Dental Caries

Operative Dentistry refers to the diagnosis, treatment planning, and placement of direct restorations to restore the comfort, health, function, and esthetics of tooth defects.

1 Tooth Composition

Apatite is a naturally occurring isomorphous mineral group that contains repeats of the same crystal lattice with a molecular structure of **$Ca_5(PO_4)_3X$.** In the human body, apatite is referred to as **biological apatite** and is a major component of tissues such as enamel, dentin, and bone.

The molecular charge breakdown of **$Ca_5(PO_4)_3X$** is described below:

- 5 of Ca (2+) = net charge of +10
- 3 of PO_4 (3-) = net charge of -9
- Therefore, X must have a net charge of -1
  Variants of X include:
  - Hydroxyl (OH-) = hydroxyapatite
  - Fluoride (F-) = fluorapatite
  - Chloride (Cl-) = chlorapatite

Biological apatite is most commonly found as **hydroxyapatite (HA),** and has the molecular structure of **$Ca_{10}(PO_4)_6(OH)_2$**.

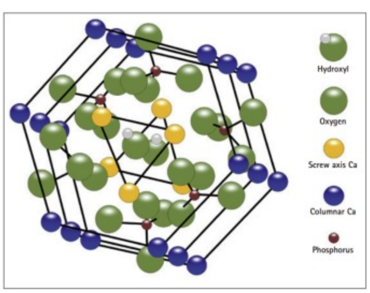


Figure 1.01 Hydroxyapatite

As shown above, hydroxyapatite has an atomic arrangement of hexagonal cells.

In its pure form, hydroxyapatite can be found as a white powder. Hydroxyapatite is biocompatible for bone implants, however, it has a low bioresorption rate and does not imitate the inorganic portion of our bones and teeth.

Carbonate-substituted hydroxyapatite (CHA) is a form of naturally occurring hydroxyapatite substituted with carbonate groups (CO_3) and is the main component of enamel and dentin. Because carbonate substitution increases the solubility of hydroxyapatite, it is more susceptible to decay.

Tooth composition is 85% hydroxyapatite by volume and 95% by weight. During amelogenesis, ameloblasts stack HA unit cells on top of each other to form crystallites that create long **enamel** rods or prisms.

Enamel rods have a **keyhole pattern** with a head and tail.

INBDE Pro-Tip: the tail has a higher organic composition with less mineral content which makes it more susceptible to decay.

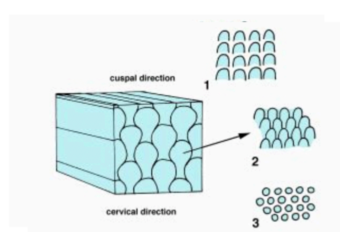


Figure 1.02 Enamel Rods

Enamel is structurally and compositionally variable; **superficially**, enamel has more **fluoride** substitution due to contact with fluoridated water and other fluoridated products entering the oral cavity. In contrast, at the **DEJ**, there is higher **carbonate** substitution. Thus, the deeper a cavity penetrates, the more soluble enamel is, due to the higher carbonate substitution.

2 Caries Formation

In the oral cavity, Ca^{2+} and PO_4^{3-} are constantly being transferred between hydroxyapatite of the tooth and free Ca^{2+} and PO_4^{3-} ions in the mouth and/or plaque at equilibrium.

$$Ca_{10}(PO_4)_6(OH)_2 \leftrightarrow Ca^{2+} + PO_4^{3-}$$

The oral cavity provides an optimal environment with moisture and crevices for bacteria. This allows for the growth of **cariogenic bacteria,** which digest sugars via glycolysis and produce lactic acid as a byproduct of fermentation.

When lactic acid is secreted directly onto enamel, the H^+ ions complex with free PO_4^{3-} ions to form phosphoric acid (H_3PO_4), driving equilibrium towards the dissolution of hydroxyapatite due to **Le Chatelier's Principle.**

$$Ca_{10}(PO_4)_6(OH)_2 \leftrightarrow Ca^{2+} + PO_4^{3-}$$
$$Ca^{2+} + PO_4^{3-} + H^+ \text{ (bacteria)} \leftrightarrow Ca^{2+} + H_3PO_4$$

Le Chatelier's Principle states that any alterations to a system at equilibrium will result in predictable opposing changes in the system to achieve a new equilibrium state. Other direct sources of acid include food or drinks, as well as, gastric acid from gastroesophageal reflux disease (GERD) or bulimia nervosa. These acidic sources can cause **erosion** by lowering the oral cavity's pH.

INBDE Pro-Tip: the process of dissolution results in the loss of Ca^{2+} + PO_4^{3-} from tooth structure, which results in tooth decay; this process is called **demineralization.**

Stephan Curve

The Stephan Curve describes changes in the pH of the oral cavity that occur during exposure to sugars and acids as a function of time.

At rest, the pH of the oral cavity is **neutral** at a pH of 7. However, upon exposure to acid or sugars, the oral pH decreases rapidly to reach a minimum value within 10 minutes. If the plaque or oral pH falls below the **critical pH**, dissolution of tooth structure begins via **demineralization**. For **carbonate-substituted hydroxyapatite (CHA), the critical pH is 5.5.**

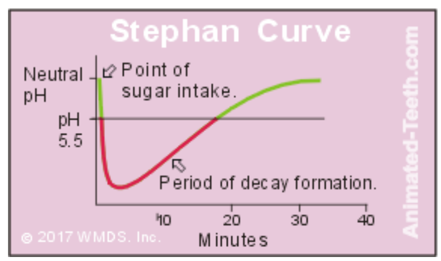


Figure 1.03 Stephan curve

Over time, **saliva** acts as a natural buffer to neutralize pH and combat acidity. Saliva is a natural protector against demineralization as it contains a weak base called **bicarbonate (HCO^{3-}).** Bicarbonate complexes with H^+ to form **carbonic acid (H_2CO_3)**. This prevents the formation of phosphoric acid, which allows the oral pH to neutralize **30 minutes** after exposure to acids or sugars.

$$HCO^{3-} \text{ (Saliva)} + H^+ \leftrightarrow H_2CO_3$$

In addition, saliva contains Ca^{2+} ions which can drive the equilibrium towards hydroxyapatite formation. This process is called **remineralization**, as Ca^{2+} and PO_4^{3-} ions are reincorporated into tooth structure.

Commercial products such as MI Paste contain buffers and increase the concentration of free minerals in saliva to shift the equilibrium towards remineralization.

Fluorapatite

Fluoride ions in saliva from fluoridated water or oral hygiene products promote tooth remineralization through the formation of **fluorapatite ($Ca_5(PO_4)_3F$)**.

Fluorapatite is a more stable apatite crystal due to its stronger bond to Ca^{2+}. In result, this increases the hardness of teeth and increases resistance to acid damage. Therefore, a stronger acid challenge is required for tooth demineralization of fluorapatite at a **critical pH of 4.5**.

Other factors may effect pH recovery after sugar or acid exposure. pH recovery may be faster when chewing sugar-free gum (xylitol), as it stimulates saliva secretion without a drastic pH decline due to its lack of sugar. Conversely, **xerostomia** (dry mouth) patients may have a longer pH recovery time of over 1 hour, due to decreased saliva production.

Generally, pH recovery to neutral is dependent on eating and drinking frequency and duration, as well as, the composition and stickiness of foods consumed, one's brushing frequency, and one's quality of saliva.

INBDE Pro-Tip: fluorapatite promotes tooth remineralization by:

- Shifting the equilibrium towards incorporation of Ca^{2+} and PO_4^{3-}
- Decreasing enamel solubility with a lower critical pH
- Preventing the growth of cariogenic bacteria

3 Caries

Caries are a multifactorial transmissible infectious dynamic oral disease. They are a result of the interaction between **cariogenic bacteria (plaque), tooth surfaces (host), and fermentable dietary carbohydrates (sugars)** occurring over a period of **time**.

The modified **Keyes-Jordan model** incorporates several modifying factors that may effect caries development. Caries can be managed by maintaining a balance between demineralization/remineralization and pathologic/protective factors at the tooth and holistic level.

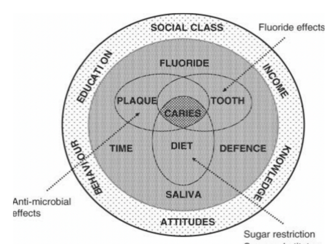


Figure 1.04 Keyes-Jordan model

Lesion Progression

- **Pit and fissures lesions**: widen into an **inverted V-shape** as they progress deeper
- **Smooth surface (and root surface) lesions**: wider on surface and narrow, penetrating enamel as a **V-shape**
  - Most common on mesial/distal surfaces at inter-proximal contacts

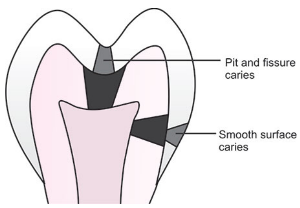


Figure 1.05 Lesion progression

- **Dentinal lesions**: widen again due to the higher penetrability of dentin and narrows as it deepens to form **V-shape** within the dentin

INBDE Pro-Tip: The critical pH of tooth structure varies depending on the tissue type

	Critical pH
Enamel (fluorapatite)	4.5
Enamel (carbonate-substituted hydroxyapatite)	5.5
Dentin and Cementum	6.2 - 6.7

and mineral composition.
The higher critical pH of dentin and cementum increases the susceptibility of exposed root surfaces to acid erosion and tooth decay.

Caries Zones

1. **Enamel surface –** when **intact**, the lesion can be remineralized and is classified as a **reversible white spot lesion**. An unmanaged white spot lesion may become **cavitated** after 1-2 years. A cavitated lesion is classified as **irreversible** and requires restorative treatment.
2. **Infected dentin –** bacteria loaded, superficial, mushy, soft, wet, and necrotic. Infected dentin must be completely removed prior to restoring the tooth.
3. **Affected dentin –** deeper, dry, demineralized, leathery affected by bacterial toxins/acids, but not invaded by bacteria. Affected dentin does not have to be removed during restoration as it does not contain bacteria.

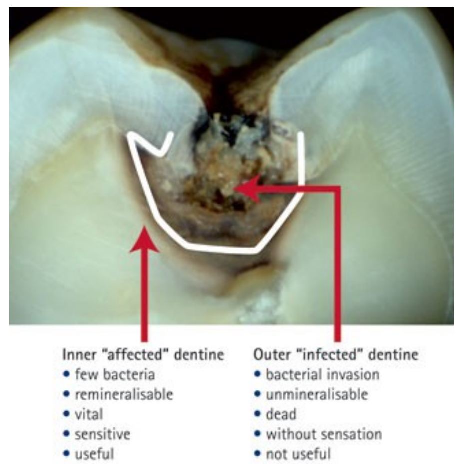


Figure 1.06 Caries zones

Caries Progression

Caries progression begins with **enamel demineralization (surface intact)** to **dentin demineralization**. When the lesion progresses further to **enamel cavitation**, it cannot be reversed and furthers into **dentin cavitation** where it quickly progresses.

Figure 1.07 Caries progression

Caries Classification

Caries have several systems of classification as described below.

Extent

Caries can be classified based on their progress:

- **Incipient/reversible** – on smooth surface, appears white and opaque when air-dried, and cannot be detected when wet
  - Occurs during enamel demineralization and some dentin demineralization stages
- **Cavitated/irreversible** – enamel surface is not intact and the lesion can progress into dentin
  - Occurs during enamel cavitation to dentin cavitation stages

Location

Location based caries classification can also be used to classify restorations (simple, compound, complex):

- **Simple** – includes one surface of a tooth (occlusal most common)
- **Compound** – includes 2 surfaces of tooth (ex: DO)
- **Complex** –includes 3 or more surfaces of tooth (ex: MOL)
- **Primary** – original caries lesion which occurs on a virgin tooth surface
- **Secondary/recurrent** – occurs at the junction of tooth structure and restorative material including small leakage under a restoration
  - Marginal gap between the tooth and restoration must be minimized to reduce bacterial penetration
- **Residual** – caries that remain even after a tooth preparation is completed

Rate

Caries can be classified based on progression rate:

- **Acute/rampant** – immediately damages tooth structure, light-colored, very infectious, and is soft
- **Chronic/slow** – demineralized tooth structure that has nearly remineralized, discolored, and is hard
- **Arrested** – completely arrested caries; brown/black, it becomes caries-resistant when exposed to fluoride
  - Arrested caries are often accompanied by sclerotic dentin that prevents bacterial ingress

Microbiology of Caries

Caries progression is usually thought to abide by the **specific plaque hypothesis** which states that only specific (cariogenic) bacteria in the oral cavity can lead to caries development.

Streptococcus mutans (S. mutans)

- S. mutans is a gram positive cocci that is thought to be a **major contributor** of enamel caries
- This bacterium produces **glucosyltransferase** (GTF), which converts sucrose into extracellular polysaccharides (glucans and fructans) that aid with bacterial adherence to tooth structure
- Additionally, S. mutans produce **bacteriocins** that kill off competing microbes; this allows for cariogenic biofilm (plaque) accumulation on the tooth surface, which can promote caries development
- S. mutans is also **acidogenic** (acid producing), as it produces lactic acid from sucrose via fermentation
- S. mutans is lastly **aciduric**, meaning it can thrive in acidic environments without damage to itself

INBDE Pro-Tip: by the specific plaque hypothesis, the following bacteria are thought to be the main cause of caries:

- ***Streptococcus mutans*** – enamel caries
- ***Lactobacillus*** – dentinal caries
- ***Actinomyces*** – root caries

Saliva

Saliva contains several components which help to naturally protect teeth against caries:

- **Urea and other buffers** – dilute bacterial acid byproducts to drive equilibrium towards remineralization
- **Glycoproteins** – large molecules that string bacteria together to aid in their elimination during swallowing
- **Lactoferrin** – actively binds and sequesters iron required for bacterial enzymes and function
- **Lysozyme** – breakdown bacterial cell walls
- **Lactoperoxidase** – inactivates certain bacterial enzymes
- **sIgA (salivary IgA)** – salivary antibodies which bind bacteria
- **Ca^{2+}/PO_4^{3-}/F^- ions** – used for tooth remineralization
- **Statherin, cystatin, histatin and proline rich proteins** – proteins used for remineralization

Diagnosis & Treatment Planning

1 Clinical Examination

Clinical Examination

Caries are a dynamic process that progress, arrest, or regress. Clinical examination for caries diagnosis can be conducted using multiple techniques described below.

Visual Examination

Visual examination is used to assess changes in **tooth surface texture and/or color,** and is a major component of caries detection.

Visual examination must be conducted in a **dry, well-illuminated field**, as moisture and poor lighting can make it difficult to detect irregularities.

For example, reversible incipient white lesions can disappear by the process of wetting vs. hypocalcification will not reverse

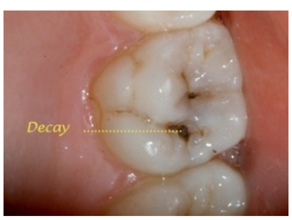


Figure 2.01 Visual examination

Tactile Examination

Tactile examination requires **field isolation** by placing cotton rolls along the oral vestibules and removing excess saliva.

It is conducted in conjunction with the visual exam by careful use of an **explorer**.

Previously, the explorer was utilized to detect any stickiness or softness of the enamel. However, recent findings support **careful examination**, as the sharp end can:

- Introduce a cavitation by accident
- Transfer cariogenic bacteria from infected to non-infected areas
- Provide false positives when the explorer catches on pits and fissures

Radiographs

Radiographs are valuable, as they help with diagnosis of lesions which may not be accessible for visual-tactile examination. White spot lesions are hardly visible on radiographs. However, enamel and dentinal lesions are evident on radiographs. These lesions appear **smaller** than they would clinically. **Periapical (PA)** and **bitewing (BW)** radiographs are often utilized for anterior and posterior caries detection respectively.

Figure 2.02 Radiographs

INBDE Pro-Tip: the tooth must undergo 30-40% mineral loss for radiographic detection.

Transillumination

During transillumination, a **bright light** is shined through **anterior tooth junctions**.

The detection of **shadows may** indicate interproximal decay.

Transillumination can also be used to differentiate between **craze lines** and **fractures**. Fractures will block light, while craze lines will allow light to pass through the tooth.

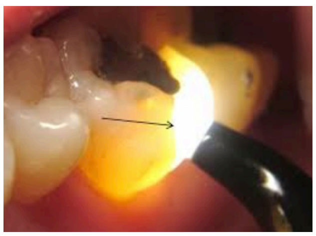


Figure 2.03 Transillumination

New Technology

New techniques for clinical caries diagnosis include:

- Digital Imaging Fibre-Optic Transillumination (DIFOTI)
- Laser fluorescence (DIAGNOdent)
- Quantitative Light-Induced Fluorescence (QLF)
- Electrical Conductance or Impedance Measurement

Amalgam Exam

Visual examinations for amalgam restorations include the following:

- Detection of **blueish hues** – indicative of corrosion products that may leach into dentinal tubules, or underlying enamel may be seen through translucent enamel
    - Corrosion products may also be beneficial for creating a marginal seal between the amalgam and tooth structure
- **Marginal gaps and/or ditching (>0.5mm);** major gaps or ditching are considered carious, or caries-prone and must be replaced or repaired
- Gaps or ditching **under 0.5mm** are **not considered defective** due **to the self-sealing** properties of amalgam
- Proximal and/or marginal overhangs
- **Voids and/or fracture lines** must be monitored

Figure 2.04 Amalgam exam

2 Tooth Examination

Other types of tooth damage that may be identified during clinical examinations include:

1. **Erosion** – chemical loss of tooth structure caused by acidic foods/beverages or gastric acid, without bacterial involvement
    - Erosion often presents as bowl shaped ditching of cusp tips on posterior teeth, known as cupping; this can result in restorations appearing higher than the tooth structure
2. **Attrition** – pathological loss of tooth structure by mechanical wear, induced by opposing natural tooth structure
    - Attrition may be induced by a combination of tooth flexure, toothpaste abrasion and chemical erosion
3. **Abrasion** – pathological loss of tooth structure by mechanical wear, induced by external materials
    - Abrasion is caused mostly by porcelain or ceramic crowns of the opposing teeth

4. **Abfraction** – loss of tooth structure in cervical regions
5. **Hypersensitivity** – can happen when the dentinal tubules on the root surfaces become exposed.

Root Surface Hypersensitivity

In the explanation of root surface hypersensitivity, **the hydrodynamic theory** hypothesizes that **dentinal fluid movement** activates mechanoreceptors located in pre-dentin to cause pain.

Dentinal tubules are filled with fluid and odontoblastic processes that contain mechanoreceptors. Exposure of these tubules, temperature change, and osmotic pressure change may result in fluid shifts, which can activate nerve endings and result in sensitivity.

GLUMA is an effective product used in occluding dentinal tubules, preventing manipulation of dentinal fluid, and consequently reducing sensitivity.

Root surfaces are especially susceptible to sensitivity, due to the fast wearing of its thin cementum layer.

3 Treatment Plan Sequencing

The concept of **greatest need treatment planning** states that, patient need dictates the order of phases of operative treatment planning.

The sequence of phases is as follows:

1. **Urgent Phase** – addresses the patient's acute oral health needs such as from emergencies like infections, swelling, and high pain
    - Treatment may include placing a temporary restoration, endodontics, and extractions
2. **Control Phase** – includes controlling oral disease by eradicating active signs of disease and managing risk factors contributing to disease
    - Operative intervention may include oral hygiene practice and/or managing diet
3. **Re-evaluation Phase** – monitoring patient improvement and ensuring there is no active disease
4. **Definitive Phase** – includes reforming the patient's oral condition by establishing ideal function and esthetics
    - Treatment may include, for example, orthodontics or prosthodontics
5. **Maintenance Phase** – establishing excellent at home self-care of the patient, routine cleanings and/or examinations

Criteria for Restoring Teeth

The criteria for restoring teeth includes:

- A carious lesion extending into the **DEJ** radiographically and/or clinically
- A **cavitated** carious lesion

Any carious lesion that is not cavitated is considered reversible. Non-cavitated lesions can also be treated with **fluoride** or be arrested with **silver diamine fluoride**.

Patients with a high caries risk must be monitored. High risk patients may demonstrate several of the following:

- 2 or more active caries
- Multiple number of restorations
- Poor oral hygiene and dietary habits
- Low fluoride exposure and salivary flow
- Uncommon tooth morphology – ex: deep pits/fissures

Preventive Dentistry

Preventive dentistry differs from interceptive treatment because it focuses on preventing manifestations of disease prior to their initiation and progression.

One example includes the remineralization of incipient smooth surface lesions. This process can be promoted via fluoride treatment or reversal of high caries risk behaviors.

Another example may include treating caries-prone pits and fissures with sealants in pediatric patients.

Instrumentation

1 Dental Hand Instruments

Dental hand instruments are largely categorized into non-cutting and cutting instruments.

Instrument Design

Hand instruments generally have 3 main regions:

1. **Handle** – usually 6mm in diameter, can be 8 sided or round, ribbed grip or smooth/ flat-hold
2. **Shank** – transition region between handle and working end, which may have 1 or more bends
    - Bends allow the working end to be aligned with long axis of handle
3. **Working end** – region used to perform the function of the hand instrument, which lies along long axis of instrument for best balance and control
    - With **cutting** instruments, the working end contains:
        - **Blade** – cutting portion of instrument
        - **Cutting edge** – the specific sharp edge of the working end that contacts the tooth or restorative material
    - With **non-cutting** instruments, the working end contains:
        - **Nib** – region of working end following the shank
        - **Face** – the specific end of the instrument which contacts the tooth or restorative material

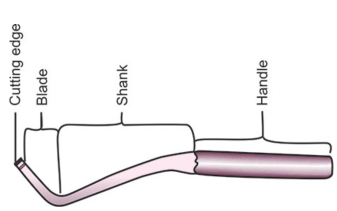


Figure 3.01 Instrument design

Non-Cutting Instruments

Non-cutting instruments do not cut hard or soft tissue. They can be used for diagnostic or restorative procedures.

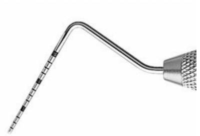
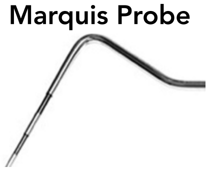
1. **Mirror** – allows for visualization of areas of mouth that are hard to see
    - **Indirect vision** – visualizing oral structures through the use of a mirror
    - **Direct vision** – the eyes directly observe structures without the use of a mirror
2. **Explorer** – provides tactile sensitivity to detect margins of restorations or crowns

Figure 3.02 Dental Mirror

Explorer Type	Instrument Number	Description
Shepherd's Hook 	23	Most commonly used explorer with a classic curved end
Back Action 	17	Flat, short hook explorer used to detect restoration margins between teeth, interproximal regions, and subgingival calculus

Pigtail Explorer 	2	Working end curves under and around for detection of crown and restoration margins

Periodontal Probe – dull-ended instrument with graduations to routinely measure gingival pocket depth or width of teeth.

Probe Type	Description
UNC 15 	Measures up to 15mm with each small graduation representing 1mm increments and each larger graduation representing 4-5mm, 9-10mm and 14-15mm
Williams Probe 	Each graduation represents 1mm increments, but there are no graduations for the 4mm and 6mm mark
Marquis Probe 	Each graduation represents 3mm increments

Amalgam condenser – used to condense amalgam (or composite resin) into cavity prep to ensure there are no voids in the material.

Figure 3.03 Amalgam condenser

Ball Burnisher – used to burnish amalgam and for early carving, to provide contour and anatomy of restorations. With composite restorations, burnishers can be used to smooth out occlusal surfaces. Typically has 2 ends of a small round sphere and a larger football shaped end.

Figure 3.04 Ball Burnisher

2 Cutting Instruments

Cutting instruments cut hard or soft tissue.
Cutting hand instruments:

1. Scalers – remove calculus
2. Chisels – remove unsupported enamel
3. Excavators – remove carious dentin
4. Other – modify the restoration

Cutting Instrument Formula

Cutting instruments have a four number formula that is used for visualization and identification:

- **1st number – blade width** measured in 10th of a mm
- **2nd number – cutting edge angle** – this can be omitted if perpendicular (90°) to blade
- **3rd number – blade length** in mm
- **4th number – blade angle** relative to long axis of handle in % of 360°

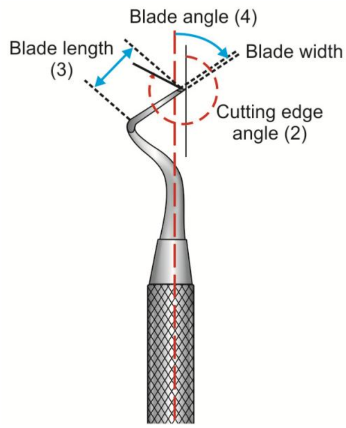
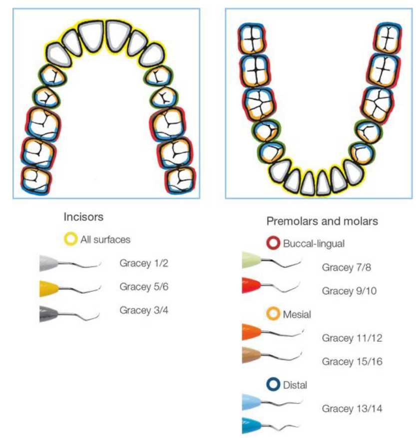


Figure 3.05 Cutting instrument formula

INBDE Pro-Tip: the board exam will frequently refer to the cutting instrument formula.

Scaler – adapts closely to tooth surface to remove calculus. They often have two sides with 2 cutting edges present at each working end. As an instrument used to remove calculus, it follows a different instrument formula.

Figure 3.06 Scalers: H6/H7 (top), H5/33 (middle), 204S (bottom)

Scaler Type	Description
Universal	Used anywhere in mouth 
Gracey's	Multiple types for use in specific teeth and areas of mouth 
Sickle Scaler	Contains sharp points at end of blade, thus used for supra-gingival calculus removal 
Curette	Contains rounded edge for sub-gingival calculus removal 

Spoon Excavator (11.5-7-14) – used for controlled caries removal, considered most useful for soft infected dentin.

Figure 3.07 Spoon excavator

Black Spoon (15-8-14) – larger spoon excavator can be used to burnish metal like the margin of a gold crown.

Enamel Hatchet (10-7-14) – double-ended cutting instrument used to plane walls of enamel, with one end for use on the facial wall and the other for use on the lingual wall.

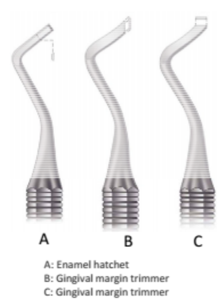


Figure 3.08 Enamel hatchet

Bin-Angle Chisel – double ended instrument with 2 angles in the shank (bin-angle) used for planning walls of enamel. The double angle allows for proper orientation of the blade, and optimal control and balance.

- Similar to the enamel hatchet in function, but has a perpendicular blade orientation to the enamel hatchet, allowing usage in areas that the enamel hatchet cannot reach.

Gingival Margin Trimmer – used to plane enamel at gingival floor of cavity prep

- The angle of the cutting edge allows for proper beveling of the gingival floor, which the enamel hatchet cannot provide

The formulas for the distal and mesial gingival marginal trimmer differ and are as follows:

- **Distal** – 10-95(>90)-7-14
- **Mesial** – 10-80(<90)-7-14

Cleoid-Discoid Carver – double ended instrument with a rounded handle that is used to contour and carve amalgam.

- The cleoid end is claw-like for carving **grooves** and the discoid end is a circular disc for carving **pits and fossa**

Figure 3.09 Cleoid-discoid carver

Hollenback Carver – double ended, round-handled instrument used for placing, carving and contouring amalgam; the two ends are oriented perpendicular to one another.

Figure 3.10 Hollenback carver

3 Instrument Grasp

Pen Grasp is an instrumentation methodology where the instrument handle is held with the index finger and thumb, while the remainder of the instrument rests on the middle finger for support. The ring finger is used as finger rest on a nearby stable surface.

Modified Pen Grasp

The modified pen grasp is similar to the pen grasp, however, the **middle finger** is used to hold the handle of the instrument and placed slightly underneath the handle for additional control of fine motor function. Similar to the pen grasp, the ring and pinky fingers are used as a fulcrum on a steady surface.

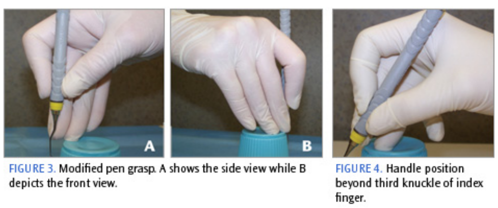


Figure 3.11 Modified pen grasp

Fulcrum – a finger rest on a steady surface, such as adjacent teeth, maxilla, or mandible for stabilization of the hand.

Additional stability may also be provided by utilizing a **short working radius** for more control, accuracy, and protection by holding the instrument closer to the working end.

4 Rotary Instruments

Rotary instruments are variable in terms of their speed and bur. The speed of the hand-piece and the bur's composition and shape determine the best use of the rotary instrument.

Rotary instruments are controlled by a **rheostat**. The rheostat is a foot pedal used to control hand-piece varieties at various speeds depending on pressure applied. They often contain a switch for turning water on or off for use with the high-speed hand-piece.

Low-speed Hand-piece: <12,000 rpm

- Slow-speed can be used with a **latch-type contra-angle attachment** for caries excavation, or restoration polishing using **a large round bur** or **polishing cup/brush** respectively
- Use of the slow-speed motor with a **straight attachment** and **prophy-cup** is commonly used for **hygiene cleanings**

INBDE Pro-Tip: the best way to carefully remove affected dentin and caries near the pulp is with a low-speed hand-piece and large

Medium-Speed Hand-piece: 12,000-200,000rpm

- Medium-speed is used similarly to the high-speed, but is not routinely used due to its lower efficiency.

High-speed Hand-piece: >200,000rpm

- High-speed can be used for preparations in caries removal, previous restoration removal, and crown preparations
- High-speed hand-pieces typically have built-in **fiberoptic light and air-water spray**

Burs

Burs are the working end of the rotary instrument which are loaded into hand-pieces. They primarily have three sections:

- **Head** – cutting part of bur (working end)
- **Neck** – merges into the head
- **Shank** – inserted into the head of hand-piece

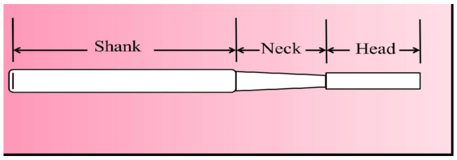


Figure 3.12 Dental burs

INBDE Pro-Tip: commonly tested bur types include:

- **245 (3x0.8mm)** - pear shaped or inverted cone bur
- **330 (1.5mmx0.8mm)** - pear shaped instrument commonly used for pediatric preparations
- **169L** - tapered fissure bur with a thin tip used to create retentive and secondary retentive features

Figure 3.13 Different bur types:
245 (left), 330 (middle), and 169L (right)

Bur Categorization

Burs can be categorized based on their shank attachment to the hand-piece:

- **Latch Type** – attaches via a latch locking mechanism; common for slow speed hand-pieces
- **Friction grip** – common for high-speed

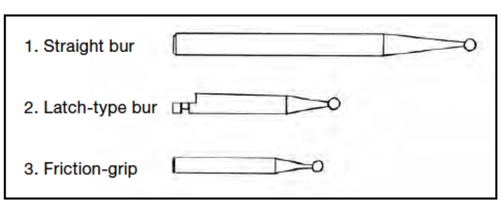


Figure 6.13 Types of Burs and Parts of the Bur

Figure 3.14 Bur categorization

Burs can also be categorized based on their material:

Carbide Bur (Tungsten Carbide)	Diamond Bur
- Prefers end-cutting (i.e punch cuts to begin preparations) - Generates minimum heat - Creates smooth preparation wall - For amalgam removal and creating retentive features - Variety of sizes and shapes The number of blades corresponds to the function, with more blades resulting in less cutting efficiency, but finer finishing.	- Prefers side-cutting ex: bevels - Generates more heat - More rigid The grit of the bur corresponds to the function, with a higher grit providing a less aggressive cutting efficiency with finer finishing.

Hand-piece Instrument Hazards

Hand-piece instruments can pose hazards to **pulp** due to the vibration, heat, and desiccation produced during drilling. Therefore, an **air-water spray** must be used to minimize these effects.

High rotary speed can also pose potential dangers to **soft-tissue damage**, which can be minimized with good isolation, firm finger rests, and short operating distances.

The potential for flying debris must also be minimized using **safety glasses** with side shields for the **eyes** and **rubber dams** or **masks** for potential hazardous **inhalation**.

Rotary instruments may also introduce a potential for **hearing loss,** which is dependent on the intensity of loudness.

Cavity Preparation

1 G.V. Black's Classifications of Caries Lesions

G.V. Black developed many concepts in modern dentistry, including the classification of caries, which can also be used to classify their respective cavity preparations and restorations.

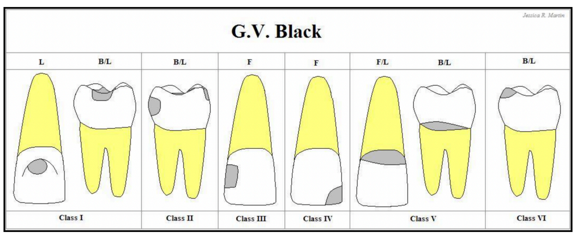


Figure 4.01 G.V. Black's Classifications

Class I

Carious lesions affecting:

1. Fissures and pits
2. Occlusal thirds of premolars and molars
3. Buccal and lingual pits of molars
4. Lingual pits of upper incisors

Class II

Carious lesions affecting:

- **Proximal** surfaces of posterior teeth – **molars and premolars**

Lesions involving occlusal surfaces and at least one proximal surface are still considered class II.

- Ex: Mesial Occlusal (MO), Distal Occlusal (DO), Buccal Distal Occlusal (BDO)

Class III

Carious lesions affecting:

- **Proximal surfaces** of anterior teeth (**incisors and canines**) **without** the involvement of the **incisal edge**

Class IV

Carious lesions affecting:

- **Proximal surfaces** of anterior teeth (incisor and canines) with involvement of the **incisal edge**

Class V

Carious lesions involving the:

- **Gingival third of facial** or **lingual surfaces** of any tooth along the gumline
  - Frequent site of decay for individuals with poor oral hygiene or exposed root surfaces.

Class VI

Caries involving the:

- **Incisal edge** of anterior teeth – **incisors and canines**
- **Cusp tip(s)** of posterior tooth – **premolars and molars**
  - Class VI lesions are often caused by initial abrasion and erosion.

2 Cavity preparation

Cavity preparation refers to the process of altering a tooth to receive a restorative material.

In a completed cavity preparation, there is a **cavosurface margin** that outlines the preparation containing **external** and **internal preparation walls**.

- Cavosurface margin: the junction of the cavity preparation and the external tooth surface

Preparation Walls

External walls refer to the distinct walls which contact with an edge with the cavosurface margin. They are named according to the outer tooth aspect that they are parallel and closest to.

Internal walls are classified based on their plane of dimension:

- **Axial Wall** – runs parallel to long axis of tooth
- **Pulpal Wall/Floor** – runs perpendicular to long axis of tooth along base of preparation, above pulp chamber

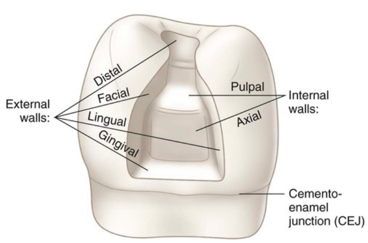


Figure 4.02 Preparation Walls

The junctions of preparation walls are also named based on their intersecting walls:

- **Line Angle** – where 2 walls meet
- **Point angle** – where 3 walls meet

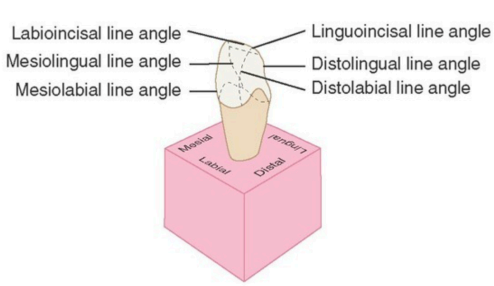


Figure 4.03 Line Angles

Initial Tooth Preparation

INBDE Pro-Tip: cavity preparation according to G.V. Black is a high yield topic and involves the following 8 steps:

1. Outline Form
2. Resistance Form
3. Retention Form
4. Convenience Form
5. Removal of Remaining Caries
6. Pulp Protection
7. Secondary Retention and Resistance Form
8. Finishing of External Walls

1. Outline Form

The outline form establishes the external outline of the preparation and cavosurface margin. It is determined by extent of carious lesion.

Requirements include:

- Initially extend **0.2 mm into the dentin** of sound tooth structure just below the DEJ
  - Only extend depth if deeper caries exist
- For Class II - extension of gingival floor to get **0.5mm clearance** with adjacent tooth
  - Facial and lingual proximal walls require an extension of 0.5 mm clearance to the adjacent tooth.
  - Exception: if it would require unnecessary removal of sound tooth structure to open the contact
- Removal of unhealthy enamel:
  - **Friable enamel** - demineralized enamel which cannot be effectively boned.
  - **Unsupported/Undermined Enamel** - enamel with no underlying dentinal support which cannot support cyclic loading

2. **Primary Resistance Form**

Resistance form is a design developed to allow for the tooth and restoration to withstand the forces of mastication and not fracture.

Requirements include:

- Horizontal and flat gingival and pulpal floors
- Rounded internal line angles- to reduce stress concentration
- Preservation of cusps and marginal ridges, this will maintain tooth strength
  - o Consider **capping** the cusp, when the extension is greater than half the distance from the primary groove to the cusp tip.

3. **Primary Retention Form**

Retention form refers to design features that allow for the retention of the restoration during function.

Features include:

- Occlusal surface preparations – convergent external walls to prevent occlusal displacement
- Dovetail feature to prevent proximal displacement

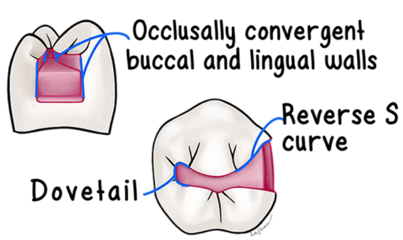


Figure 4.04 Primary retention form

4. **Convenience Form**

Convenience form involves extending the preparation for visibility and access.

Final Tooth Preparation

1. **Removal of Remaining Caries**

Removing any remaining caries with hand instruments, where indicated, or burs.

2. **Pulp Protection**

When indicated, **liners** and **bases** can be applied to protect the pulp or aid in pulpal recovery.

- Liners, such as **calcium hydroxide (Dycal)** or **Resin Modified Glass Ionomers**, provides a barrier to protect the dentin. They also provide thermal protection and can promote 3° dentin formation.
- Bases, such as **Resin Modified Glass Ionomers (Vitrebond)** or **GI cements**, are used for metal restorations or on top of liners to protect liners from being absorbed or washed away. They provide thermal protection and help stress distribution.

Indications for pulp protection include:

- Deep excavation approximating pulp – requires indirect pulp cap with base material
- <1mm diameter **asymptomatic** pulp exposure asymptomatic – requires direct pulp cap with liner and base
- >1mm diameter **symptomatic** pulp exposure via carious or mechanical means – requires pulpotomy or root canal treatment

Sealers and desensitizers can be used in preparations involving dentin to minimize sensitivity. **GLUMA** is a common desensitizing agent, which minimizes dentinal tubular fluid movement, by occluding dentinal tubules through the cross-linking of tubular proteins.

- GLUMA: glutaraldehyde 5%, HEMA (Hydroxyethyl methacrylate) 35%), water

INBDE Pro-Tip: Pulp protection indications vary depending on the **remaining dentin thickness (RDT)**.

Amalgam	
≥ 2mm RDT	Sealer
0.5-2mm	Base, Sealer
<0.5mm	Liner, Base, Sealer
Composite Resin	
≥0.5mm	Bond
<0.5mm	Liner, Base, Bond
Gold or Ceramic	
≥2mm	Cement
0.5-2mm	Cement (2mm thick)
<0.5mm	Liner, Base, Cement

7. Secondary Resistance and Retention Form

Additional resistance and retention forms may be indicated for larger restorations.

- **Retentive Grooves** – shallow grooves designed to prevent material from being dislodged proximally or occlusally
- **Beveled enamel margins** – provide more surface area for enamel bonding with composite
- **Slots/pins** – used for retention during advanced amalgam restorations where a cusp or wall maybe missing

8. Finishing of External Walls

This is the last step before progressing to the restoration phase, and it involves insuring smoothness of the cavosurface margin and inspecting for a clean preparation.

Moisture Control

Moisture control is crucial to restoration success, as many restorative materials are moisture-sensitive. This can be done by using for example: rubber dams, suctions, and cotton rolls.

3 Restorative Material Specific Preparations

Amalgam Preparation

Amalgam preparations require a **carbide bur** for **smooth** walls. Preparation step specific features include:

- **Retention Form** – occlusal convergence (1°), grooves/slots/pins (2°)
- **Resistance Form – 90° cavosurface margin**, preservation of cusps and marginal ridges, flat pulpal and gingival floors, removal of unsupported tooth structure, and rounded internal line angles
- **Amalgam Thickness: 1.5 mm to 2.0 mm**

Composite Resin (CR) Preparation

Composite resin restorations require a coarse diamond bur for rough walls. This creates more surface area for better bonding retention.

CR preparations have similar requirements as amalgam, but require less retentive features. Occlusal convergence and uniform depth are not as crucial to material success, allowing for more conservative preparations.

Gold Onlay Preparation

Gold onlay preparations often involve 2° resistance and retention form features such as: **collar** (beveled shoulder around capped cusp) and **skirt** (feather edged margin around capped cusp).

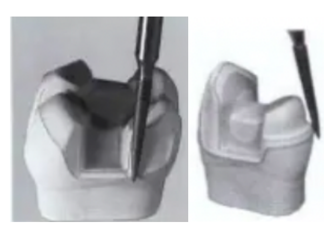


Figure 4.05 Gold only preparation

Amalgam

1 Amalgam

Amalgam is a mixture of metals. **Dental amalgam** is more specific, in that it is a combination of **liquid elemental mercury** and a **metal alloy**.

One common combination is based on the **Eames' Ratio** of half mercury and half metal alloy. Alloy contains:

- **Silver and Copper** – provider of strength
- **Tin** – primary provider of corrosion products
- **Zinc** – a deoxidizer

Trituration

In an amalgam capsule, the amalgam components are often separated by a membrane, which must be broken prior to mixing via a machine called the **triturator** or **amalgamator**.

Trituration results in three phase compositions:

- **γ Phase** – composed of unreacted silver-tin alloy and is the **strongest and least corrosion resistant**
- **γ1 Phase** – composed of silver-mercury matrix and is the **next** strongest and corrosion resistant
- **γ2 Phase** – composed of tin-mercury matrix, which is weak and susceptible to corrosion and creep
  - Corrosion can seal the restoration margin overtime, but due to its weak mechanical properties, excess γ2 is unwanted

Trituration for 1-2 minutes results in manipulable amalgam.

A **properly** triturated amalgam is shiny, **smooth** and **easily loaded**. This amalgam will set into a carvable consistency and reach its peak strength **after 24h**.

Over-triturated amalgam is warm, soft, and sets quickly; while **under-triturated** amalgam is dry, crumbly, and sets quickly.

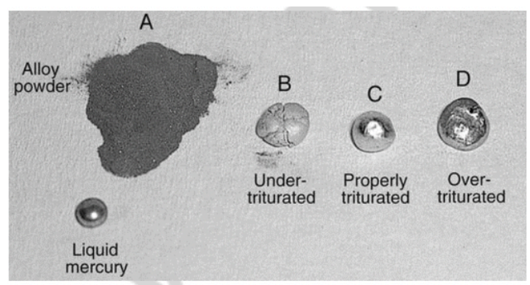


Figure 5.01 Types of Amalgam Titrations

Alloy Types

Historic Amalgam:

- In the past, copper composition was low inside of dental amalgam. However with time, more copper was incorporated to provide more strength, lower corrosion ability, and longer marginal longevity.

Low copper – contains under 12% Cu and yields in the production of γ, γ1, γ2 phases.

High copper – contains over 12% Cu and yields only γ and γ1 phases, with minimum corrosion products and creep.

INDBE Pro-Tip: **alloy particle types** are high yield topics. They are commonly:

- **Spherical** – small spheres
  - More plastic
  - Quicker set time
  - Condenses better – ideal for pins and slots
  - More durable
- **Admixed** – contains both spherical and irregular particles
  - Needs higher condensation forces
  - Yields better proximal contacts with adjacent teeth

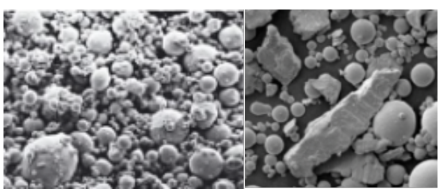


Figure 5.02 Alloy particle types; Spherical (left), and Admixed (right)

2 Dental Amalgam

Indications	Contraindications
• Bigger preparations that require heavier functional loading • Areas that are harder to isolate from saliva • Teeth which serve as abutments • Non-esthetic regions • Preparations that extend to root surfaces	• Esthetics zones • Metal allergy

After amalgam is triturated, it will begin to set and reach a hardness that requires metal instruments for manipulation or **carving**.

Commonly used instruments and their purposes include:

1. **Hollenback carver** and **cleoid-discoid** – occlusal carving
2. **Amalgam knife** – removing excess amalgam on proximal surfaces and carving of the gingival embrasures
3. **Explorer tip** – occlusal embrasure carving

The **marginal ridge fracture** can occur from an amalgam restoration. This may occur due to:

- Overbuilt marginal ridge
- Axiopulpal line angle not being rounded
- Excessive carving and leaving less than 2 mm of thickness of amalgam
- Incorrect removal of matrix band

Class V Restorations

Class V preparations may be indicated for amalgam restorations when moisture control is a concern.

Class V amalgam restoration preparations must demonstrate:

- **Occlusal divergence** due to the enamel rod orientation
- **Retention features** such as gingival or circumferential grooves can be used

Mercury Toxicity

80% of elemental mercury is absorbed through the lungs making **inhalation** as the greatest health risk.

INDBE Pro-Tip: Mercury toxicity is a high yield topic.

Due to its potential hazard, amalgam must be handled in a **well-ventilated space**, such as, **pre-capsulated** mercury that is mixed in an **amalgamator with a closed hood**. Good ventilation is also required for storage and removal or polishing of amalgam restorations.

Any spills must be managed by covering with **sulfur powder** and cleaned with a **special vacuum**.

Acute mercury toxicity can result in:

- Muscle weakness (hypotonia)
- GI trouble
- Loss of hair (alopecia)

Mercury forms

- **Methylmercury** – organic highly toxic form, however exposure can only occur with ingestion of **seafood**
- **Elemental** – a liquid metallic form found in **dental** amalgam
- **Mercury salts** – an inorganic form

INDBE Pro-Tip: Mercury forms is a high yield topic.

Composite Resin & Glass Ionomer

1 Composite Resin

Composite resin is a tooth-colored restorative material, which provides additional retention via bonding to enamel and dentin.

Enamel Bonding

Enamel bonding is **reliable** and **predictable**.

Acid etching transforms the smooth low energy enamel surface, into an irregular surface, with increased **surface free energy and wettability**. The increased wettability allows fluid-based resin to easily spread into the irregularities and become **mechanically interlocked** following polymerization.

Enamel bonding can generate up to **20 MPa** of shear bond strength, when conducted without moisture contamination.

Dentin Bonding

Dentin bonding is equally as strong as enamel bonding, but it is not as reliable and predictable.

This is due to:

- Difference in **composition** – dentin has a higher water composition than enamel, which reduces the effectiveness of acid etching
- Difference in **structure** – enamel rods are arranged in parallel and have a regular pattern that is easily etched, while dentin tubules are composed of a disorganized organic matrix of collagen
- **Dentinal tubule arrangement** – dentinal tubules become larger in diameter and more numerous near the pulp; this results in decreased bond strength closer to the pulp, due to the interference of dentinal fluid.
- **Smear layer** – the smear layer will plug the dentinal tubule orifices to form a **smear plug**, which will decrease dentinal permeability by up to 90%. The smear layer is composed of the shavings of hydroxyapatite and collagen generated during tooth preparation

INBDE Pro-Tip: remember the characteristics of dentin which make dentinal bonding less reliable than enamel bonding.

2 Enamel and Dentinal Bonding

Acid Etch

After preparation, a **30-40% phosphoric acid** (commonly 37% gel acid etchant) is applied to for **15 seconds** and rinsed with **water** for **10 seconds**. Acid etching **dissolves** the **smear layer** and cleans the surface debris.

After etching, the surface must be gently air-dried and left moist. A desensitizer (**GLUMA**) can be applied to re-wet the tooth.

Enamel has a **chalky white appearance** after etching due to the creation of microporosity. Etching exposes the collagen layer in dentin, **widening** the **dentinal tubules**.

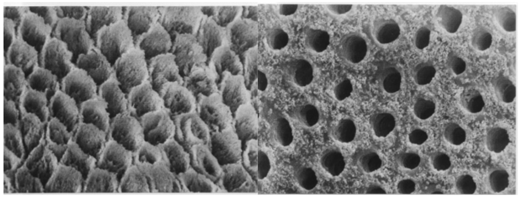


Figure 6.01 Enamel (left) and Dentin (right) Surface after etching

Primer

The primer is typically composed of **HEMA (hydroxyethyl methacrylate)**, an **amphiphilic resin monomer wetting agent** and **solvent**. Common solvents include acetone, ethanol and water.

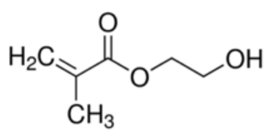


Figure 6.02 HEMA Monomer

Primer will infiltrate the enamel prisms and dentinal tubules to **prevent collagen collapse** and allow for better adhesion.

After application, the primer must be gently air-dried to evaporate the solvent and leaving only the monomers.

> **INBDE Pro-Tip**: Primer can result in an allergic reaction called **contact dermatitis** when it contacts bare skin.

Bond or Adhesive

The bonding agent is primarily composed of **Bis-GMA (bisphenol A-Glycidyl Methacrylate) monomers** which chemically bonds to the primer below and composite resin above through **methylmethacrylate (MMA) bonds**.

After application, the bond is gently air dried to evaporate the solvent and **light cured**.

Hybrid Layer Formation

Acid etching generates a high-energy surface with microporosity in which adhesive resins are mechanically interlocked. This layer of **micro-mechanical** retention between the resin and irregular tooth surface is called the **hybrid layer**. More specifically, the resin that is polymerized after penetration into the exposed dentinal tubules is called **resin tags**.

The micro-mechanical bond created by the hybrid layer is the main contributor to composite resin retention, followed by the chemical bond between the primer, adhesive, and composite.

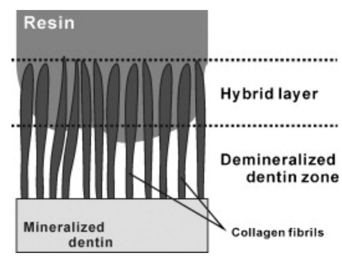


Figure 6.03 Hybrid layer formation

Enamel-Dentin Bonding Systems

> **INBDE Pro-Tip:** enamel-dentin bonding systems are a high yield topic.

Etch and Rinse Systems

Etch and rinse systems involve a **total etch** of acid etching and subsequent rinsing as individual steps.

- 4th Generation – ex: Optibond FL
  The 4th generation system is a 3-step process with each etch, primer and adhesive as individual steps.
- 5th Generation –
  The 5th generation system is a 2-step process in which etch is followed by a primer and adhesive product, combined into a single step.

Etch and rinse systems can also be used with the **selective etch technique** in which etchant is applied selectively to **enamel** to potentially reduce post-operative sensitivity, while maintaining a strong enamel bond.

Self-Etch Systems

Self-etch systems combine the acid etch with another step. The acid etchant is **less potent** because it is **not rinsed** after application. This has several implications:

- Smear layer is not removed – a carbide bur is recommended for preparation to minimize smear layer formation
- Less post-operative sensitivity
- Weaker enamel bond

Self-etch materials must commonly be refrigerated.

- **6th Generation –** The 6th generation is a 2 step process which combines acid etch and primer into a single step, followed by adhesive.
- 7th Generation – The 7th generation combines acid etch, primer and adhesive into a single step.

3 Composite Resins

A composite is defined as a material that is composed of two or more constituent parts.

They are composed of:

- **Resin Matrix** – an organic component of a highly viscous pre-polymer, which proceeds to polymerize into a solid form when cured
  - i.e. Bis-GMA, TEG-DMA, UDMA
  - Leaching of **Bisphenol-A (BPA)** can happen with uncured resin and through the wearing of composite
- **Filler Particles** – small radiopaque particles of **silica** (silicone dioxide) and **powdered ceramic glass** (barium silicate, silver silicate, strontium silicate, zinc) that range in different shapes and sizes
- **Coupling agent** – coats filler particles to promote adhesion between fillers and resin-matrix – i.e silane

Composite Resin Types

The filler size, loading and shape affect the mechanical properties of the composite resin. Composite resins can be categorized by **filler characteristics**:

Macrofill – conventional composites that are no longer used

- Filler Loading – 80% filler
- Particle Size – 8μm
- Characteristics – high strength, low polishability, fast wearing of resin matrix to increase roughness overtime

Microfill

- Filler Loading – 40% filler
- Particle Size – 0.04μm
- Characteristics – weak, better polish/wear resistance due to higher matrix composition, and it can flex under pressure

Hybrid

- Filler Loading – 80% filler
- Particle Size – 1μm

Nanofill

- Particle Size – 0.005-0.01μm
- Characteristics – small particles can group together with each other to form larger particles, resulting in a full range of filler sizes

Nanohybrid- incorporates nano-sized and larger particles

INBDE Pro-Tip: larger filler particles provide more strength, but also demonstrate low polishability and high wear into a rougher surface. In addition, higher filler loading has a lower matrix content, which results in less water absorption.

Composite resins can also be categorized based on their viscosity:
Flowable Composite – various composites with minimum filler amount – ex: microfill
- Characteristics – Lower wear resistance

Packable Composite – composites with high filler amount
- Characteristics – very viscous, handles like amalgam

Composite resins can also be categorized based on their method of polymerization:
Self-Cure or Chemical Cure – a two-paste system which must be mixed in equal parts to initiate the polymerization reaction
- Base Paste – composed of composite and **tertiary amine (activator)**
- Catalyst Paste – composite and **benzoyl peroxide(initiator)**

Self-cure composites have a limited working time of around **2 mins**.

Light Cure – a single paste system which does not involve mixing; and requires a **468nm blue visible light** to initiate the polymerization reaction
- Initiator – **camphorquinone** (photoinitiator)

Dual cure – composite resin combining elements of self-cure and light cure
- Dual cure composites are useful for large build-ups which allow a light curing of the surface and a chemical reaction to cure the deeper material.

INBDE Pro-Tip:

Composite Resin	Initiator
Self-Cure	Benzoyl Peroxide (Activator: Tertiary Amine)
Light Cure	Camphorquinone
Dual Cure	Benzoyl Peroxide, Camphorquinone

Polymerization Shrinkage

During the polymerization reaction, free radicals break the **carbon double bond** in a **Bis-GMA** monomer to form a single bond with an adjacent monomer. The side groups will **cross-link** by sharing electrons via a **covalent bond** to create strong cured material. The continuous recruitment of monomers results in a decrease in resin volume and subsequent **shrinkage**.

INBDE Pro-Tip: polymerization shrinkage of composite resins commonly ranges between 2-3%.

Configuration (C) Factor
The C-factor is commonly used to represent the expected polymerization shrinkage. The C-factor is determined by the **proportion of bound to unbound surfaces** of the composite resin restoration.

The G.V Black classification number of cavity preparations is inversely related to the c-factor.

A higher C-factor indicates a higher chance for **shrinkage**, **micro-leakage** and **post-operative sensitivity**. To minimize shrinkage, **smaller increments of 2mm** can be cured for a larger restoration.

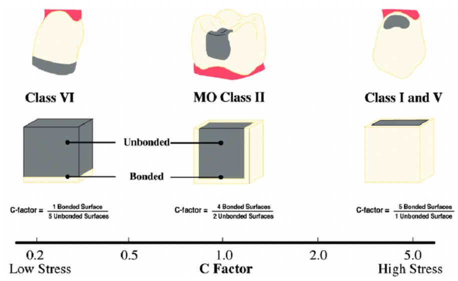


Figure 6.04 C-factor classification

4 Glass Ionomers

Glass ionomers (GI) are a tooth-colored restoration material composed of a **salt matrix**. Glass ionomers are self-adhesive to tooth surfaces; and rely on the chemical, **calcium chelation bond**, formed between the carboxylate groups of the glass ionomer and hydroxyapatite (tooth).

Some characteristics include:

- Fluoride storage – released overtime within material
- Weaker material
- Less shrinkage
- Uncontrolled and lengthier set time

The table below provides a comparison of glass ionomers to composite resin.

Glass Ionomer	Composite Resin
Acid – Polyacrylic Acid Base – Fluoro-alumino-silicate glass	Matrix – Bis-GMA Filler – barium silicate glass
Self-cure	Light or self-cure
Chemical bonding	Micromechanical bonding
Release Fluoride	Do Not Fluoride
Weaker	Stronger

INBDE Pro-Tip: Glass Ionomers are composed of:

- Acid – Poly acrylic acid
- B a s e –

Hybridization of glass ionomer and composite resins have created a spectrum between salt-matrix glass ionomer and resin-matrix composite resin materials.

Resin-Modified Glass Ionomers (RMGI) – set by an **acid-base reaction (GI)** and **free-radical addition polymerization** (by light or chemical curing):

- Free-radical initiation of resin induces more rapid polymerization
- Some control over setting time with light cure
- More strength compared to conventional GI
- Fluoride release due to incorporation of GI

Compomers (Polyacid-Modified Resin Composites) – anhydrous single pastes which possess primary elements of both CR and GI, except for water (anhydrous).

Excluding water ensures that the initial setting occurs only by polymerization, which prevents untimely setting and increases setting time with proper moisture isolation. The acid-base reaction of the GI occurs later with water absorption from oral cavity.

- Compomers are commonly used in orthodontics as their slow polymerization provides more time to clean up excess around orthodontic bands.

Ionomer-Modified Composites – set only by **polymerization mechanism**, but include ion-leachable glasses to release very minimal fluoride.