OPERATIVE DENTISTRY (LECTURE 5)

BY: DR. YASSER HAMEED EDAN

MASTER IN ESTHETIC AND RESTORATIVE DENTISTRY

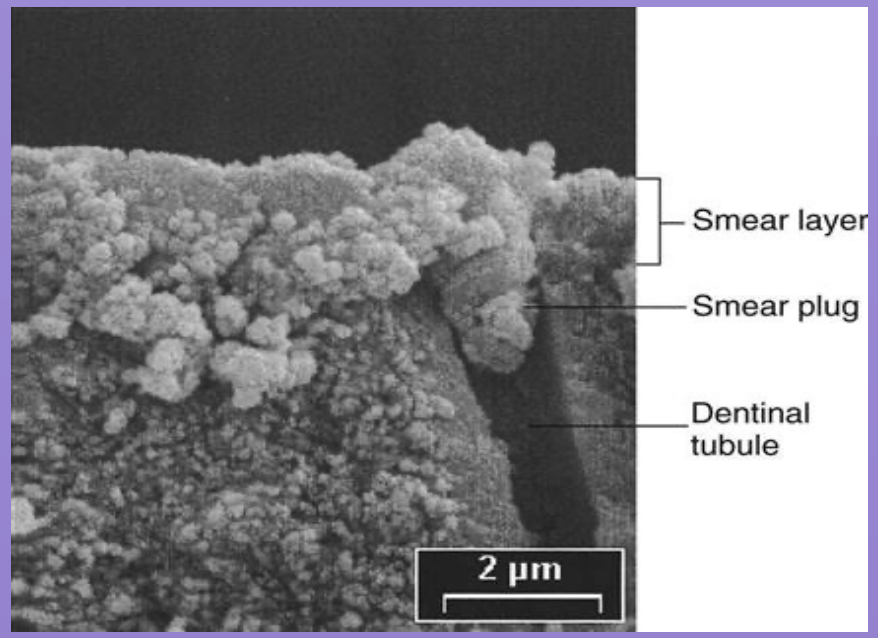
ISLAMIC UNIVERSITY

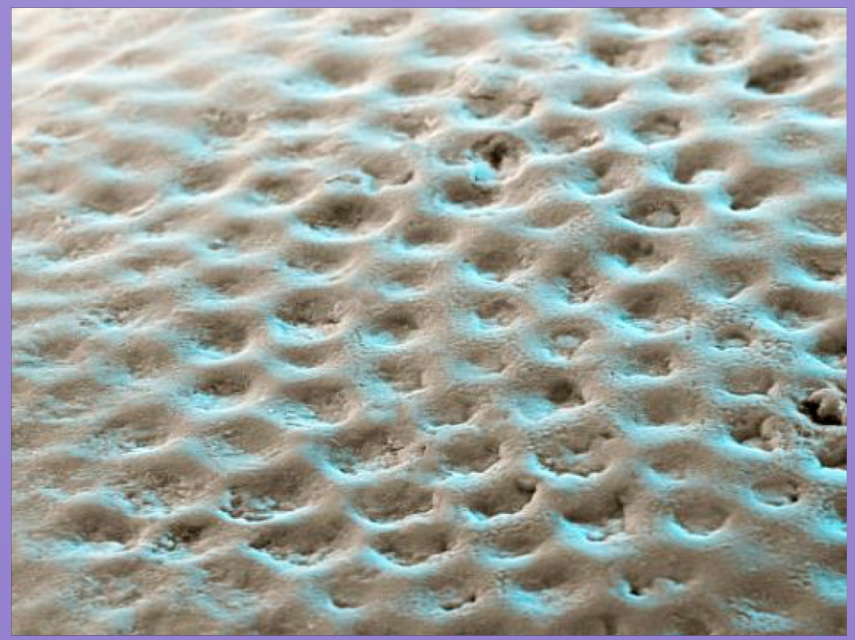
Enamel and Dentin Bonding or Adhesive (Agents and Techniques)

INTRODUCTION:

- Bonding agents can be **defined** as material of low viscosity, when applied on the tooth surface can form thin film after setting; used to enable the restorative material to bond and adhere to dental tooth structures (enamel and dentin)
- This thin film strongly bonded to tooth surface by resin tag from one side and from the another side chemically bonded to resin composite.

- The presence of **smear layer** of debris on the surface of the tooth after tooth preparation may affect the adhesion, (smear layer can defined as a semi permeable film of organic and inorganic debris on the prepared dentinal surface, and the smear layer fills the orifices of dentin tubules, forming smear plugs).





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.

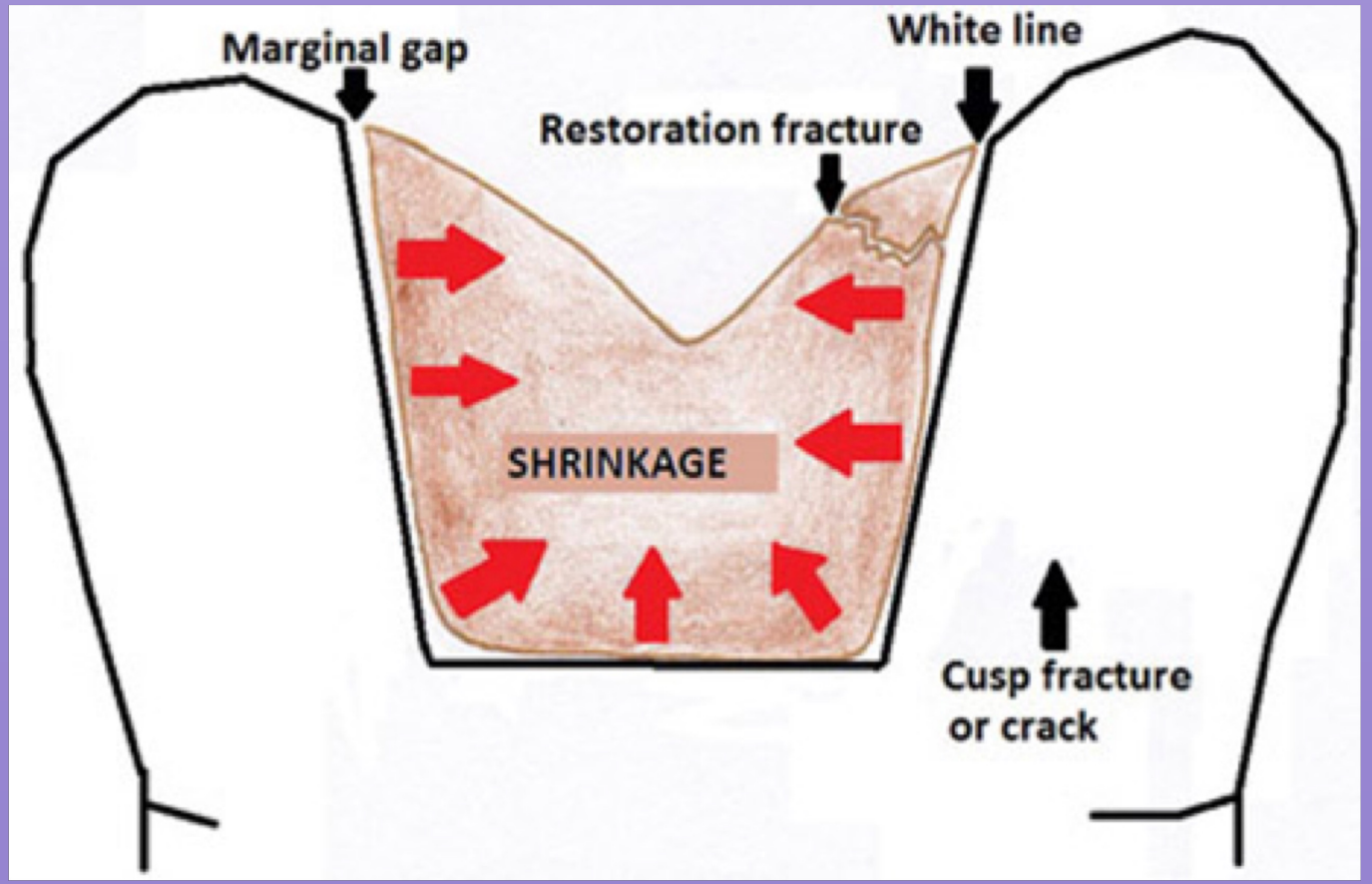
- Dental adhesives consist of three main components: *(1)* etchant (acidic molecules that alter or remove the smear layer), *(2)* primer, and *(3)* bonding resin.
- The latter is often referred to as the ***adhesive resin***, but the entire system also is typically called an ***adhesive.***
- Dental bonding agents are designed to provide a **sufficiently strong interface** between restorative composites and tooth structure to withstand mechanical forces and shrinkage stress.

- **The success of adhesives is dependent on two types of bonding:**

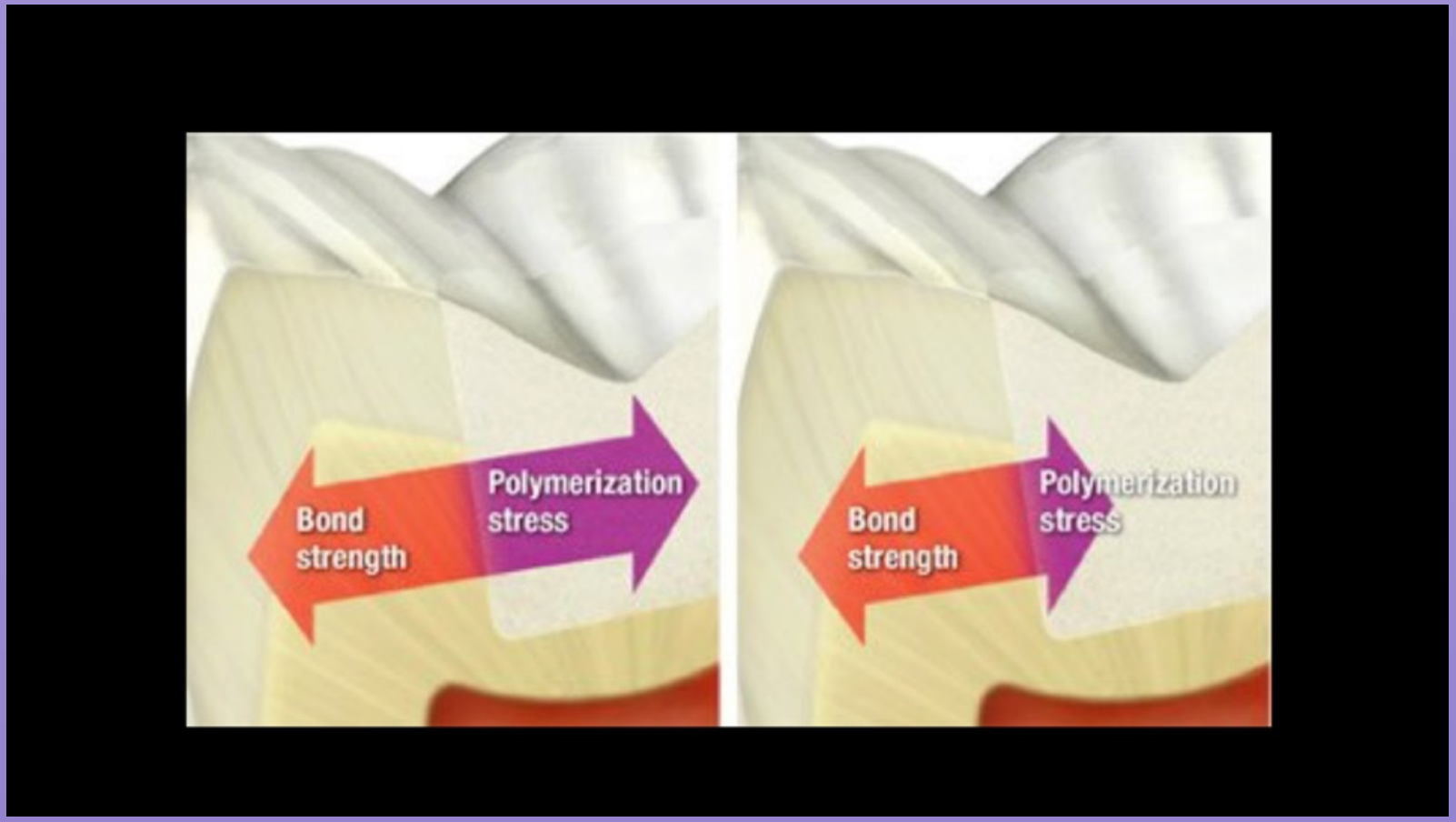
1. Micromechanical interlocking, chemical bonding with enamel and dentin, or both.

2. Copolymerization with the resin matrix of composite materials.

THE MAIN CAUSE OF COMPOSITE FAILURE IS **SHRINKAGE**



THE MAIN CAUSE OF COMPOSITE FAILURE IS **SHRINKAGE**



THE MAIN CAUSE OF COMPOSITE FAILURE IS **SHRINKAGE**

THE MAIN CAUSE OF COMPOSITE FAILURE IS **SHRINKAGE**

THE MAIN CAUSE OF COMPOSITE FAILURE IS **SHRINKAGE**

WHAT ARE THE

ETCHANT (E) - PRIMER (P) - BONDING AGENT (B)

ETCHANT:

- The etchant is composed of acidic molecules that alter or remove the smear layer and demineralize the enamel and dentin and prepare it for bonding.
- A number of acidic agents have been used to produce the required microporosity.
- However, phosphoric acid at a concentration between **30%** and **50%**, typically **37%**, is the preferred etching agent to produce consistent etching patterns while not damaging the pulp.
- Generally, the etchant is supplied as an **aqueous gel** to allow precise placement over a specific area**.**

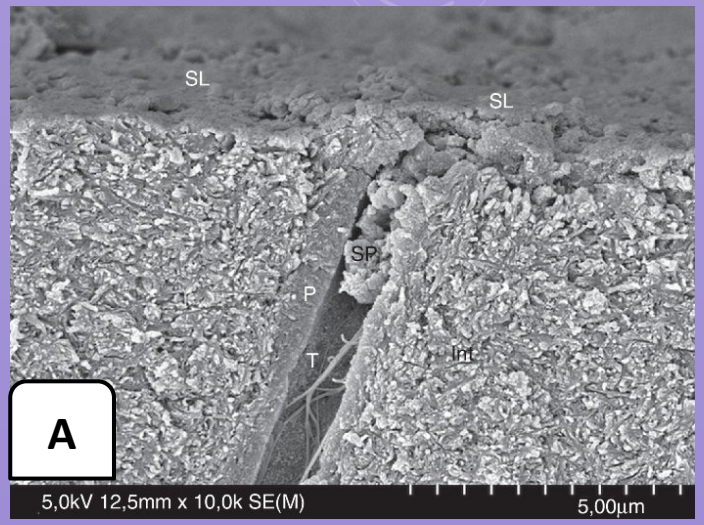
- ***In E&R Adhesives on enamel***

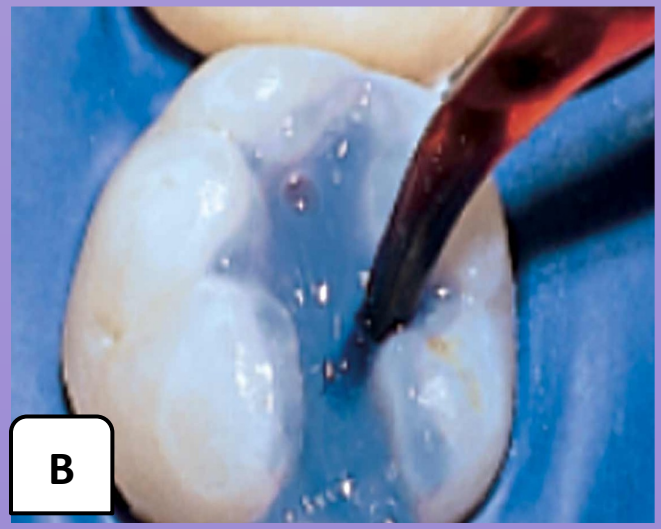
- It has been shown that optimal enamel–resin bonds could be achieved as long as ***the etched enamel surface was clean and free from any contamination***.
- If phosphoric acid concentration is greater than **50%**, then monocalcium phosphate monohydrate will get **precipitated**.
- If concentration 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 a prismatic enamel in deciduous teeth***.

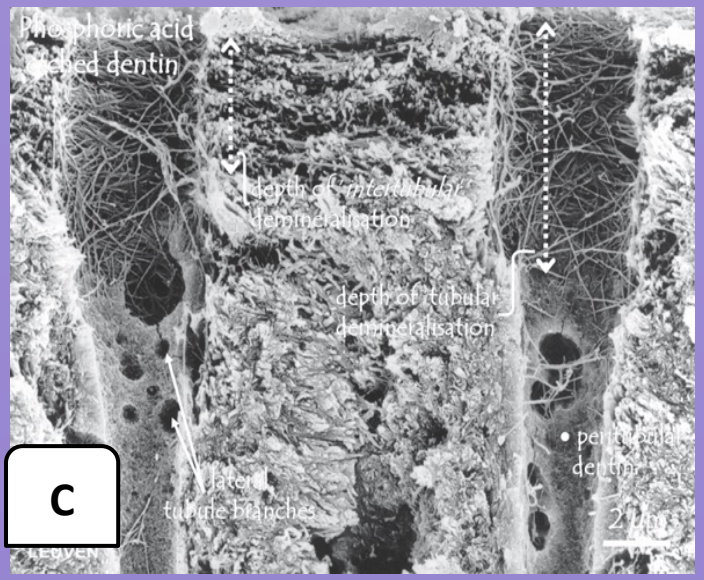
- *In E&R Adhesives on dentin*

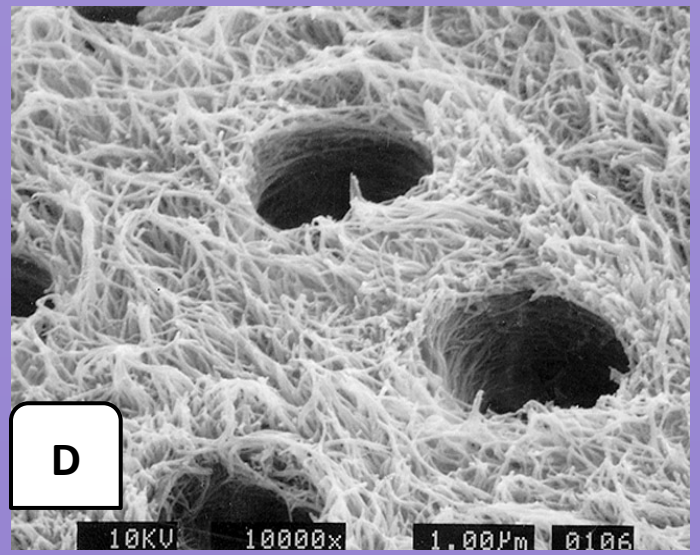
- the etchant is applied for not more than **15** seconds followed by thorough rinsing with water.
- The acid **1)** removes the smear layer (**1-5**µm thick amorphous layer comprised of residual organic and inorganic debris formed as a result of mechanical cutting of enamel and dentin), **2)** demineralizes 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**.
- If the dentin surface is made **too dry**, there will be **collapse of the collagen fibers** of demineralized dentin.
- This results in **low bond strength** because of ineffective penetration of the adhesive into the dentin.









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

- ***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 i**nfiltrate** enamel and dentin, using the mineral content of the substrate to **buffer** the acidic monomers and **inhibit** their dentin-etching ability with **increasing** depth.

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)

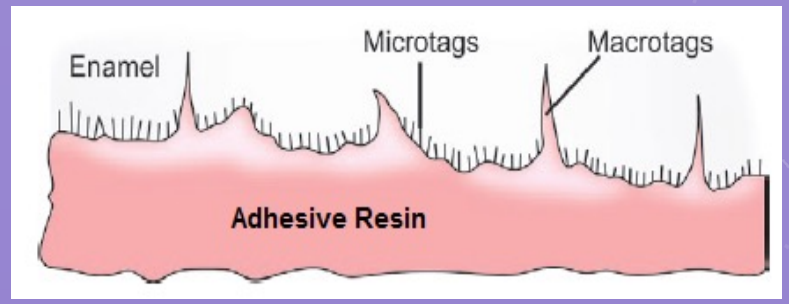
✓ UDMA (urethane dimethacrylate), and

✓ 4-META (4-Methacryloxyethyl trimellitate anhydride)

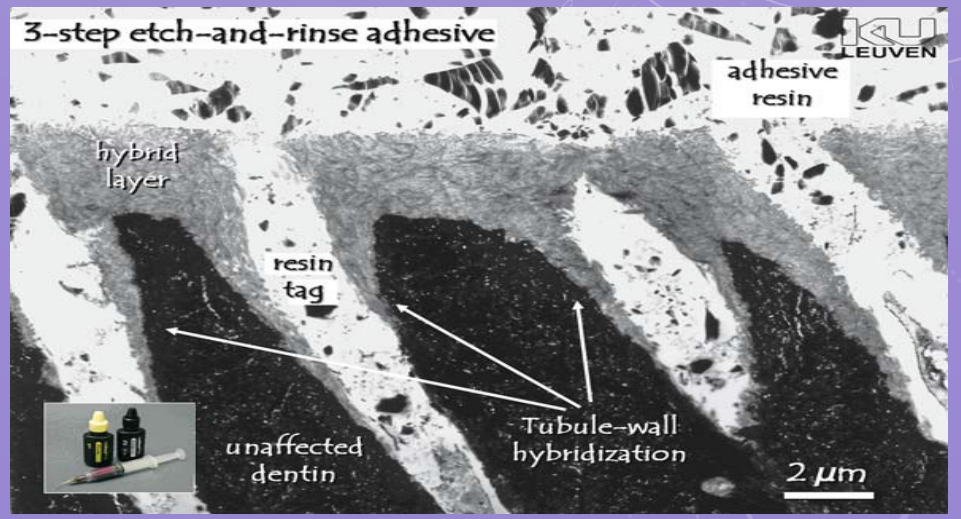
DENTAL ADHESIVE:

- 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.

- **Etchant (E):**

✓ Removes the smear layer.

✓ Exposes the intertubular and peritubular collagen.

✓ Opens the tubules.

✓ Decreases the surface free energy.

- **Primer (P):**

✓ Includes a difunctional 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 molecules penetrates and polymerizes into interfibrillar spaces to serve as a structural backbone to hybrid layer

Enamel bonding

- ***<u>Bonding to enamel requires two clinical steps:</u>***

1) Acid etching.

2) The application of the adhesive resin to the etched surface.

- **Usually 37% phosphoric acid is used for 15 to 30 seconds.**

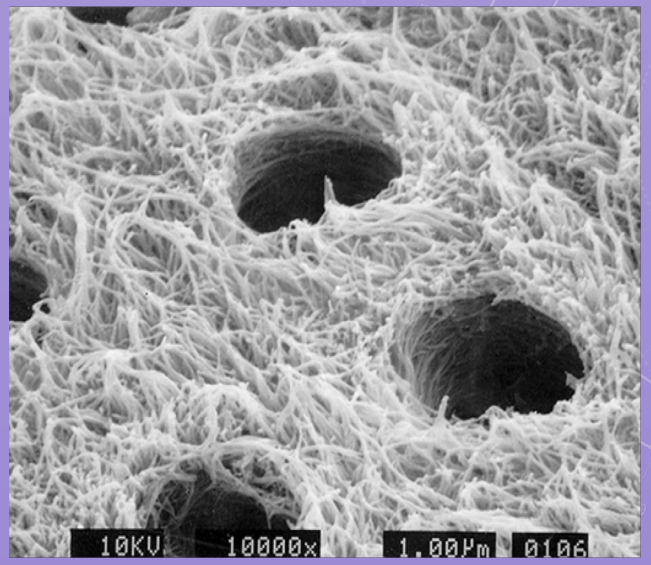
- ***The goals of enamel etching are:***

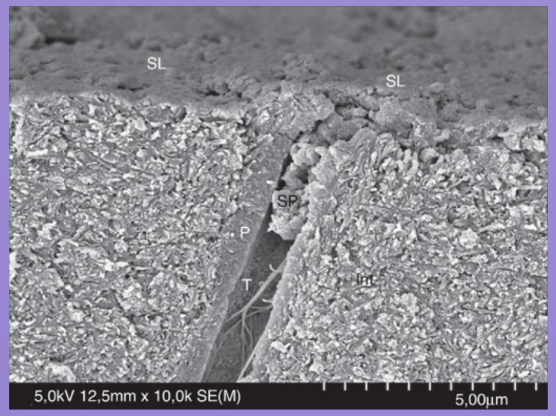
1) To clean enamel surface from debris.

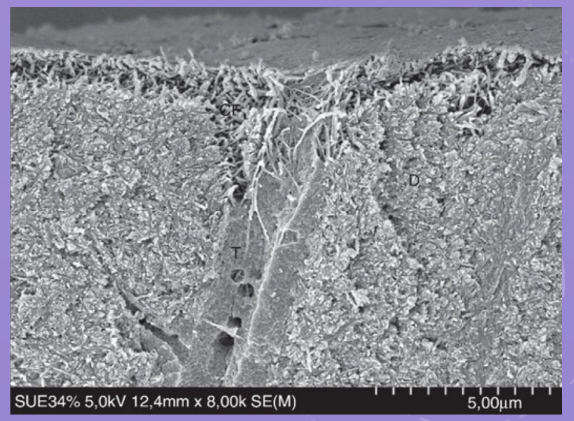
2) To increase the enamel surface area available for bonding.

3) To partially dissolve the mineral crystallites to create retentive microporosities into which the resinous bonding agent can infiltrate and form retentive resin tags (micromechanical retention).

4) In addition, acid etching increases the surface energy and lowers the contact angle of resins to enamel.







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.

- ***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.

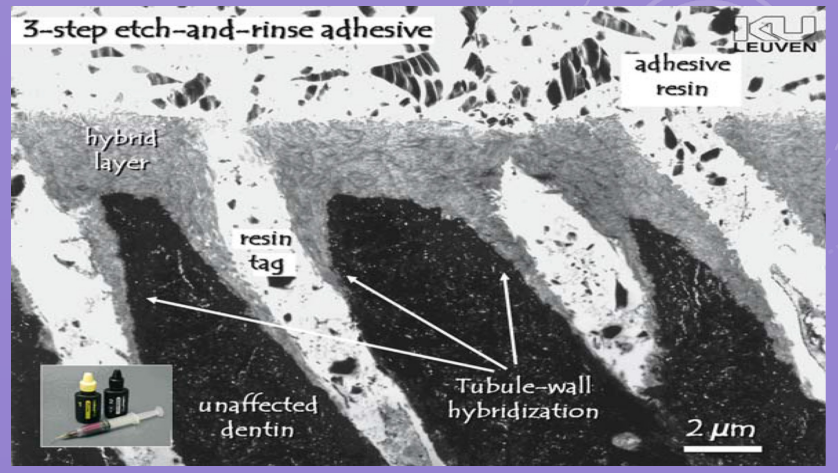
Generations of Dental Adhesives

- 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 7th** generations are **SE adhesives**.

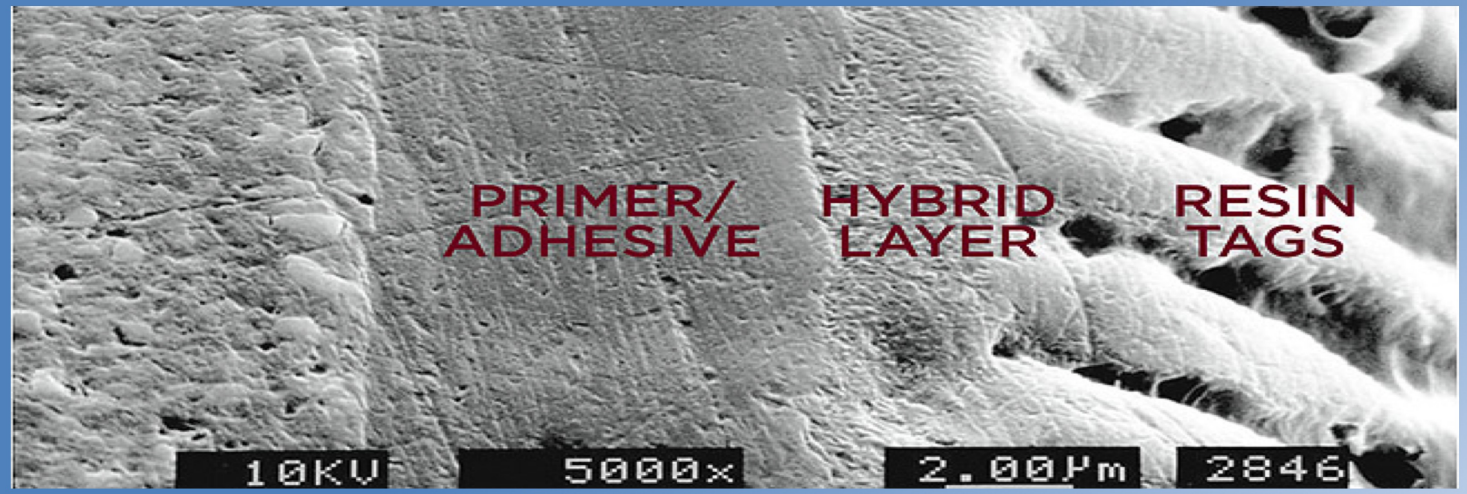
FOURTH GENERATION ADHESIVES:

- 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**.



4th Generation



- ***Advantages :***

- Ability to form a strong bond to both enamel and dentin.
- High bond strength to dentin (**17–25** MPa)
- Ability to bond strongly to moist dentin
- Can also be used for bonding to substrates such as porcelain and alloys (including amalgam).

- ***Disadvantages :***

- Time consuming.
- More number of steps
- 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**.
- 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 :**

- Reduces **postoperative sensitivity** because ***they etch and prime simultaneously***.
- It etches the dentin **less aggressively** than total etch products.
- Demineralized dentin is infiltrated by resin during the etching process.
- Since they **do not remove the smear layer**, the tubules remain sealed, resulting in **less sensitivity**.
- They form a relatively **thinner hybrid layer** than traditional product, which results in complete infiltration of the demineralized dentin by the resin monomers.
- **Much faster** and **simpler technique**.
- **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:

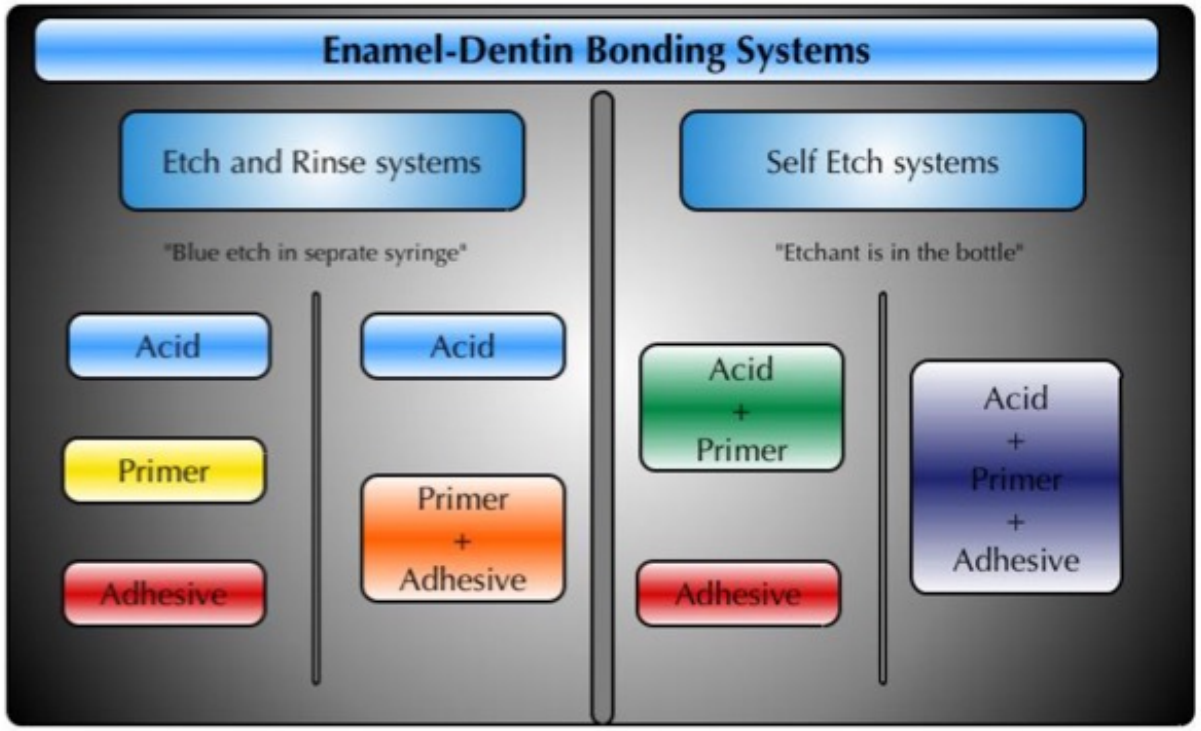
- Slight modifications of dentin adhesive formulations were made to produce a new class of **universal adhesives**.
- These materials are called **multimode** or **universal** because they can be used as **SE**, **E&R**, or **selective enamel-etch** systems.
- These adhesives have the ability to bond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

Generation	Developed	Mechanism / Steps		Description
1	1960s	No Longer in Use		Enamel etch only – poor adhesion
2	1970s			Enamel etch only – improved adhesion
3	1980s/1990s	Etch & Rinse	**Selective-Etch/ Multi-Step**	Selective enamel etch/etch-and-rinse with H_3PO_4. Dentin conditioned with primer to modify or remove smear layer
4	1990s		**Total-Etch/ Multi-/3-Step**	Total-etch/etch-and-rinse: separate primer and adhesive
5	Mid 1990s		**Total-Etch/ 2-Step**	Total-etch/etch-and-rinse: combined primer and adhesive
6	Late 1990s	Self-Etch	**Self-Etch/ 2-Step**	Self-etch: etch and primer combined then hydrophobic bonding i.e. self-etch/multi-component
7	2000 +		**Self-Etch/ 1-Step**	Self-etch: etch, primer and adhesive combined i.e. self-etch/single component
Universal	2011 +	All-Etch	**Total-/Self-/Selective-Etch/ 1 or 2-Step**	Total or selective etch procedure followed by universal adhesive or universal adhesive only in self-etch mode

The new classification of bonding agent

- The classification that best characterize adhesive systems was proposed ***by Van Meerbeek et al. in 2003***, as it considers the interaction mode with the substrate and the number of clinical application steps.
- Nowadays, two main adhesion strategies are identified: **etch-and-rinse** adhesive systems, which **remove the smear layer** and **self-etching** adhesive systems, which **dissolve and incorporate the smear layer**.
- A new group of materials called **universal** or **multimode** adhesive systems has recently been marketed.
- The main feature of these systems is that they can be applied according to different adhesion strategies.

(Alexandra V. and João R; 2016)


Enamel-Dentin Bonding Systems
Etch and Rinse systems
Self Etch systems
"Blue etch in seprate syringe"
"Etchant is in the bottle"
Acid
Primer
Adhesive
Acid
Primer + Adhesive
Acid + Primer
Adhesive
Acid + Primer + Adhesive
Classic categories
4th Gen
5th Gen
6th Gen
7th Gen
Examples
Optibond
Prime & Bond
Clearfil SE
Prompt L Pop

THE SUMMERY OF CLASSIFICATION OF THE VARIOUS TYPES OF ADHESIVES?

- ***According to :***

1. By the number of clinical steps and their interaction with the tooth surface.

Adhesive Categories
Etch&rinse
- Three-step
- conditioner, primer, adhesive
- Two-step
- conditioner, (primer & adhesive)
Self-etch
- Two-step
- (conditioner & primer), adhesive
- One-step
- (conditioner & primer & adhesive)

2. By generation

Adhesive Generations
Fourth generation
- three-step "etch&rinse"
Fifth generation
- two-step "etch&rinse"
Sixth generation
- two-step "self-etch"
- one-step "self-etch"

CURRENT STRATEGIES FOR ADHESION OF RESIN TO DENTIN

- I-Total etch adhesive:
- A- Three-step total etch adhesive.

  B- One bottle total-etch (two step total etch adhesive)
- II-Self-etch adhesive:
- A- Two-bottle self-etch

  B- All in one self-etch (we call it single application)
- III-SELECTIVE ETCHING TECHNIQUE

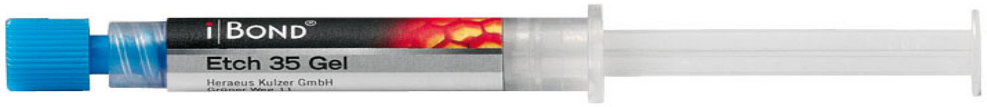
I- TOTAL ETCH ADHESIVE

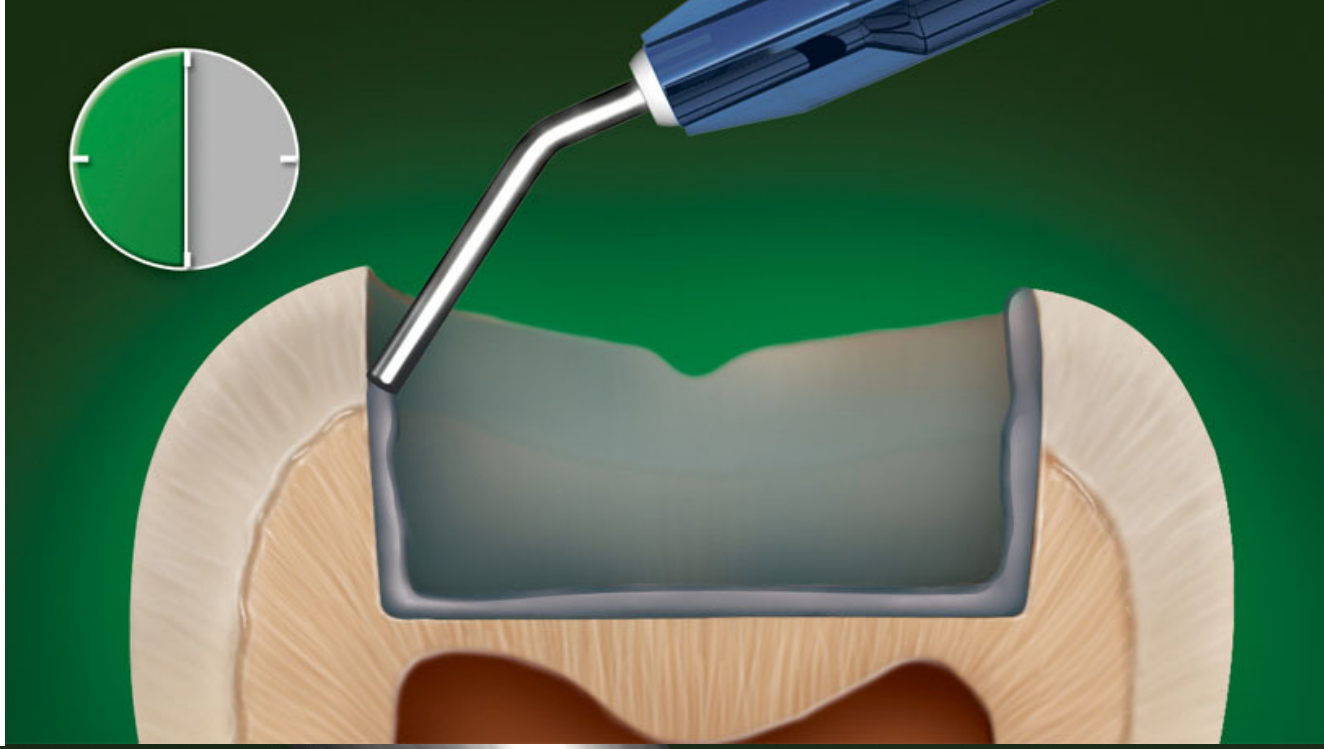
A- THREE-STEP TOTAL ETCH ADHESIVE

Etchant (E) + Primer + Bonding Agent (PB)

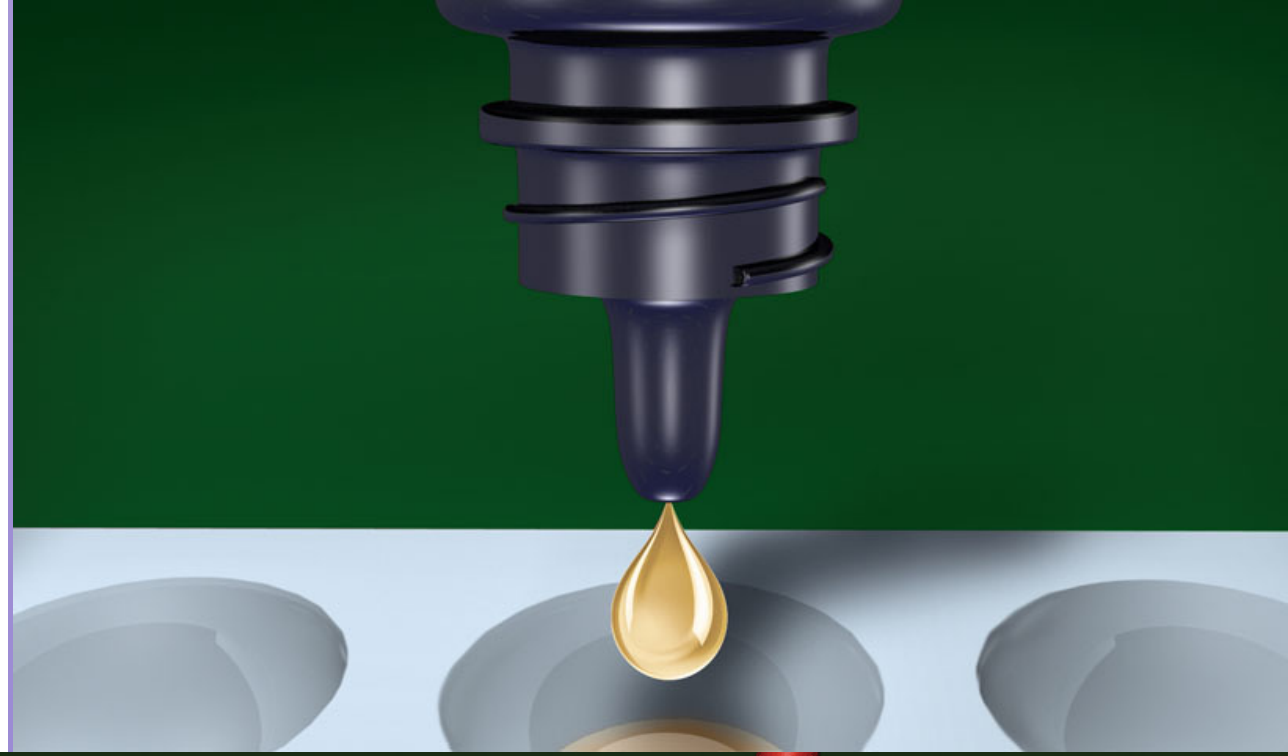
B- ONE BOTTLE TOTAL-ETCH (TWO STEP TOTAL ETCH ADHESIVE)

Etchant (E) + Primer And Bonding Agent (PB)

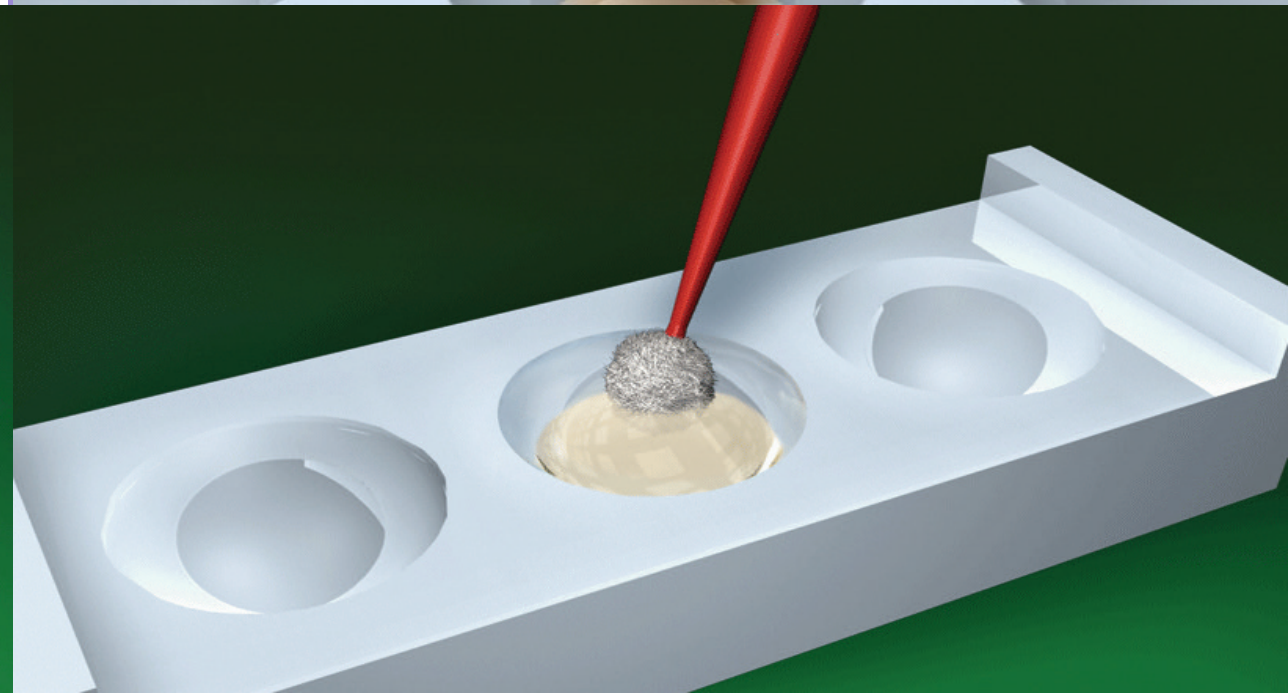

i|BOND®
Etch 35 Gel
Heraeus Kulzer GmbH

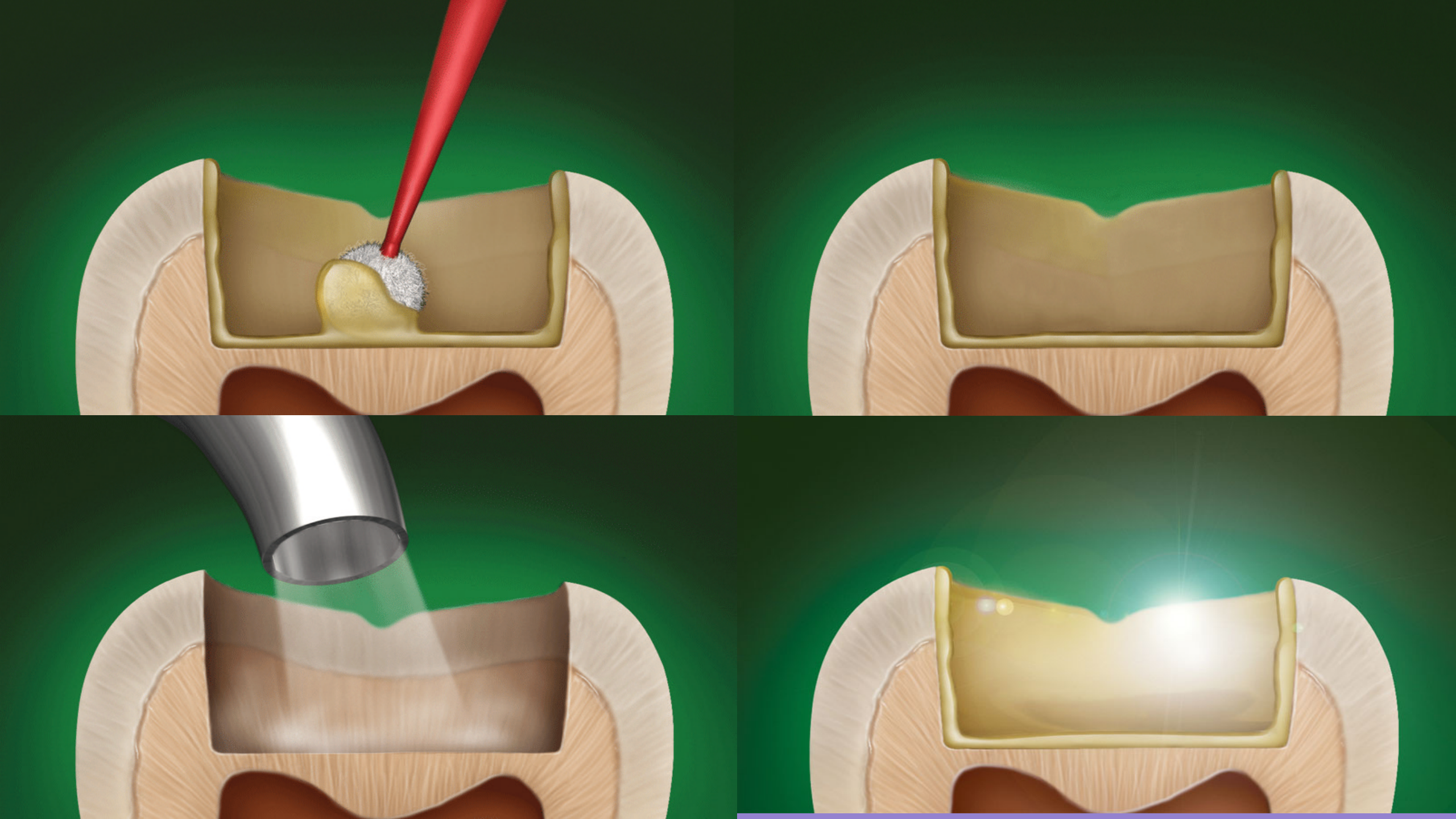


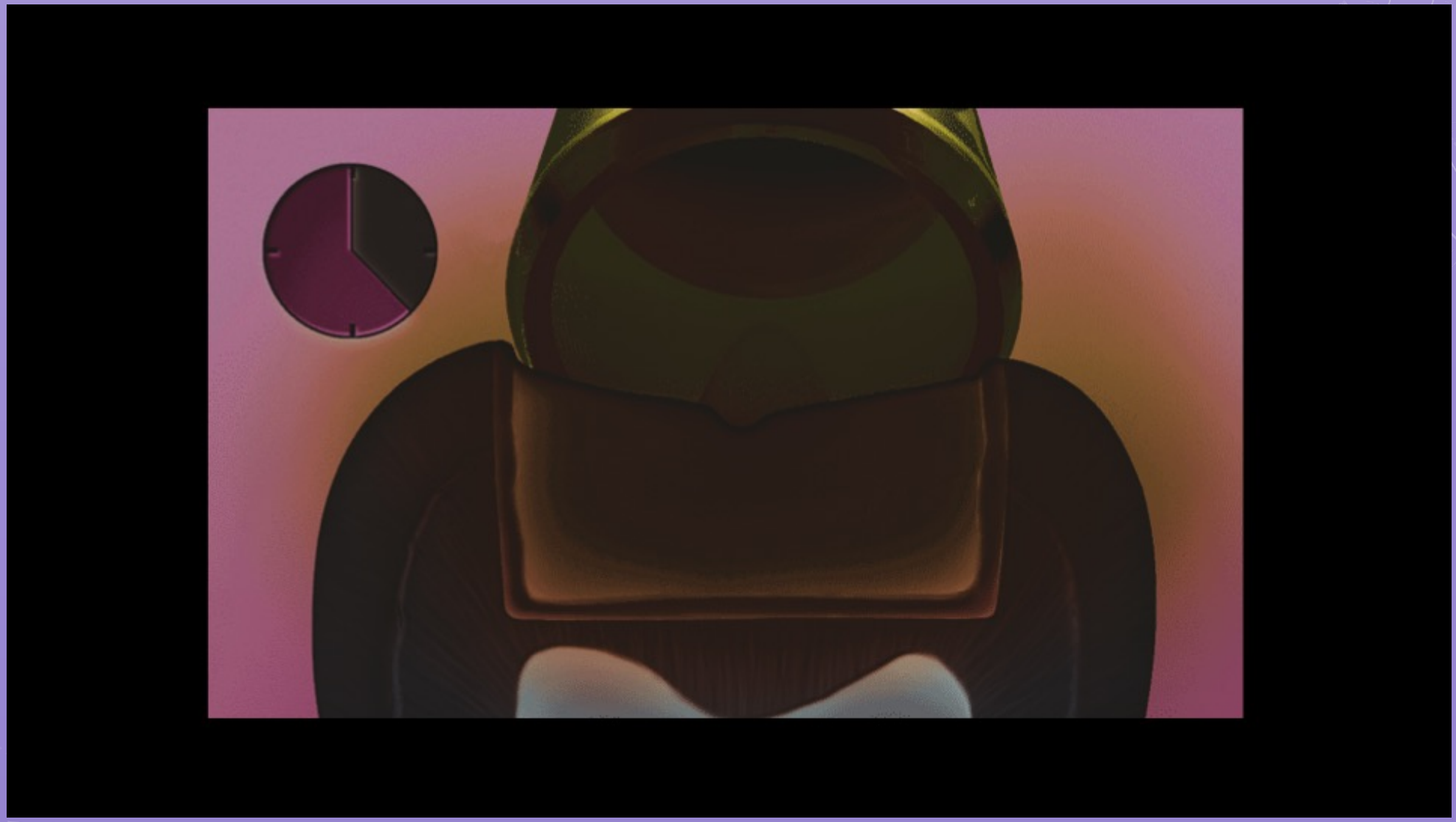

i|BOND®
Total Etch
4ml
Heraeus Kulzer GmbH
63450 Hanau (Germany)
REF 66039866




i|BOND
Total Etch
Contents: 4 ml
Heraeus Kulzer GmbH
Grüner Weg 11, 63450 Hanau
REF 66039612







II-SELF-ETCH ADHESIVE

A- TWO-BOTTLE SELF-ETCH

Etchant and Primer (EP) + Bonding Agent (B)

- Self-etch adhesive **does not remove** the smear layer, but fixes 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.

B- ALL IN ONE SELF-ETCH (WE CALL IT SINGLE APPLICATION)

- It demineralizes and penetrates dentin **simultaneously** leaving a precipitate on the hybrid layer.
- Forms a **thin layer of adhesive**.
- A multi-coat approach is **recommend**.

- The advent of one-step or all-in-one self-etch adhesives has improved the efficiency in clinical procedures by **reducing the steps and the complexity of the technique and times**. These adhesives combine the three cardinal steps of **etching**, **priming** and **bonding** in a single application.

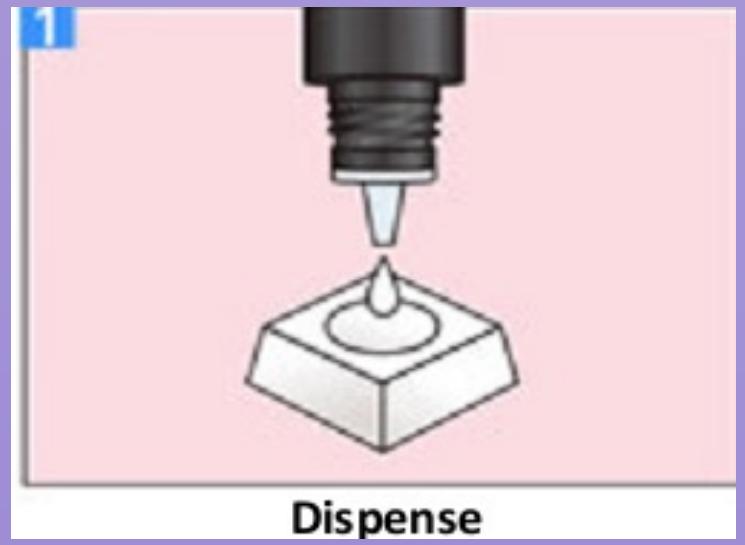
- Most of them are **methacrylate-based** and contain highly acidic monomers with a pH around **1.5-2.5** range.

- With the use of self-etching systems, it is generally accepted that **there less discrepancy between the depth of demineralization and the depth of resin infiltration**.

- Self-etch adhesives present various advantages over etch-and-rinse procedures: they are **more user-friendly**, **less technique-sensitive** and they have been reported to induce **less post-operative sensitivity**.

- One-step self-etch adhesives are the **easiest and fastest adhesive procedure** available today.

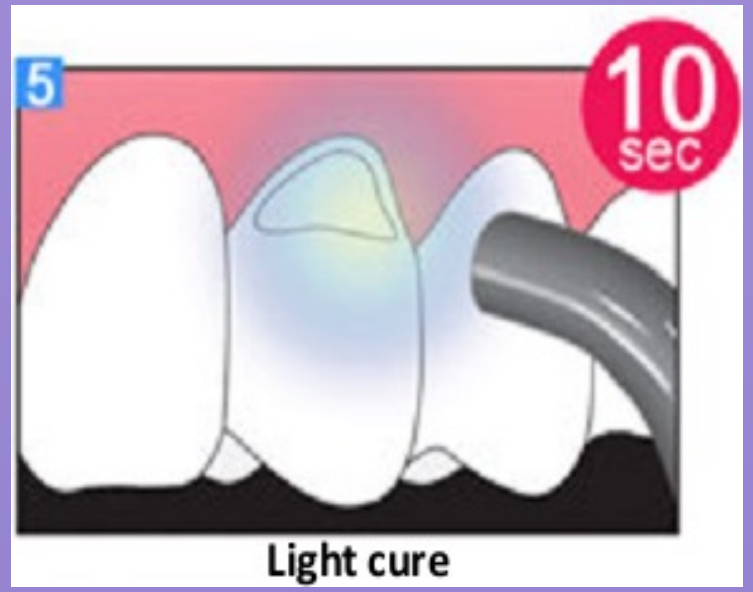
APPLICATION OF ALL-IN-ONE SELF-ETCH ADHESIVES


1
Dispense


2
Apply Bond Force


3
20 sec
Then rub the margins


4
10 sec
Apply weak air (5 sec)
→ strong air (+5 sec) *

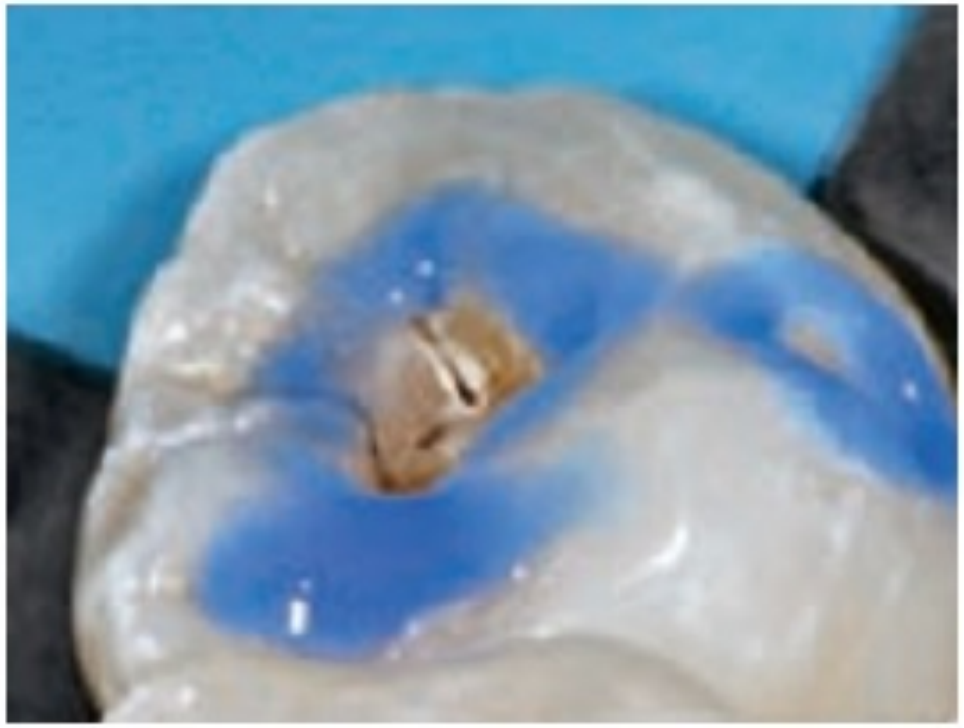

5
10 sec
Light cure

III-SELECTIVE ETCHING TECHNIQUE

- The debate between total etching and self etching rages on, but now we have a third choice known as **selective etching** or **a hybrid etching technique**.
- Selective etching **combines** the best of both the total etch technique and the self etching systems.
- One of the things that phosphoric acid is **good** at is effectively etching enamel.
- In a selective or hybrid etching technique you apply phosphoric acid to the enamel surfaces, **avoiding the dentin**.
- After 15 seconds the gel is rinsed off the tooth and the tooth is **dried**.

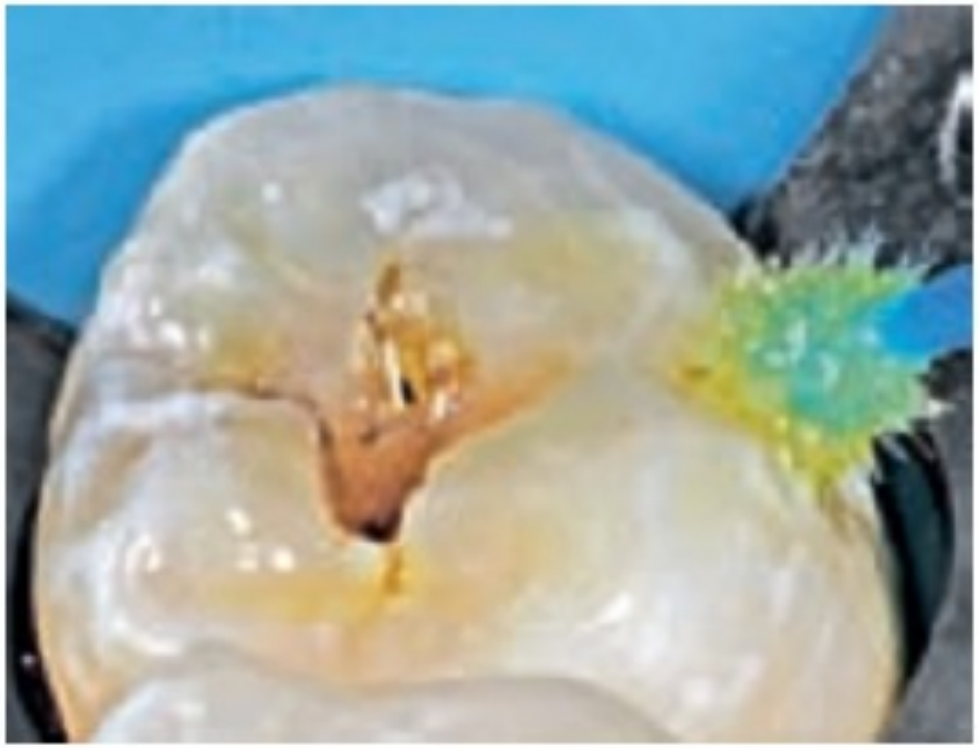
- This technique **maximizes** enamel bond strengths while **eliminating the risk of over- drying the dentin** after rinsing off phosphoric acid or **over-etching the dentin**.

- Using this technique successfully depends on a phosphoric acid gel that is **viscous enough** to stay just on the enamel and not run.



1. Etchant has been applied to both prepared and unprepared enamel margins. Gelled etchant allows precise placement.

2. Careful use of the air/water syringe as well as immediate collection via suction will reduce contact of the etchant with the dentinal surfaces to a minimum. However, inadvertent etching of dentin is not detrimental with Adper™ Easy One Self-Etch Adhesive.



3. Adper™ Easy One Self-Etch Adhesive is applied to all surfaces that are to be bonded. Apply using a rubbing motion for 20 seconds.

4. Dry gently for approximately 5 seconds to remove the ethanol.

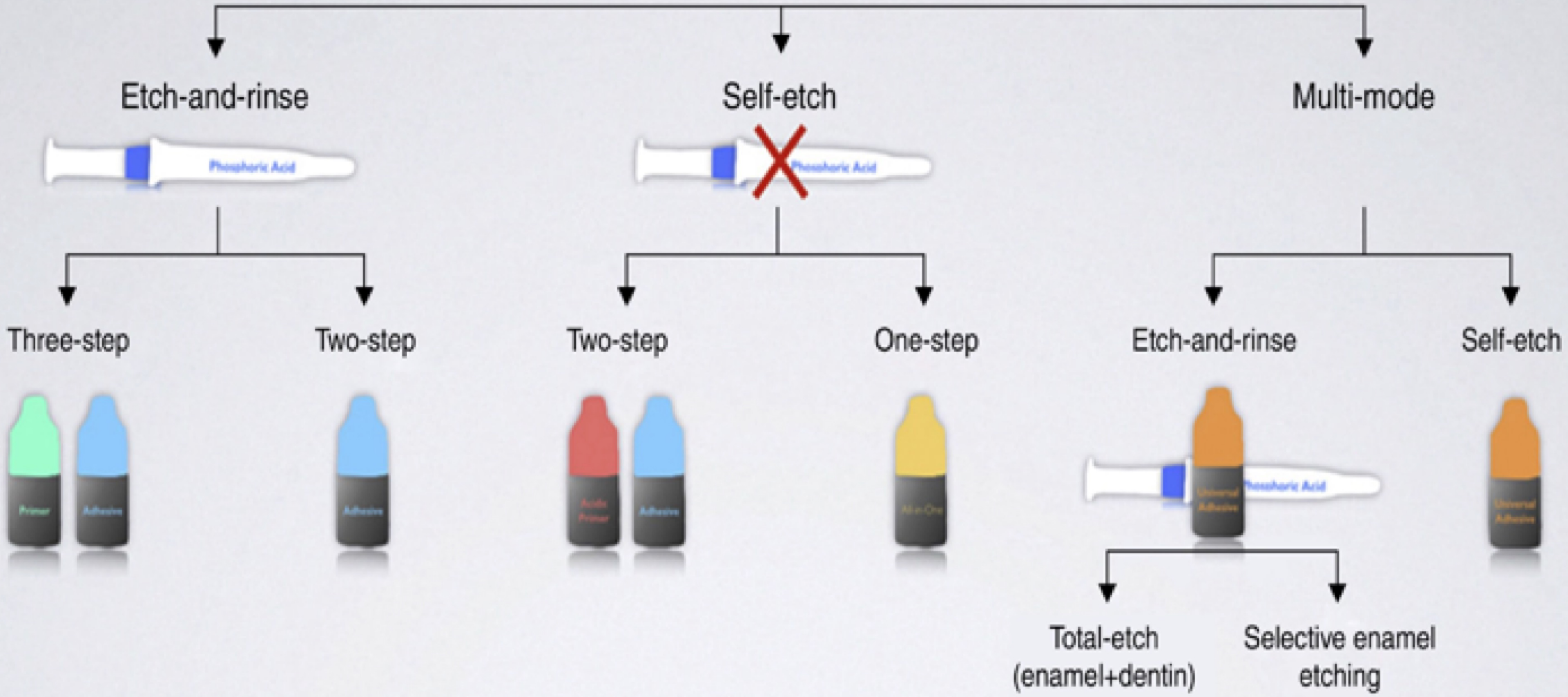
5. Light cure for 10 seconds.

6. The final restoration

finally

Choose your preferred bonding technique

Adhesive strategies



Thank You