Lec. 6 **Restorative Dentistry**

Fundamental Concepts of Enamel and Dentin Adhesion

Adhesion: the state in which two surfaces are held together by interfacial forces.

Adhesive: is a material, frequently a viscous fluid that joins two substrates together by solidifying and transferring a load from one surface to the other.

Adhesion strength: is the measure of the load-bearing capacity of an adhesive joint.

MECHANISM OF ADHESION:

In dentistry, bonding of resin-based materials to tooth structure is a result of following mechanisms:

1. ***Mechanical***—penetration and interlocking of the adhesive resin with irregularities in the surface of the substrate (the tooth surface).

2. ***Adsorption***—chemical bonding to the inorganic component (hydroxyapatite) or organic components (mainly type I collagen) of tooth structure.

3. ***Diffusion***—precipitation of substances on the tooth surfaces to which resin monomers can bond mechanically or chemically

For good adhesion, close contact must exist between the adhesive and the substrate (enamel or dentin). A major problem in bonding resins to tooth structure is that all methacrylate-based dental resins shrink during polymerization. Thus, dental adhesives must provide a strong initial bond to resist the stresses of resin shrinkage.

Enamel Adhesion:

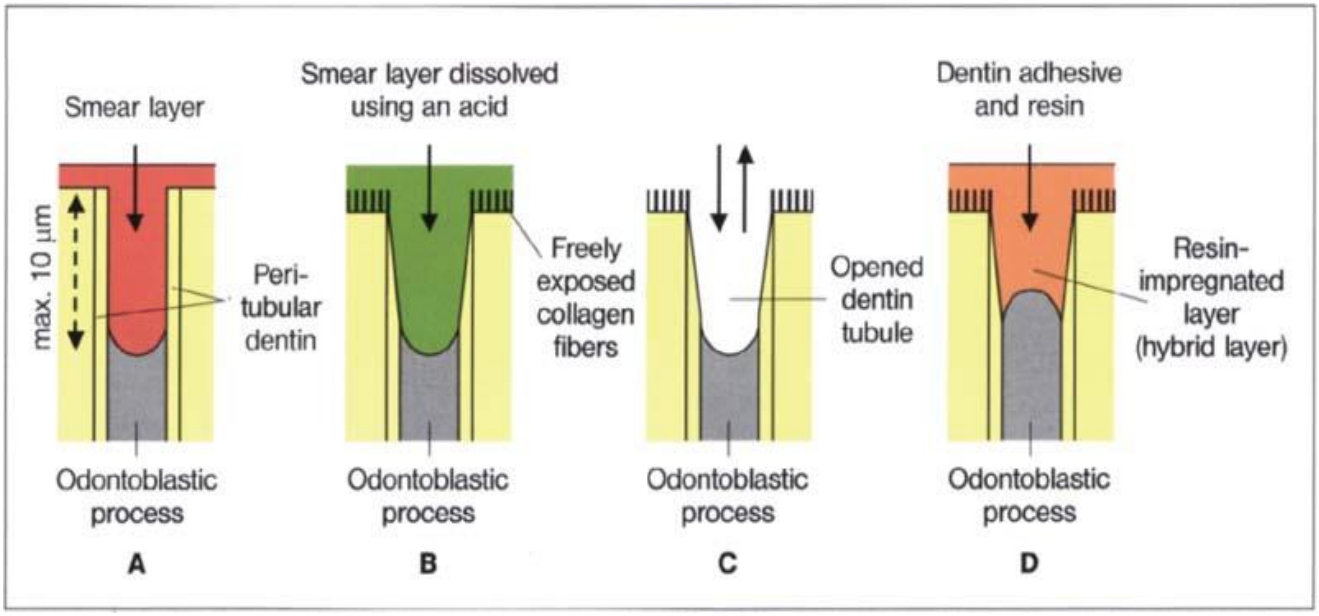
Enamel etched with 37% phosphoric acid liquid or gel (Gel form preferred) applied by syringe or brush for 15-20 seconds. Etching produces micropores into which the resin material flow and mechanically interlock with enamel. Clinically, etching procedure results in frosty white appearance of the etched enamel.

The formation of resin microtags within the enamel surface is the fundamental mechanism of resin-enamel adhesion, when a fluid resin-based material is applied to the irregular etched enamel, the resin penetrates into the surface by capillary action, then when the material polymerize, it becomes interlocked with the enamel surface. Bond strength of etched enamel to composite resin usually varies between 15 and 25 mpa.

Dentin Adhesion:

Adhesive materials can interact with dentin mechanically, chemically, or both. Dentin adhesion relies primarily on the penetration of adhesive monomers into the network of

collagen fibers left exposed by acid etching, to form resin tags into open dentinal tubules and also form a layer of hybridization' incorporating dentinal collagen with resin.



Challenges in Dentin Bonding:

Bonding to dentin has been proven more difficult and less reliable than enamel. This is because of the following:

1. Enamel is a highly mineralized tissue composed of more than 90% (by volume) hydroxyapatite, whereas dentin contains 50 percent inorganic material and more water than does enamel.
2. Dentin contains dentinal tubules, which contain vital processes of the pulp odontoblasts. This makes the dentin a sensitive structure.
3. Fluid present in dentinal tubules constantly flows outwards, which reduces the adhesion of the composite resin.
4. Presence of smear layer ***(composed of residual organic and inorganic components and debris formed during tooth preparation, it fills the orifices of dentin tubules, forming "smear plugs")*** and decreases dentin permeability; makes wetting of the dentin by the adhesive more difficult.
5. Dentin is a dynamic tissue, which shows changes due to aging, caries or operative procedures.

Moist vs Dry Dentin

By etching dentin, the smear layer and minerals from it are removed, exposing the collagen fibers.

If the Dentin Surface is Made Too Dry, collapse of the collagen fibers and demineralized dentin occurs. This results in low bond strength because of ineffective penetration of the adhesive into the dentin.

If the Dentin Surface is Too Wet, there is reduction in bond strength because presence of water droplets dilute resin primer and out-compete it for sites in the collagen network which prevents hybridization

Generations **of adhesives:**

First and second generations bonding agents

- Developed in 1960s and 1970s.
- These products did not recommend dentin etching and ignored the smear layer.
- Low bond strength (2–3 MPa) and (4-6MPa).

Third generation bonding agents

- Employed the concept of conditioning and priming before application of bonding agent
- Involved removal or modification of smear layer
- Three steps application, i.e. Etching of enamel + Application of primer + Bonding agent application
- High bond strength (8-15 Mpa) and reduced microleakage.

Fourth generation bonding agents

- Developed in early 1990s represented significant improvements in the field of adhesive dentistry
- Based on total etch technique (etch both enamel and dentin and rinse).
- Based on concept of hybridization and hybrid layer formation. (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).
- Three steps application, i.e. Total etching + Application of primer + Application of bonding agent
- High bond strength (17-25 MPa).

Fifth generation bonding agents

- Developed in mid 1990s.
- Uses two steps, i.e. Total etching + Application of primer and bonding agent.
- Primer + Bonding agent are available in single bottle.

- High bond strength.
- Easy to use.
- Reduced number of steps.

Sixth generation bonding agents

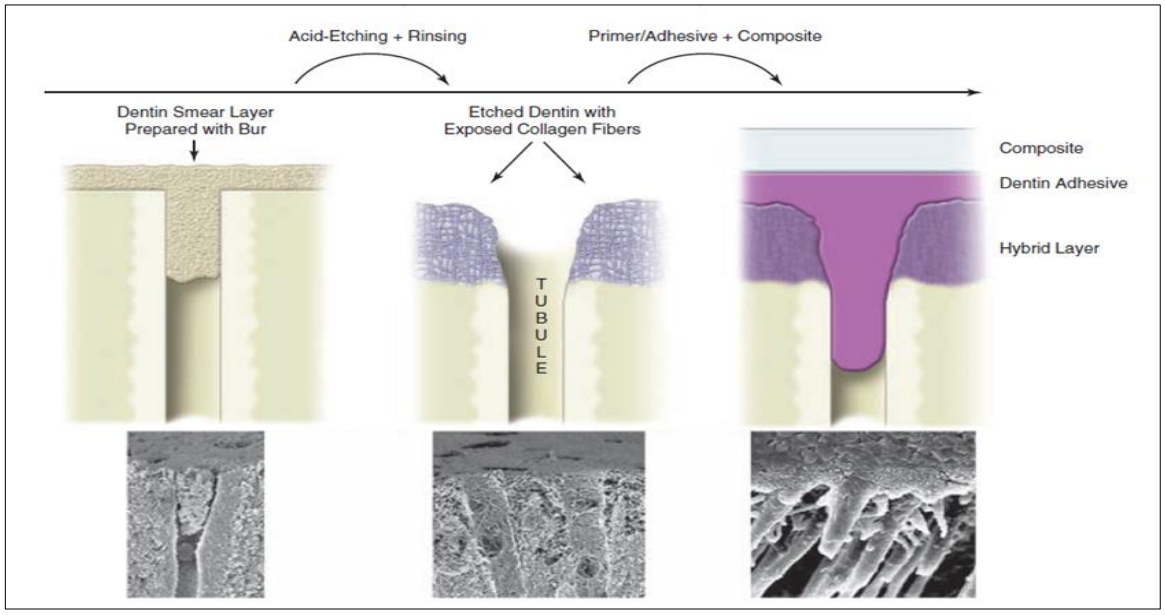
- Developed in early 2000s.
- Use self-etch primer. (Because of the presence of an acidic primer. Acidic with a pH that ranges between 1.8 and 2.5).
- Bond strength lower than fourth and fifth generation bonding agent.
- Reduced postoperative sensitivity.

Seventh generation bonding agents

- Developed in late 2000s
- All in one concept, i.e. components available as single component
- Uses self-etch primer
- Good bond strength
- No postoperative sensitivity.

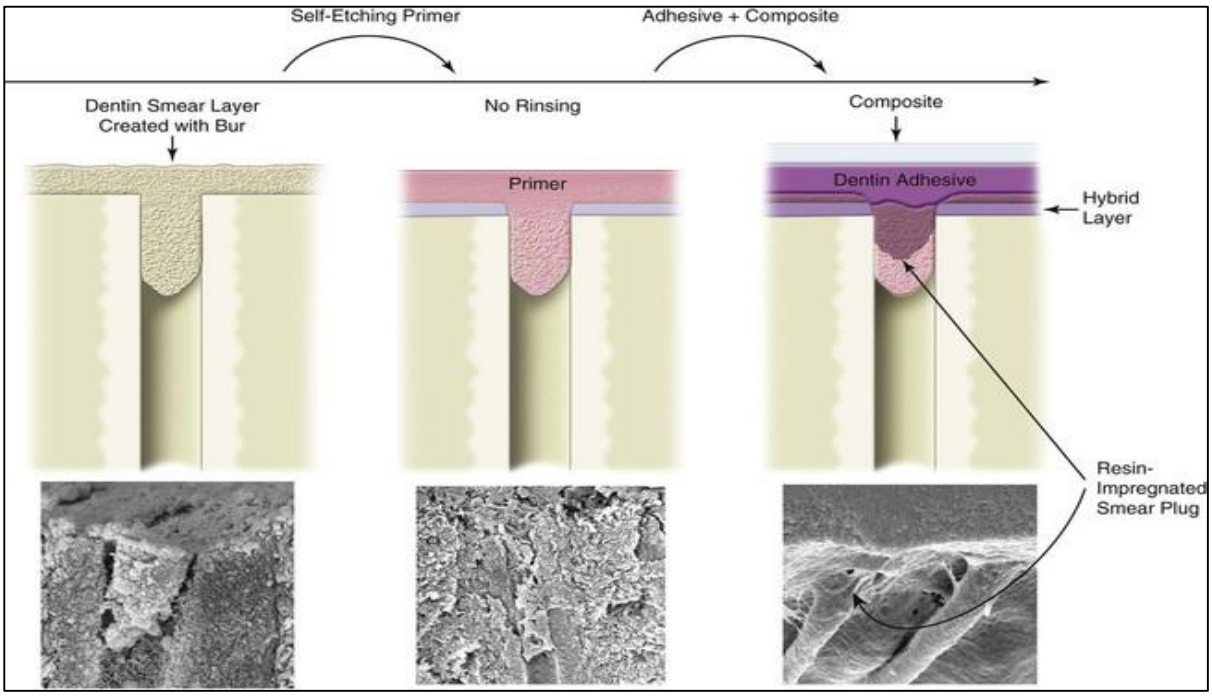
Total etch $\mathcal{VS}$ self-etch systems.

Total etch technique involves complete removal of smear layer by simultaneous acid etching of enamel and dentin. After total etching, primer and adhesive resin are applied separately or together. Acid removes the dentin smear layer, raises surface energy and modifies the dentin substrate so that it can be infiltrated by subsequently placed primers and resins.



Total etch (etch and rinse)

In self etch system; self etching primer is applied on prepared tooth surface. Then the demineralized dentin and smear layer is infiltrated by resin during etching process. In this type, smear layer is not removed and there is a formation of continuous layer incorporating smear plugs into resin tags. Since smear layer is not removed, it results in sealing of dentinal tubules thus reduced the post-operative sensitivity.



Self-etch system

Current bonding strategies:

1. **Total etch adhesive**

A-<u>Three step total etch adhesive:</u>

Etchant + Primer + Bonding Agent

Etchant (E):- -Removes the smear layer.

- Exposes the intertubuler and peritubular collagen.

- Opens the tubules.

-Decreases the surface free energy.

Primer (P):- Includes bifunctional molecules (hydrophilic and hydrophobic). - Envelops the external surface of collagen fibrils.

-Re-establishes surface free energy to levels compatible with more hydrophobic restorative materials

Bonding Agent (B): - Includes monomers that are mostly hydrophobic such as Bis-GMA.

- Copolymerizes with the primer molecule, penetrates and polymerizes into interfibriller spaces to serve as a structural backbone to hybrid layer.

B-<u>One-bottle total -etch (two step total-etch adhesive):</u>

Etchant +Primer and Bonding agent

2. Self-etch adhesive:

<u>A- Two -bottle self-etch;</u> Etchant and Primer + Bonding

Self-etch adhesive does not remove the smear layer, but modify it, the smear plug is impregnated with acidic monomers, but it is not removed and prepares the pathway for the penetration of fluid resin into micro channels that permeate the smear plug.

<u>B-All-in-one self-etch (EPB) we call it single application:</u>

-it demineralizes and penetrates dentin simultaneously leaving a precipitate on the hybrid layer.

-Forms a thin layer of adhesive.

- A multi-coat approach is recommended.