Operative Dentistry

Lecture (5) Dr. Raghad Noori

Enamel and Dentin Bonding (Agents and Techniques)

❖ Definition

The bonding agents (dental adhesives) are resinous materials used to enable the restorative material to bond and adhere to dental hard tooth structures (enamel, dentin, and cementum).

❖ Requirements of Dental Adhesives

1. Provide high bond strength to enamel.
2. Provide bond strength to dentin similar to that to enamel.
3. Show good biocompatibility to dental tissue, including the pulp.
4. Prevent and minimize microleakage at the margins of restorations.
5. Prevent recurrent caries and marginal staining.
6. Easy to use.
7. Possess a good shelf life.
8. Compatible with a wide range of resins.

❖ Indications

1. To aids in bonding composite and even amalgam restorations to tooth structure.
2. To treat dentinal hypersensitivity.
3. For the repair of fractured porcelain, amalgam and resin restorations.
4. For pit and fissure sealants.
5. To lute crowns.
6. To bond orthodontic brackets.

❖ Adhesive System Classification

Adhesives have been classified using several methods:

- ✓ generation (from 4th through 8th)
- ✓ solvent type (water, ethanol, and acetone)
- ✓ mechanism of smear layer removal (etch and rinse "E&R", and self-etch "SE")

- ✓ number of clinical steps (3-step E&R, 2-step E&R, 2-step SE, and 1-step SE).

❖ Enamel Bonding

Bonding to enamel requires two clinical steps:
1) Acid etching, followed by
2) The application of the adhesive resin to the etched surface.

❖ Dentin Bonding

Bonding to dentin has been proven more difficult and less reliable and predictable than enamel. This is because of morphologic, histologic and compositional differences between them. It requires etching, priming, and bonding.

❖ Problems Encountered During Dentin Bonding:

1.Dentin contains more water than does enamel.

2. Hydroxyapatite crystals have a regular pattern in enamel whereas in dentin, hydroxyapatite crystals are randomly arranged in an organic matrix.

3. Presence of smear layer makes wetting of the dentin by the adhesive more difficult.

4. Dentin contains dentinal tubules which contain vital processes of the
pulp, odontoblasts. This makes the dentin a sensitive structure.

5. Dentin is a dynamic tissue which shows changes due to aging, caries or
operative procedures.

6. Fluid present in dentinal tubules constantly flows outwards which reduces the adhesion of the composite resin.

❖ Components of Dental Adhesives

Dental adhesives consist of three main components:

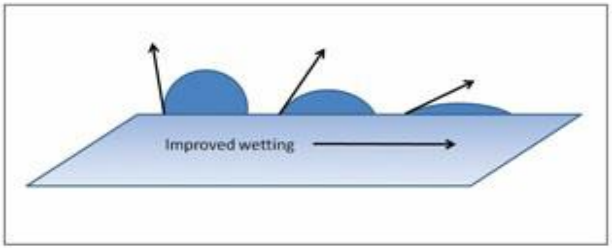
- 1. Etchant (acidic molecules that alter or remove the smear layer)
- 2. Primer
- 3. Bonding resin (adhesive resin).

1. Etchant:

A-In E&R Adhesives: A separate etching step is required using a strong acid (usually 35% to 37% phosphoric acid at a pH of approximately 0.9) to completely etch enamel and dentin, followed by a thorough water rinse.

☒ **On enamel**, it is applied for 15 to 30 seconds and the goals of enamel etching are:

1. Cleaning enamel surface from the smear layer.
2. Increasing the enamel surface area available for bonding.
3. Demineralization and partially dissolving the mineral crystallites to create retentive microporosities into which the resinous bonding agent can infiltrate and form retentive resin tags (micromechanical retention). These tags are formed within a 550-μm-thick microporous layer.
4. In addition, acid etching increases the surface energy and lowers the contact angle of resins to enamel. It has been shown that optimal enamel–resin bonds could be achieved as long as the etched enamel surface was clean and free from any contamination.

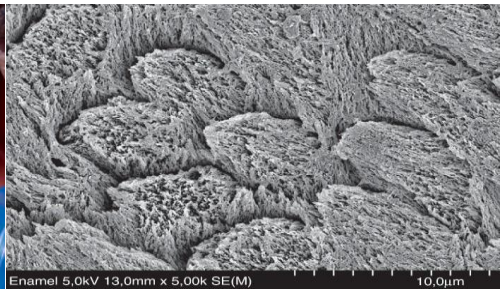


• If phosphoric acid concentration is greater than 50%, then monocalcium phosphate monohydrate will get precipitated.

• If concentration is lower than 30%, dicalcium phosphate monohydrate is precipitated which interferes with adhesion.

• Deciduous teeth require longer time for etching than permanent teeth because of the presence of aprismatic enamel in deciduous teeth.

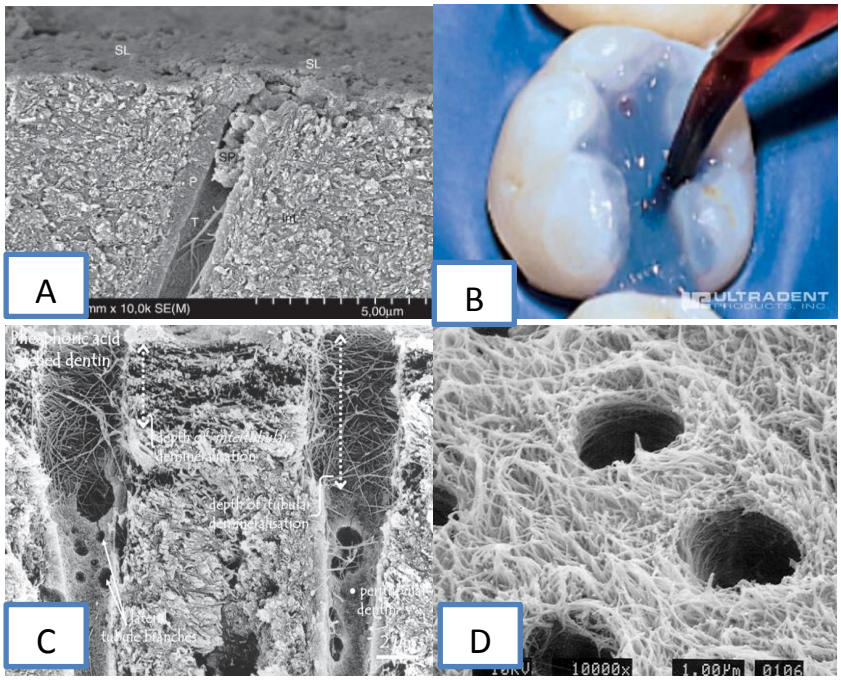




☒ **On dentin,** the etchant is applied for <u>not more than 15seconds</u> followed by thorough rinsing with water.

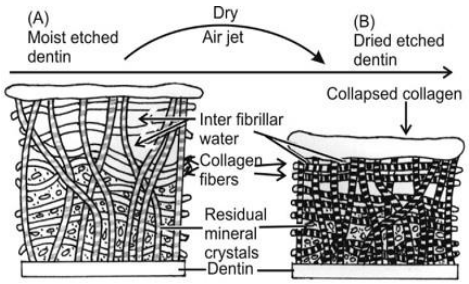
The acid:

1. removes the smear layer (1-5µm thick amorphous layer comprised of residual organic and inorganic debris formed as a result of mechanical cutting of enamel and dentin),
2. demineralizes the superficial 3-5 µm of the superficial dentin exposing the collagen fibrils of the dentinal matrix, and
3. removes smear plugs (debris occluding the dentinal tubules orifices) and open the dentinal tubules, funneling their orifices. Areas from where minerals are removed are filled with water. This water acts as a plasticizer for collagen, keeping them in an expanded soft state. Thus, spaces for resin infiltration are also preserved.



Dentin Etching. A: prepared cavity showing smear layer SL, B: acid etching, C: demineralized dentin, D: exposed collagen fibrils.

✓ If the dentin surface is <u>made too dry</u>, there will be <u>collapse of the collagen fibers of demineralized dentin</u>. This results in <u>low bond strength</u> because of ineffective penetration of the adhesive into the dentin.



B- In SE Adhesives: No separate step of etching is required since the etching component (either weak acid or acidic monomer) is already included within the primer or adhesive solution. These adhesives render the smear layer permeable to monomers rather than removing it completely. Some self-etching adhesives simultaneously dissolve the smear layer and infiltrate enamel and dentin, using the mineral content of the substrate to buffer the acidic monomers and inhibit their dentin-etching ability with increasing depth.

- ✓ **Note: The smear layer** : is the layer of grinding debris, which adheres to the surface and partially plugs the tubular orifices. For optimum success, dentin bonding systems must remove, modify, or penetrate this organic-inorganic barrier to facilitate resin diffusion and micromechanical bonding with the demineralized dentinal substrate. Etch-and rinse adhesives completely dissolve the smear layer while self-etching adhesives only modify it, and so their bond strength can be affected by the smear layer thickness. Smear layer modification is correlated to the pH of the self-etching adhesives.

2. Primer:

The primer is a mixture of monomer molecules possessing both hydrophilic as well as hydrophobic ends which have affinity for the exposed collagen and resin respectively. Solvents are added to reduce the inherent viscosity of co-monomer blends, allowing them to infiltrate wet demineralized dentinal matrices. Primers are used to increase the diffusion of resin adhesive into moist and demineralized dentin and thus obtaining optimal micromechanical bonding. After rinsing of the etching agents, the presence of adequate water maintains the full expansion of the demineralized dentinal matrix. It is important to remove excess pooled moisture by air blotting or wiping with a micro-brush or an absorbent paper. Properly moist dentin should exhibit a shiny, hydrated surface.

However, excessive air drying of dentinal surfaces removes most of the water from the matrix, causing the collagen fibrils to collapse and shrink resulting in lack of sufficient interfibrillar spaces available for resin penetration. To resolve this undesirable situation, the dentin must be rewetted and primed to re-expand the collapsed matrix. For optimal penetration of primer into demineralized dentin, it should be applied in multiple coats and it should be gently air sprayed after application to volatilize any remaining solvent before the adhesive resin is applied. Any remnant solvent will be trapped in the polymerized interface and will weaken the adhesive-dentin bond.

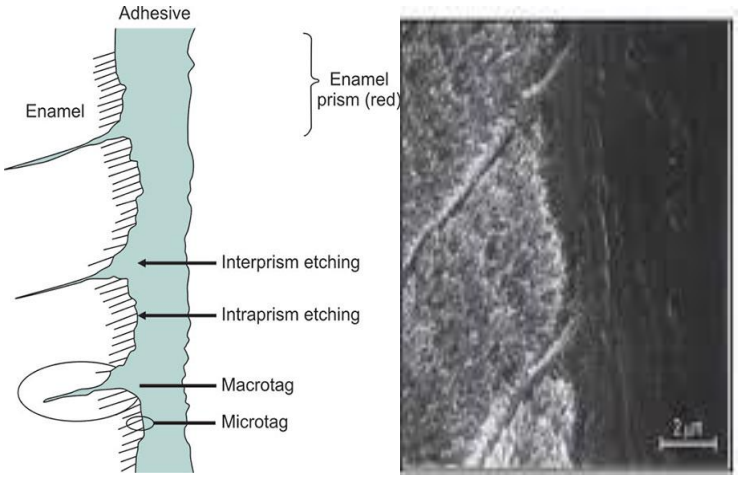
NOTE: After priming, do not light cure. The primer function is to pave the way for the resin adhesive.

- ✓ **Examples of primer monomers are:**
- ✓ HEMA (hydroxyethyl methacrylate),
- ✓ TEGDMA (triethyleneglycol dimethacrylate),
- ✓ bis-GMA, (Bisphenol glycidyl methacrylate)
- ✓ UDMA (urethane dimethacrylate), and
- ✓ 4-META (4-Methacryloxyethyl trimellitate anhydride).

3. Adhesive resin:

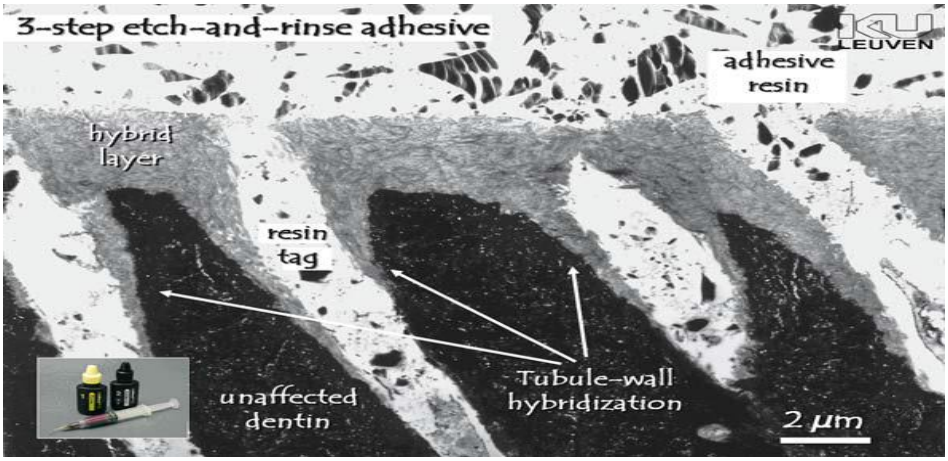
Adhesive resins are hydrophobic solvent-free monomer blends (usually bis- GMA or UDMA with TEGDMA added to lower the viscosity of the bonding agent).

☒ **On Enamel:** The bonding agents rapidly wet and penetrate the clean, dried, conditioned enamel into the microspaces forming resin tags. The resin tags which form between enamel prisms are known as macrotags. Finer network of numerous small tags is formed across the end of each rod where individual hydroxyapatite crystals were dissolved and are known as microtags. These microtags are more important due to their larger number and greater surface area of contact. Micro and macrotags within the enamel surface constitute the fundamental mechanism of enamel-resin adhesion.



☒ **On dentin:** Adhesive resins when applied to the etched and primed dentin surface, they will diffuse and infiltrate the demineralized wet-primed exposed collagen layer and fill the interfibrillar spaces covering exposed collagen fibrils (forming the hybrid layer) and enter the opened dentinal tubules (forming resin tags) achieving resin-dentin micromechanical bonding.

The adhesive resin is applied actively on the primed surface with a brush and then the excess is removed by controlled air thinning, by bristle brush or microbrush before curing.



Bonding to the inorganic part of dentin involves ionic interaction among the negatively charged group of the bonding agent (for example, phosphates, amino acids and amino alcohols, or dicarboxylates) and the positively charged calcium ions.

Commonly used bonding systems employ use of phosphates. Bonding to the organic part of dentin involves interaction with Amino (–NH), Hydroxyl (–OH), Carboxylate (–COOH), Amide (–CONH) groups present in dentinal collagen. Dentin bonding agents have isocyanates,

aldehydes, carboxylic acid anhydrides and carboxylic acid chlorides which extract hydrogen from the above mentioned groups and bond chemically.

❖ Generations of Dental Adhesives

Historically, dentin bonding agents have been classified based on chemistry and the manner in which they treat the smear layer into 7 generations.

The first three generations failed to provide adequate bond strength to dentin. The 4th and 5th generations are E&R adhesives, while the 6th and 7^{th} generations are SE adhesives.

➢ Fourth Generation Adhesives

Fourth generation bonding agents represented significant improvements in the field of adhesive dentistry. These agents are based on "E&R technique" and moist bonding concept.

Mechanism of Bonding

Fourth "generation" is characterized by the process of hybridization at the interface of the dentin and the composite resin. Hybridization is the phenomenon of replacement of the hydroxyapatite and water at the dentin surface by resin. This resin, in combination with the collagen fibers, forms a hybrid layer. In other words, hybridization is the process of resin interlocking in the demineralized dentin surface. This concept was given by Nakabayashi in 1982.

Bonding with 4th generation involve three separate steps; etching, priming and resin bonding.

- **Advantages**
  1) Ability to form a strong bond to both enamel and dentin.
  2) High bond strength to dentin (17–25 MPa)
  3) Ability to bond strongly to moist dentin
  4) Can also be used for bonding to substrates such as porcelain and alloys (including amalgam).
- **Disadvantages**
  1) Time consuming
  2) More number of steps
  3) Technique sensitive

➢ Fifth Generation Adhesives

Fifth-generation adhesives were made available in the mid-1990s. Similar to the fourth generation, they are based on the E&R technique (a separate step of acid etching is needed). In these agents the primer and adhesive resin are in one bottle. Basic differences between fourth and fifth generation is the number of basic components of bottles. In this adhesive, only 2 steps are required;

1. separate etching step, and
2. priming and bonding step.

➢ Sixth Generation Adhesives

These were made available in 2000. In sixth generation etching step is eliminated, because in sixth generation; etchant and primer are available in single solution and the adhesive resin in a separate bottle (2 step).

Most self-etching primers are moderately acidic with a pH that ranges between 1.8 and 2.5. Because of the presence of an acidic primer, sixth generation bonding agents do not have a long shelf-life and thus have to be refreshed frequently.

In these agents as soon as the decalcification process starts, infiltration of the empty spaces by the dentin bonding agent is initiated

- **Properties**
  1) Reduces postoperative sensitivity because they etch and prime simultaneously.
  2) It etches the dentin less aggressively than total etch products. Demineralized dentin is infiltrated by resin during the etching process.
  3) Since they do not remove the smear layer, the tubules remain sealed, resulting in less sensitivity.
  4) They form a relatively thinner hybrid layer than traditional product, which results in complete infiltration of the demineralized dentin by the resin monomers.
  5) Much faster and simpler technique.
  6) Less technique sensitive as fewer number of steps are involved for the self-etch system.

➢ Seventh Generation Adhesives

They achieve the same objective as the sixth generation systems except that they simplified multiple sixth generation materials into a single component, single bottle one-step self-etch adhesive, thus minimizing the number of steps and avoiding any mistakes that could be encountered (the bottle contains all the components which are the weak acid, primer, and the adhesive).

➢ Multimode or Universal Adhesive Systems

Slight modifications of dentin adhesive formulations were made to produce a new class of universal adhesives. These materials are called multimode or universal because they can be used as SE, E&R, or selective enamel-etch systems. These adhesives have the ability to bond methacrylate- based restoratives, cement, and sealant materials to dentin, enamel, glass ionomer, and several indirect restorative substrates, including metals, alumina, zirconia, and other ceramics.

☒ Summery for the clinical steps in etch and rinse adhesive :

1. Apply 35% to 37% phosphoric acid to enamel for 15 to 30 s and to dentin for 15 s (*sound dentin should be etched for no longer than 15 seconds).
2. Rinse the etched surface for 15 s with an air-water spray.
3. Gently air dry to remove excess moisture.
4. Apply primer/bonding solution generously, producing a shiny appearance, then vigorously rub at least 30 s.
5. Air dry to evaporate solvent for 30 to 40 s.
6. Actively reapply the primer/bonding solution and air dry.
7. Cure for manufacturer recommended time, which is typically about 10 to 20 s.

☒ Summery for the clinical steps in self-adhesive:

1. Selectively etch enamel with 35% to 37% phosphoric acid for 15 s.
2. Air-water rinse for 15 s, dry gently.
3. Actively apply the one step self-adhesive on etched enamel and un-etched dentin for the time recommended by the manufacturer.
4. Air dry to remove any excess solution and solvent and terminate the etching reaction.
5. Reapply the adhesive in multiple layers using an active rubbing motion.
6. Air dry to remove any excess solution and solvent and terminate the etching reaction.
7. Cure for manufacturer recommended time, which is typically about 10 to 20.