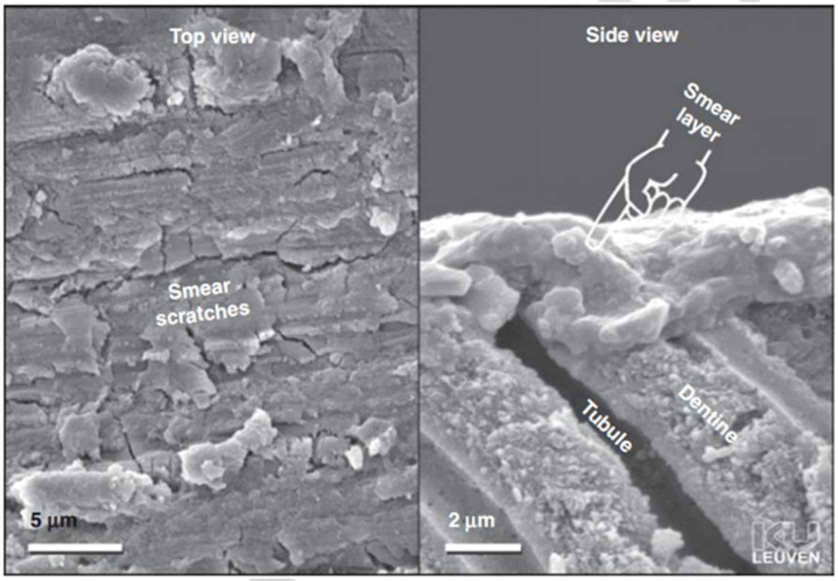

Fig. 13. A smear layer on dentin (from B. Vanmeerbeek, J. Demunck)

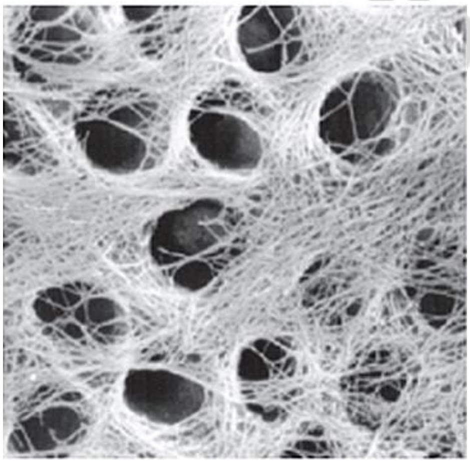

Fig. 14. Collagen mesh
(from J. J. Manappallil)

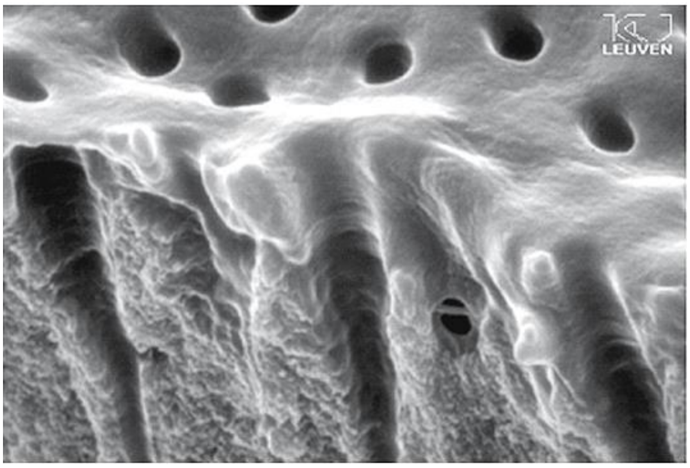

Fig. 15. Collapsed collagen mesh
(from K. Van Landuyt)

When primer (or primer+adhesive) is applied to wet/moist dentin, water diffuses from the primer to the organic solvent and the solvent diffuses along with the polymers into the demineralized dentinal matrix and tubules. When the primer is applied, most of the solvent evaporates quickly. Thus, several layers must usually be applied to ensure a complete impregnation. Water-based primers are not dependent on moist dentin because of their ability to self-wet a dried dentin surface and, thus, separating the collapsed collagen fibers. Application of the primer usually takes around 15–30 seconds. A hybrid layer (Fig. 16) is formed after the polymerization of the primer and adhesive. It is relatively reliable with the underlying dentin. A hybrid layer blocks circulation of the dentinal fluid around the perimeter of the carious cavity, protects the pulp from any chemical, thermal and mechanical effects. The thickness and morphology of the hybrid layer are quite variable and depend both on the characteristics of the dentin itself, and on the technique of its processing. Following the self-etching, the thickness of the hybrid layer averages 0.5–2 μm, and after total etching, it averages 2–5 μm.

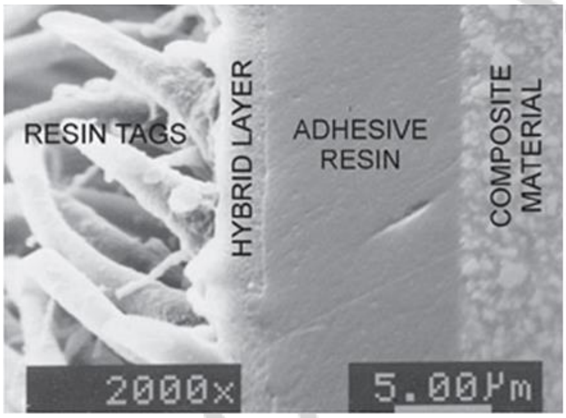

Fig. 16. Hybrid layer in dentin (from J. J. Manappallil)

Self-etch systems have a great advantage of eliminating the risk of incomplete primer/adhesive penetration into the collagen scaffold as well as eliminating the subjectivity when determining the amount of moisture on the dentin surface ideal for primer diffusion. With these systems, the smear layer is dissolved and incorporated into the hybrid layer.

Hybrid layer in enamel and dentin is an intermediary substance which provides reliable and long-term fixation of different dental materials to the hard tooth tissue. It is in charge of complete isolation of the pulp from external influences. Thus, hybrid layer functions as an insulation lining of the pulp.

GENERATIONS OF DENTAL BONDING AGENT

The development of adhesive dentistry after the discovery of Buonocore was very slow and without much success for twenty years. It was associated, first of all, with the problems of adhesion to dentin.

First generation (developed in 1960s.). The first dentin bonding agent to appear on the market was Cervident (SS White Co, King of Prussia, PA). Mineral acids were used to etch enamel. Dentin etching was not recommended, as it was believed to harm the pulp. They used glycerophosphoric acid dimethacrylate to provide a bifunctional molecule. The hydrophilic phosphate part reacted with calcium ions of the hydroxyapatite. The hydrophobic methacrylate groups bond to the acrylic restorative resin. These were generally self-cured. The main disadvantage was their low bond strength (2 to 3 MPa) because of their high polymerization shrinkage. Leakage was a concern at the dentin-resin interphase.

Second generation was introduced in the late 1970s. When used, most of the second-generation bonding agents left the smear layer intact but some of them used mild cleansing agents to remove the smear layer. There were three types of products:

– Etched tubule dentin bonding agent (*25 % citric acid* and then making use of ethylmethacrylate to mechanically interlock with the etched tubules)

– Phosphate ester dentin bonding agents. They modify the smear layer. These bonding agents used analogs of Bis-GMA with attached phosphate esters. The phosphate group bonded with calcium present in the tooth structure, while the methacrylate end of the molecule bonded to the composite resin.

– Polyurethane dentin bonding agents. These bonding agents were based on the isocyanate group of the polyurethane polymer which bonds to different groups present in dentin like carboxyl, amino and hydroxyl groups.

Bond strengths tripled in comparison with the first generation, BUT it was still low (to 6 MPa). The adhesion was short-term, and the bond eventually hydrolyzed. Examples are Bondlite, Dual- Cure Scotchbond, Creation Bonding Agent.

Third generation (in the late 1980s). The main difference from the previous generations is modification of the dentin smear layer. It was a three-step application system which included:

1) Etching of enamel using 37 % phosphoric acid, conditioning of dentin using mild acids.

2) Application of primer.

3) Bonding agent application.

Bond strength improved to 12–15 MPa. However, as time passed, bond strength has been decreasing and microleakage increasing. Examples are A.R.T. Bond, Allbond, Denthesive, Gluma, Scothbond 2, Superbond, Tenure, Metabond, Amalgambond, Syntac Classic, XR Bond.

Fourth generation (the mid-1990s). This generation is based on total etch technique and moist bonding concept. Research showed that acid etching of dentin did not significantly harm the pulp as long as bacterial contamination and microleakage was avoided. The 4^{th} generation is characterized by removing the smear layer and creating a hybrid layer. Hybridization is a phenomenon of replacement of the hydroxyapatite and water at the dentin surface by resin. However, dealing with the collagen mesh was not easy. It is delicate and can be destroyed by ***desiccation***. This concept was put forward by Nakabayashi in 1982. Kanca (1991) introduced the idea of wet bonding again breaking with the traditional belief that thorough drying was necessary to improve bonding. This technique includes at minimum three steps (Fig.17):

1) Etching (37 % phosphoric acid) using ***"total-etch"*** technique

2) Priming. Primers consist of monomers like HEMA (2-Hydroxyethyl methacrylate) and 4-META (4-Methacryloxyethyl trimellitate anhydride) dissolved in acetone or ethanol. It is a hydrophilic component. These monomers infiltrate demineralized peritubular and intertubular dentin.

3) Bonding. The adhesive resin is a low viscosity, semi-filled or unfilled resin which flows easily and matches the composite resin. It is a hydrophobic component.

Examples are All-Bond 2, AmalgamBond Plus, OptiBond FL, Perma Quick, ScotchBond Multipurpose Plus, Solid Bond, Definite Multibond.

By this day, the 4^{th} generation is ***the gold standard*** in adhesive dentistry.

Advantages:

– bond strength is high (>20 mpa);

– strong bond both to enamel and dentin;

– strong bond to moist dentin;

– multifunctional system (can be used with porcelain and alloys including amalgam);

Disadvantages:

– difficult to use;

– high sensitivity to work-stages disruption;

– high cost.

Fifth generation (the mid-1990s). Because of the clinical complexity and multiple steps of the fourth generation, dentists began asking for more simple adhesives. It is 'one-bottle' system (Fig. 18), which means the primer and adhesive resin are in the same bottle. This technique includes two steps:

1) Total etching.

2) Primer-adhesive mixture application.

Examples are Exite, Gluma Comfort Bond (+Desensitizer), One Step (Plus), OptiBond Solo (Plus), PQ1, Prime&Bond NT, XPbond, Single Bond, Adper Single Bond 2, Tenur Quick, Easy Bond, Fuji Bond LC, One Coat Bond, Solobond M, AdmiraBond.

Advantages:

– high bond strength (>20 mpa) both to enamel and dentin;

– easy to use;

– little technique sensitivity;

– reduced number of steps;

– reduced postoperative sensitivity.

Disadvantages:

– bond strength to enamel is higher than to dentin, therefore, restoration may detach from dentin and cause postoperative sensitivity;

– Incompatibility of most chemical-cured materials.

Fig. 17. Separated bottles with primer and adhesive. (from Kerr, Ivoclar Vivadent)

Fig. 18. One-bottle (primer+adhesive) system. (from 3M ESPE, Dentsply, Ivoclar Vivadent)

Sixth generation. In this system etching as a separate step *is eliminated*. It is a 2-bottle system. It can be in 2 varieties. *Type 1* (Fig. 19) — etchant and primer are combined in one bottle (called self-etching primer); the other bottle contains adhesive, 2-step system. Examples are Clearfil SE bond (Kuraray), Adhese (Ivoclar), Optibond solo plus (Kerr), Nano bond (Pentron). *Type 2* (Fig. 19) — 2 bottles, 1-step system. Liquid A contains the primer. Liquid B contains a phosphoric acid modified resin (self-etching adhesive). Both liquids are mixed just before application. For example, Xeno III (Dentsply) Adper prompt L-pop (3 M), Tenure unibond (Dent Mat).

Advantages:

– it reduces postoperative sensitivity because it etches and primes at the same time;

– it etches the dentin less aggressively than total etch products;

– much faster and simpler technique;

– less sensitive technique as fewer number of steps are involved for the self-etch system;

– multifunctional system.

Disadvantages:

– pH is not enough to etch enamel, thus, bond to enamel is weaker as compared to dentin;

– may require refrigeration for storage;
– high hydrophilicity due to acidic primers;
– limited clinical data;
– bond strength is lower than the fourth and fifth generation bonding agent.

Fig. 19. Type 1 system on the left (from Kuraray), type 2 system on the right (from 3M ESPE, unit dose)

Seventh generation is represented by one-bottle self-etching system (Fig. 20). It means that the same bottle includes etchant component, primer and bonding agents. Examples are i-Bond Gluma inside (Self-Etch), Xeno IV, Brush&Bond, Adper EasyBond, AdheSE One, G-Bond, Optibond All in One. Self-etch systems have a great advantage of eliminating the risk of incomplete primer/adhesive penetration into the collagen scaffold, as well as eliminating the subjectivity when determining the amount of moisture on the dentin surface ideal for the primer diffusion. With these systems, the smear layer is dissolved and incorporated into the hybrid layer.

Advantages:
– simple and quick method of working;
– ho postoperative sensitivity;
– collapse of the collagen network is prevented.

Disadvantages:
– different bond strength for enamel and for dentin;
– no long-term results.

Fig. 20. One-bottle system, 7th generation (from 3M ESPE, Dentsply, GC Europe)

Self-etching adhesives have been classified according to their acidity (Fig. 21): ***strong (pH≤1)***, ***intermediate (pH=1.5)***, and ***mild (pH≥2)***.

Mild self-etch systems demineralize dentin only superficially (a few microns) and leave residual hydroxyapatite attached to collagen fibers. This characteristic may protect the collagen against hydrolysis and, thus, early degradation of the bond. Mild self-etch systems may present relatively low bond strength values when applied to *sclerotic dentin*. In spite of the small hybrid layer and the absence of resin tags (little micro-mechanical retention), ‘mild’ self-etch adhesives can reach satisfactory results as far as bond strength is concerned. Together with the finding that the thickness of the hybrid layer and the presence of resin tags do not overly influence the bonding performance, additional chemical interaction between the monomers and hydroxyapatite may be a plausible explanation for the good performance of some self-etch adhesives. One has to keep in mind that the interaction of self-etch adhesives with tooth substrate is dependent to a great extent on the kind of acidic functional monomer, and eventually the overall composition of the adhesive. This results generally in a larger variation in bonding performance of different self-etch adhesives available today than of the etch&rinse adhesives that all rely largely on the use of phosphoric acid and the subsequent infiltration of monomers. The carboxylic and phosphate groups that render these monomers hydrophilic and that function as proton donors, have been proven to bond ionically with calcium in hydroxyapatite. Intermediary strong’ self-etch adhesives exhibit morphological features that lie between the ‘mild’ and ‘strong’ self-etch adhesives.

Researchers have pointed out that some functional monomers in self-etch adhesives, such as 10-MDP, 4-MET and phenyl-P can chemically interact with hydroxyapatite within a clinical time, and this interaction has been connected to better resistance towards degradation by prevention of micro- and nanoleakage.

Another drawback associated with all-in-one systems is that, due to their high water content, they behave as semipermeable membranes, which increases degradation by hydrolysis.

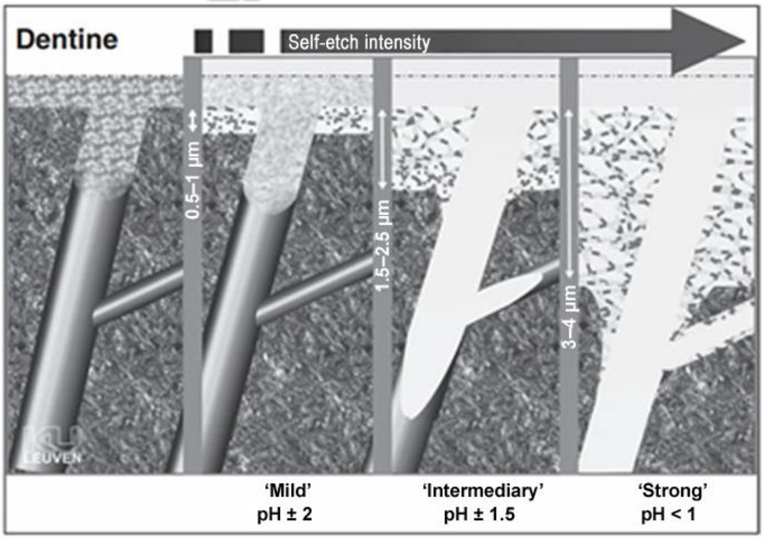

Fig. 21. The difference in interfacial ultrastructure depending on the pH of the self-etch adhesive. (Richard V. Curtis and Timothy F. Watson, 2008)

FILLERS IN BONDING SYSTEM

The presence of filling agents in bonding system determines its properties. There are 3 types of adhesive systems according to the filling agents:

1. ***Unfilled*** (Gluma Comfort Bond (+Desensitizer), One Step, Single Bond, Solobond M, i-Bond Gluma Inside, Brush&Bond, FuturaBond, Etch&Prime 3.0, Adper Promt L-Pop, Touch&Bond, Tenure Uni-Bond).

2. ***Filled*** (FL-Bond, OptiBond FL, OptiBond Solo Plus, One Step Plus, PQ1). These adhesive systems contain fillers with particle size 0,4–7 μm (up to 45 % by volume). Thickness of the covering adhesive layer is 10–25 μm (Fig. 22).

3. ***Nanofilled*** (Prime&Bond NT, Adper Single Bond 2, Exite, One Coat Bond, Xeno III, FuturaBond NF, One-Up Bond F, AdheSE, Clearfil Liner Bond 2V, Clearfil SE Bond, i-Bond SelfEtch). They contain filler particles of 5–20 nm to 15 % by volume, which, due to their size, are capable to penetrate into the network of collagen fibers and into the dentinal tubules. Nanofillers provide nanoretention of the material to the structures of the tooth tissues. Thickness of the covering adhesive layer is 5–10 μm.

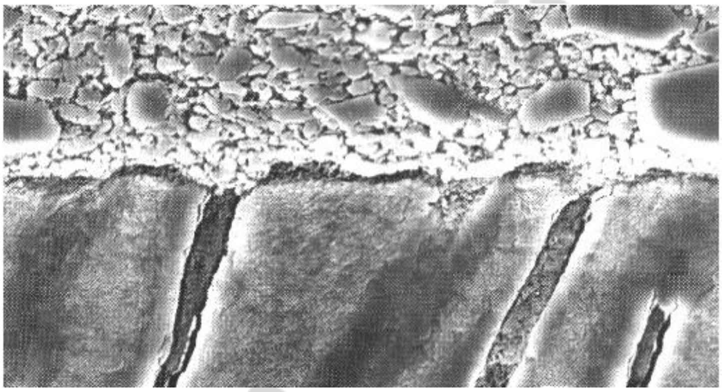

Fig. 22. Filled adhesive system. (from Tokyo Medical and Dental University)

The presence of fillers in the adhesive system improves the stability and durability of the hybrid layer, compensates stress on the border «tooth/filling material» and prevents the appearance of microcracks.

SOLVENTS IN DENTAL ADHESIVES

All existing adhesive systems are produced in a liquid form, in which the solvent plays an important role. The only exception is the One-Coat Bond system in a gel. It doesn’t contain a solvent. The functions of the solvent are:

– dissolving and preserving the working properties of organic monomers;
– wetting the surface of the tooth tissues;
– increasing the permeability of dentin for hydrophilic monomers.

Water-based adhesives have the highest ability to moisturize. The impregnation rate of dentin is good, but lower among the others adhesive systems. All self-etching systems contain water as a solvent, which provides hydrolysis of phosphoric esters of methacrylates, triggering the demineralization reaction of tooth tissues.

The disadvantage of water-based adhesives is low volatility and difficulty to remove water. These factors affect the quality and the rate of adhesive force. Normally one coat of a material in this category is sufficient to appropriately cover the entire surface. Extra coats may have a thickening effect and result in the imprisonment of the solvent between the layers. This may lead to lower bond strength values.

To overcome these shortcomings, different combinations of the solvents are proposed (acetone + water, alcohol + water).

Acetone-based adhesives have the highest volatility. Therefore, acetone-based systems are the least sensitive to the amount of residual moisture that can interfere with the penetration of the primer to the dentin and break the polymerization. The contact of acetone with water leads to active water evaporation due to a decrease in the surface tension. Acetone-based systems require the least time among other adhesive systems to impregnate tooth tissue. The disadvantage is insufficient moistening of the dried dentin and, thus, a high risk of postoperative sensitivity.

Ethanol-based adhesives are believed to be a good compromise with regard to the user's handling and performance. Alcohol has an average volatility, thus, it takes a longer time for alcohol-containing systems to impregnate the dentin. This type of adhesives has an average moisture level and an average risk of sensitivity appearance.

The solvent, especially acetone and alcohol, according to its volatile, makes it necessary to close tightly the bottle with the material immediately after use.

There is no consensus which solvent is better (Table), but the market is more widely represented by alcohol-containing systems and systems with a combination of solvents.

Table

Advantages and disadvantages of the solvents (from Robert G. Craig, John M. Powers)

Solvent	Advantages	Disadvantages
Acetone	Dries quickly	Evaporates quickly after being dispensed; can evaporate from container; sensitive to wetness of dentin; multiple coats may be required; offensive odor
Ethanol/water	Evaporates less quickly, less sensitive to wetness of dentin	Extra drying time
Water	Slow evaporation, not sensitive to wetness of dentin	Long drying time; water can interfere with adhesive if not removed
Solvent-free	No drying, single coat	Higher film thickness

FUNCTIONALITY OF ADHESIVE SYSTEMS

Indications for the use of adhesive systems are very different, thus, the dentist should determine what tasks he/she wants to solve. The ***enamel-dentinal adhesive systems*** (OptiBond Solo (Plus), Gluma Comfort Bond, PQ1, Promt L-Pop, i-Bond, Xeno III, Touch&Bond, Etch&Prime 3.0, FuturaBond (NF), Single Bond, Exite, One Coat Bond) fix all types of light-curing materials, such as composites, ormocers and compomers. It is possible to use combination of adhesive system from one manufacturer with light-curing material and that from another manufacturer. Activators of chemical curing (OptiBond Solo Plus adhesive systems, Contax One Step, Clearfil New Bond, Clearfil Photo Bond) expand indications to using adhesive system. ***BUT***, the activator for chemical curing is used only for the adhesive system of the same manufacturer.

Universal adhesive systems (One Step (Plus), Clearfil Liner Bond 2V, Clearfil Photo Bond) have the ability of chemical or dual curing, and are designed for adhesion to the tooth of light-, chemically-curing and dual-curing materials. They differ from enamel-dentin systems by the presence of proprietary monomers, for example, in One-Step monomer BPDM.

Multifunctional adhesive systems are represented by materials that provide adhesion to the tissues of many dental materials: composites, ceramics, amalgams, noble and base metals.

WORKING PRINCIPLES OF MODERN ADHESIVE SYSTEMS

4th generation. A prerequisite for successful adhesion of the bonding system to the surface of the tooth keeps the surface slightly moist, the so-called ***wet bonding.*** It prevents the collagen collapsing (*dessication*). But sometimes it is very difficult to determine this condition, which can affect the strength of adhesion. Optimal drying of dentin is carried out for 2–3 seconds with a weak stream of air. The enamel becomes matte, and the dentin is without excess sparkling. Other methods of drying the tooth surface after etching consist in:

– drying the working field by a jet of air reflected from the mirror;

– drying the enamel and dentin with special sponges, applicators, sterile cotton balls.

After removing the smear layer, primer is applied to the moist tooth surface and rubbed into the dentin with light massaging movements on average 20–30 seconds. The entire surface of the dentin should be shiny after the primer application. It requires from 1 to 5 applications. The polymerization of the primer is carried out according to the manufacturer's instructions. Reducing the contact time of the primer with the tooth tissues leads to a decrease in the adhesion force. Bond is applied once, blown with a weak stream of air and polymerized. As a result, hybrid layer is formed, providing a strong bond between the hydrophobic composite and tooth tissues. Adhesion to dentin is often stronger than to enamel, which prevents separation of the restoration from dentin.

5th generation. This generation requires total-etching technique and applying primer and adhesive together (one-bottle system). Like all systems with the total etching technique, the 5th generation systems are very sensitive to dentin overdrying. The total time of etching enamel and dentin is not more than 30 seconds. Then, etching gel or liquid should be removed with water (not with water-air spray) for 30 seconds. The next step is gently drying the tooth surface (Fig. 23, 24).

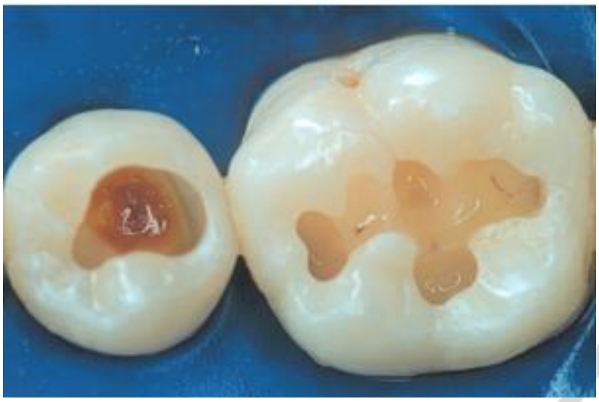

Fig. 23. Moist and shiny appearance, surface state appropriate to receive no-water systems (from M. H. Silva E Souza Junior., et al.)

Fig. 24. Dental surface when a water-based system is used (from M.H. Silva E Souza Junior., et al.)

Time of action primer+adhesive on the tooth surface is 20 seconds at minimum. After application, it should be blown with a weak stream of air. The adhesive system should stop moving on the surface from the stream of air (Fig. 25).

Fig. 25. Tooth surface after applying a bonding agent. (by Angelo Putignano)

Polymerization time is 10–30 seconds. It depends on:

– the type of the defect (big defect requires more polymerization time);

– the type of the lamp;
– the manufacturer's instructions.

6^{th} generation. The equipment of the first type system includes 2–3 bottles. All self-etching primers contain water, thus, the dentin state (dry or wet) is less important. The technique of "wet-bonding" or the technique of "dry bonding" can be used. The scheme of work includes at least two stages:

1) one-stage etching + priming;
2) bonding.

Etching agent with primer together is applied to the tooth surface for 15–30 seconds (it depends on the manufacturer's instructions), then it is dried with a weak air stream to remove excess moisture. The next step includes applying the bond and polymerizing it for 10–20 seconds.

The set of the second type system contains 2 bottles. The first component is a self-etching agent. The other component is "primer-bond". The first component usually contains a colorant which is discolored after etching the tooth tissues. The neutralization reaction is carried out by hydroxyapatite. After the etching step, a "primer-bond" mixture is applied, dried to remove the solvent and polymerized.

7^{th} generation. This system represents one-bottle system (etching agent+primer+adhesive). The standard working scheme (Fig. 26) involves preliminary shaking the solution, then applying it to the enamel and dentin in several layers, starting with the enamel (for 20–30 seconds). Then it is dried with a weak air stream and polymerized for 5–20 seconds (according to the manufacturer's instructions). The minimum time for adhesive preparation with these systems is 35 seconds.

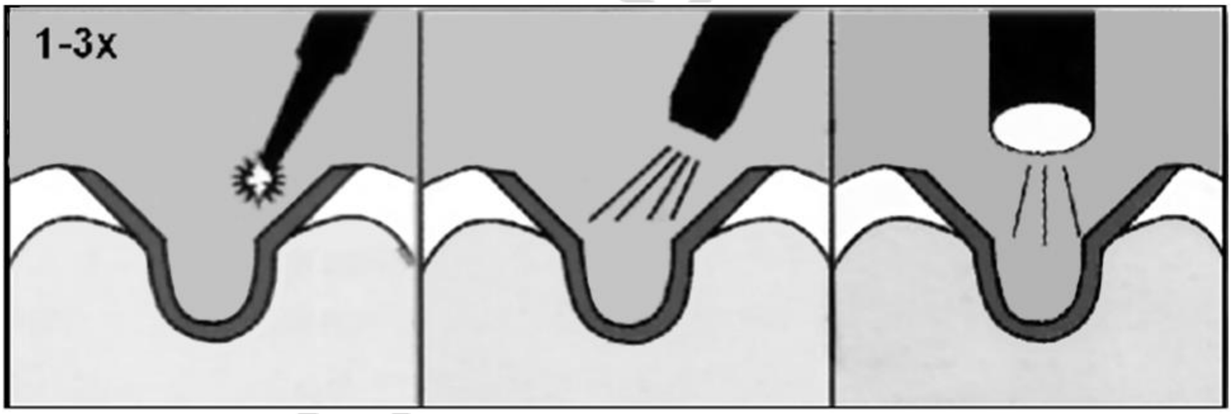

Fig. 26. The standard working scheme with 7^{th} generation (absence of the removing stage of the etching agent).

Unlike bonding to dentin, application of self-etch adhesives to enamel has been a controversial issue, particularly when mild self-etch adhesives are used on uncut enamel. The more aggressive versions can completely dissolve or disperse smear layers, forming thick hybrid layers in cut enamel and dentin that approach those achieved with conventional phosphoric acid etching. Conversely, the less aggressive versions incorporate smear layers as part of the bonded interface, forming only thin hybrid layers in intact dentin or enamel that are less than 1–2 μm thick.

For bonding to uncut enamel, the efficacy of self-etch adhesives is dependent upon their ability to demineralize the more acid-resistant aprismatic enamel layer.

Some manufacturers recommend pre-etching unground enamel (Fig. 27) with phosphoric acid prior to the application of self-etch adhesives to improve enamel–resin bond strength. The pre-etching of enamel (30 seconds) has been shown to enhance the bond strengths of self-etch adhesives to values that are comparable to those produced by etch-and-rinse adhesives.

Fig. 27. Selective etching

MISTAKES AND COMPLICATIONS IN WORK WITH ADHESIVE SYSTEMS. WAYS OF THEIR PROPHYLAXIS

All adhesive systems are sensitive to disruptions in work technique, which often leads to complications. Mistakes can be admitted at any stage of the work. Most common mistakes are:

– inadequate isolation of the working field;
– insufficient or excessive etching;
– overdrying of the tooth tissues;
– insufficient time for the application of the material;
– incorrect use of the adhesive system components;
– incomplete polymerization.

The main result of these mistakes is decrease in adhesion strength, which leads to the restoration failure. As a rule, these mistakes are reversible and can be easily eliminated, even at the stage of treatment.

The complications are divided into immediate and long-term complications.

Immediate complications appear due to a number of reasons:

– irregularities in the work technique (contamination of the working field, contact with eugenol-containing materials);

– problems are related with the properties of the material (poor-quality material, overdue material);

– patient's characteristics (allergy to the components of the material).

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Immediate complications are:
– postoperative sensitivity;
– loose dental filling;
– pulpitis;
– local allergic reaction to the gum, mucous membrane and, very rarely, a general allergic reaction.

Long-term complications are:
– inadequate marginal seal;
– secondary caries;
– loose dental filling;
– pulp necrosis.

Effective methods for preventing mistakes and complications are exact observance of technology at all stages, and dynamic monitoring of the restorations.

CONCLUSIONS AND RECOMMENDATIONS

1. The choice of an adhesive system should be based on scientifically validated data, considering recommendations of the manufacturer and tasks for the solution of which the adhesive system will be applied.
2. Adhesive system is able to completely isolate the pulp from all kinds of irritants, and take on a role of an insulating liner.
3. Work with modern adhesive systems requires complete removal of the smear layer from the surface of the enamel, dentin, and cement.
4. Application of adhesive systems with total etching technique is based on the concept of wet bonding, thus, overdrying dentin leads to a significant reduction in adhesion and post-operative sensitivity.
5. Different combinations of materials from different manufacturers are possible.
6. Contamination of the tooth surface with blood, gingival fluid, saliva or oil should be avoided at all work stages.

A competent choice and a correct working technique with modern adhesive systems will solve a large number of tasks and ensure a long-term success of tooth restoration.

TEST

1. What substance can remove the smear layer?
a) Bis-GMA;
b) Orthophosphoric acid;
c) Maleic acid;
d) Citric acid.

2. Orthophosphoric acid (enamel etchant) is commonly used in a ______ concentration:
a) 20 %;

b) 32 %;
c) 37 %;
d) 50 %.

3. Primers contain _______ monomers.

a) Hydrophilic;
b) Hydrophobic;
c) Hydrophilic and hydrophobic.

4. What substances can be used as a solvent in adhesive system?

a) Alcohol;
b) Water;
c) Acetone;
d) All the answers are correct.

5. ________ layer is created after the preparation of the caries cavity.

a) Hybrid;
b) Hybridoid;
c) Smear4
d) Middle.

6. Hydrophobic monomers are:

a) Bis-GMA;
b) TEGDMA;
c) HEMA;
d) PENTA.

7. Hydrophilic monomers are:

a) UDMA;
b) HEMA;
c) 4-META;
d) Bis-GMA.

8. What layer is created after applying the bonding system to the surface of the tooth?

a) Smear layer;
b) Bottom layer;
c) Hybrid layer;
d) Hybridoid layer.

9. What components does a smear layer contain?

a) Coagulated proteins;
b) Odontoblastic processes;
c) Saliva;
d) Fractured apatite crystallite aggregates;
e) All the answers are correct.

10. How long should a tooth be etched? (choose the most appropriate answer)

a) 10 seconds;
b) 60 seconds;
c) 100 seconds;
d) The etching time depends on the tooth structure.

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11. Should we re-etch enamel and dentin when they are contaminated by saliva after etching?

a) Yes;
b) No.

12. What type of the etchant is the most convenient for using?

a) Transparent liquid;
b) Dye liquid;
c) Transparent gel;
d) Dye gel.

13. Contraindications to using adhesives are:

a) Allergy to any component of the adhesive system;
b) Reparation of the fractured porcelain, amalgam;
c) Direct pulp capping;
d) Poor oral hygiene;
e) Minimally invasive treatment.

14. Since what generation has "total etch" technique been used?

a) 3^{rd} generation;
b) 4^{th} generation;
c) 5^{th} generation;
d) 6^{th} generation.

15. What generation of adhesive systems is considered as a "gold standard"?

a) 4^{th} generation;
b) 5^{th} generation;
c) 6^{th} generation;
d) 7^{th} generation.

16. What is the difference between the 4^{th} generation and 5^{th} generation of adhesive systems?

a) 4^{th} generation adhesive system has only chemical bonding with tooth surface;
b) There is no etching step in the 5^{th} generation adhesive system;
c) Fewer steps of adhesive preparation.

17. How many bottles are used in the 7^{th} generation of adhesive system?

a) 1 bottle;
b) 2 bottles;
c) 3 bottles.

18. Choose the *adhesive systems according to the filling agents:*

a) Filled, unfilled;
b) Unfilled, filled, nanofilled;
c) Filled, nanofilled.

19. The functions of the solvent are:

a) dissolving and preserving the working properties of organic monomers;
b) wetting the surface of the tooth tissues;
c) increasing the permeability of dentin for hydrophilic monomers;
d) responsibility for self-curing process.

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20. The self-etching adhesives of the 6th generation include:

a) One bottle with etching agent, primer and adhesive;

b) Two bottles, the first with etching agent, and the other with primer and adhesive;

c) Two bottles, the first contains etchant and primer, the other contains adhesive.

21. What are disadvantages of using the 6th generation adhesive system?

a) Bond to enamel is weaker as compared to dentin;

b) It etches the dentin less aggressively than total etch products;

c) Reduces postoperative sensitivity because it etches and primes at the same time.

22. What are advantages of the 7th generation adhesive system?

a) Different bond strength for enamel and for dentin;

b) No long-term results;

c) No postoperative sensitivity;

d) Collapse of the collagen network is prevented.

Репозиторий БГМУ

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