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Textbook of
Preclinical Conservative
DENTISTRY

THIRD EDITION



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Foreword
Mahesh Verma

JAYPEE

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Chapter

Dental Materials

Chapter Outline

- Classification of dental materials
- Properties of dental materials to be considered
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- Ethoxybenzoic acid reinforced cement
- Polymer reinforced zinc oxide-eugenol cement
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- Composition
- Setting reaction of glass ionomer cement
- Dental amalgam
- Clinical considerations
- Steps to reduce mercury exposure in the dental clinic
- Adhesive dentistry
- Definitions
- Enamel bonding
- Dentin bonding
- Evolution of dentin-bonding agents
- Composites
- Classification of composites
- Cast metal alloys
- Components of cast gold alloys
- Classification of cast gold alloys
- Waxes

Dental materials are especially fabricated materials which are designed to be used in dentistry. Many metals, nonmetals, resins, ceramics, organic and inorganic materials are used to replace or alter the tooth structure in form of dental materials.

CLASSIFICATION OF DENTAL MATERIALS

Classification According to Use

- Preventive (materials which primarily prevent or inhibit tooth decay)
  - Pit and fissure sealants
- Restorative (materials used to repair or replace the tooth structure)
  - Cements
  - Composites
  - Amalgam
  - Ceramics
  - Cast metals.
- Auxiliary (used for fabrication of prosthesis or appliances but don't become part of these devices)
  - Etchants
  - Waxes
  - Impression materials
  - Bleaching trays
  - Gypsum products.

PROPERTIES OF DENTAL MATERIALS TO BE CONSIDERED

- Physical properties
  - Coefficient of thermal expansion
  - Opacity
  - Translucency
  - Thermal and electrical conductivity
  - Hue, value and chroma.
- Mechanical properties
  - Compressive strength
  - Tensile strength
  - Shear strength
  - Malleability and ductility
  - Hardness.
- Biological properties
  - Allergy
  - Toxicity
  - Biocompatibility.
- Chemical properties
  - Setting reaction
  - Tarnish and corrosion
  - Chemical solubility and disintegration
  - Galvanic reaction.

DENTAL CEMENTS

Dental cement is the dental material which forms a hardened mass by mixing two components and are used as restorative materials, pulp protective materials underneath restorations and as luting cements for restorations. These components are available as powder and liquid or as two paste system.

Uses of Dental Cements

- As temporary restorations
- As permanent restorations
- For temporary luting

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- For permanent luting
- As root canal sealers
- For pulp protection as liners and bases.

Classification of Dental Cements based on Composition

- Conventional cement
  - Zinc oxide eugenol (ZOE) cement
  - Zinc phosphate cement
  - Glass ionomer cement
  - Polycarboxylate cement.
- Resin–base cement
  - Resin cement
  - Resin-modified glass ionomer cement.

ZINC OXIDE-EUGENOL CEMENT (FIG. 4.1)

Zinc oxide-eugenol cement is one of the oldest used cements. It has soothing action on pulpal tissues and eugenol has topical anesthetic properties therefore, it is also termed as an obtundent material. Though other cements are also used for temporization, but zinc oxide- eugenol cement is used most commonly because it is much less irritating to the pulp and produces better marginal seal than zinc phosphate.

Composition of Zinc Oxide-eugenol Powder

Sl. No.	*Component*	*Percentage (%)*	*Purpose*
1.	Zinc oxide (ZnO)	69.0%	Reactive ingredient
2.	White rosin	29.3%	Reduces brittleness
3.	Zinc stearate	1.0%	Catalyst
4.	Zinc acetate (acts as accelerator)	0.7%	Accelerator

Composition of Liquid

1.	Eugenol	85.0%	Reactor
2.	Olive oil	15.0%	Plasticizer



FIGURE 4.1: Zinc oxide-eugenol.

(*Courtesy:* Dentsply India)

Setting Reaction of Zinc Oxide-eugenol Cement

- On mixing powder and liquid, the zinc oxide hydrolysis occurs and subsequent reaction take place between zinc hydroxide and eugenol to form a chelate, zinc eugenolate
- ***First reaction:***

$$ZnO + H_2O \rightarrow Zn(OH)_2$$

- ***Second reaction:***

$$Zn(OH)_2 + 2HE \rightarrow ZnE_2 + 2H_2O$$

- Water is needed for the reaction and it is also a byproduct of the reaction. So, reaction progresses more rapidly in humid conditions
- Because zinc eugenolate rapidly hydrolyzes to form free eugenol and zinc hydroxide, it is one of the most soluble cements. To increase the strength of the set material, changes in composition can be made to the powder and liquid.

ETHOXYBENZOIC ACID REINFORCED CEMENT

- In this cement, ethoxybenzoic acid (EBA) chelates with zinc forming zinc benzoate
- Addition of fused quartz, alumina, and dicalcium phosphate improves mechanical properties of cement.

Composition of Ethoxybenzoic Acid Reinforced Cement

Sl. No.	*Component*	*Percentage (%)*	*Purpose*
1.	Zinc oxide (ZnO)	70%	Reactive ingredient
2.	Alumina	30%	Increases strength
3.	Fused quartz and calcium	30%	Improve mechanical properties

Composition of Liquid

1.	Eugenol	37.5%
2.	Ortho- ethoxybenzoic acid	62.5%

Effects of EBA on Eugenol Cement

- Increase in compressive and tensile strength
- More powder can be incorporated to achieve standard consistency
- Decrease in setting time (if concentration is <70%).

POLYMER REINFORCED ZINC OXIDE-EUGENOL CEMENT

In this mixture, resin helps in improving strength, smoothness of the mixture, and decreases flow, solubility, and brittleness of the cement.

Composition of Polymer Reinforced Zinc Oxide-eugenol Cement

Sl. No.	*Component*	*Percentage (%)*	*Purpose*
1.	Zinc oxide	80%	Reactive ingredient
2.	Polymethyl–methacrylate	20%	Increases strength
3.	Traces of zinc stearate, zinc acetate		

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Composition of Liquid

1.	Eugenol	85%	Reactor
2.	Acetic acid	15%	Accelerator

Manipulation of zinc oxide-eugenol (ZOE) cement: ZOE cement is available as:

- Powder and liquid system
- Paste-paste system.

Manipulation of Powder and Liquid System (Fig. 4.2)

- Powder is measured and dispensed with a scoop whereas liquid is dispensed as drops on glass slab
- Powder is divided in main bulk increment, followed by smaller increments
- Start the mixing by incorporating half of the powder into the liquid with a heavy folding motion and pressure
- When powder particles are wet with liquid, add the remaining powder to the mixture and continue to use a heavy folding motion to attain a putty consistency
- For base, when mixing is done, bring the mixture together and roll it. One should be able to pick up the mixture without deformation.

Paste-paste system: In this, two pastes are dispensed in equal lengths on paper pad. Two pastes have different colors, and mixing is done till a homogeneous color is obtained.

Factors Affecting Working and Setting Time

- Higher the powder: Liquid ratio, faster the material sets
- Cooling of glass slab slows down the setting reaction
- Setting time of this cement is long but since water accelerates the setting reaction, it sets faster in mouth than outside.

Advantages	*Disadvantages*
■ Least irritating cement ■ Good short-term sealing	■ Highly soluble ■ Low strength ■ Low compressive strength

ZINC PHOSPHATE CEMENT

Zinc phosphate cement is one of the oldest and most widely used cements. It was first introduced in 1878 and still used today because of excellent clinical track record. Its ADA specification number is 8.

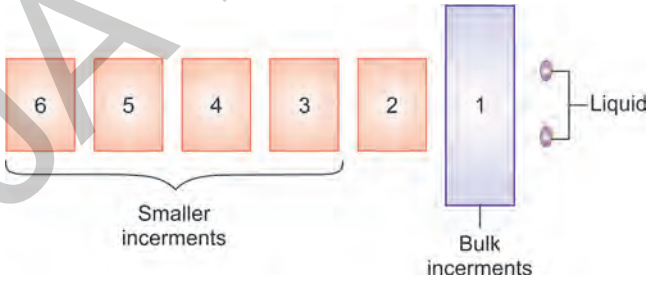


FIGURE 4.2: Distribution of powder and liquid for manipulation of ZOE cement.

The Types of Zinc Phosphate Cement

- ***Type I***: Used for cementation. It forms the film thickness of less than 25 μm.
- ***Type II***: Used as base. It results in film thickness between 25 μm and 40 μm.

Composition of Zinc Phosphate Cement

Sl. No.	*Component*	*Percentage (%)*	*Purpose*
1.	ZnO	90.2%	Main ingredient
2.	MgO	8.2%	Increases compressive strength
3.	SiO_2	1.4%	Aids in calcination process
4.	Bi_2O_3	0.1%	Imparts smoothness to the mixed cement
5.	Miscellaneous (BaO, Ba_2SO_4, and CaO)	0.1%	
All the ingredients are sintered at temperatures between 1000°C and 1400°C into a cake that is subsequently ground into fine powder			

Composition of Liquid

1.	Phosphoric acid	38.2%	Main reactive ingredient
2.	Water	36.0%	
3.	Aluminum or zinc phosphate	16.2%	
4.	Zinc	7.1%	Buffer
5.	Aluminum	2.5%	Buffer

Setting Reaction (Fig. 4.3)

Setting reaction is a two-stage process. In first part, zinc oxide powder reacts with phosphoric acid to form zinc phosphate and water. This zinc phosphate reacts with more zinc oxide forming hopeite (hydrated zinc phosphate). Aluminum prevents crystallization and permits the formation of an amorphous cement.

Manipulation of Cement

- Working time ~ 5 minutes
- Setting time ~ 2.5–8 minutes.
  Mixing on a cooled glass slab allows the heat produced in the reaction to dissipate more easily and slow the chemical reaction, thus increasing the working time. Care must be taken not to cool the slab below the dew point or water condensation will form and affect the properties of the cement.

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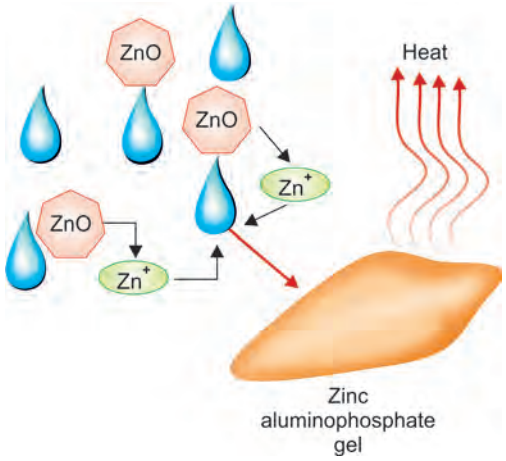


FIGURE 4.3: Setting reaction of ZOE cement.

Since setting reaction is an exothermic type, the heat liberated while setting further accelerates the setting rate. So, it is very important to dissipate the heat using chilled glass slab, mixing smaller increment for initial mixing of cement on large area of glass slab

- Powder is divided into 5–8 increments of different sizes **(Fig. 4.4)**
- ***First two increments are smaller in size so as to:***
  - Achieve the slow neutralization of the liquid
  - Control the reaction by decreasing exothermic heat of reaction
- ***Middle increments are larger in size:***
  - To saturate the liquid to form zinc phosphate
  - Because of presence of less amount of unreacted acid, this step is not affected by heat released from the reaction.
- ***In the end, the smaller increments*** of powder are added so as to:

Achieve Optimum Consistency

- While dispensing, the liquid bottle should be held vertical and close to the powder. Repeated opening of the liquid bottle or early dispensing of the liquid prior to mixing should be avoided because evaporation of liquid can result in changes in water/acid ratio which can further result in decrease in pH and an increase in viscosity of the mixed cement. If the liquid is cloudy or crystals are present in the bottle, it should be discarded as the concentration of the acid has been changed and it is no longer optimal
- For base or temporary restoration, consistency should be such that it can be rolled into a ball without sticking.

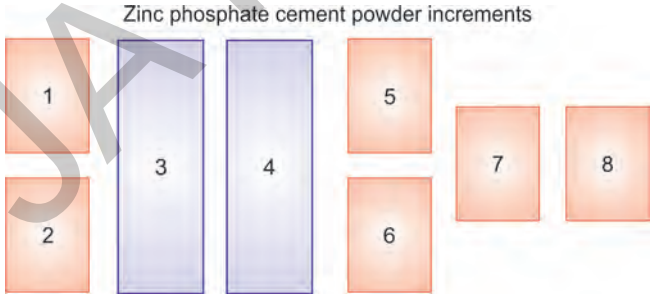


FIGURE 4.4: Division of powder into 5–8 small increments. First two increments are smaller in size so as to have slow neutralization of liquid and control the reaction. Middle increments are larger in size to saturate the liquid and form bulk and finally smaller increments of powder are added so as to achieve optimum consistency.

Mechanical Properties

- Strength depends on its powder to liquid ratio; zinc phosphate cement achieves 75% of its ultimate strength within 1 hour
- Good compressive strength of cement is 104 MPa
- Low tensile strength—5.5 MPa
- Modulus of elasticity is 13.7 gigapascals. This high MOE makes the cement quite stiff and resistant to elastic deformation
- Retention of cement by mechanical interlocking and not by chemical interaction.

Biocompatibility

Because of presence of phosphoric acid, acidity of cement is quite high (pH is 2.0) making it irritable to pulp

Advantages	*Disadvantages*
■ Long record of clinical acceptability ■ High compressive strength ■ Thin film thickness	■ Low initial pH, irritant to pulp ■ Lack of an adhesion to tooth structure ■ Lack of anticariogenic effect ■ Soluble in water

ZINC SILICOPHOSPHATE CEMENTS

It is hybrid cement which is combination of zinc phosphate cement with silicate cement and is also known as silicophosphate cement. Most commonly used cement is silicophosphate cement that consists of 90% silicate cement powder and 10% zinc phosphate cement powder.

Composition

- Powder contains an acid soluble silicate, zinc, and magnesium oxides
- Liquid consists of phosphoric acid.

Properties of Zinc Silicophosphate Cements

- Translucent and more esthetic than zinc phosphate cement
- Anticariogenic because of fluoride release from this cement
- Has sufficient strength and low solubility.

CALCIUM HYDROXIDE

Calcium hydroxide has high alkaline pH (12.5). Its alkaline pH helps in neutralization of acids produced by the microorganisms and irritating acidic component of restorative base and materials. Calcium hydroxide also provides antibacterial properties.

Calcium hydroxide is available in:

- Powder form **(Fig. 4.5A)**
- Quick-setting paste form (Dycal) **(Fig. 4.5B)**.

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FIGURES 4.5A AND B: Calcium hydroxide.

Mixing Calcium Hydroxide Cement

- Dispense equal amount of base and catalyst onto the mixing pad
- Using calcium hydroxide applicator or spoon excavator, mix the cement for 10–15 seconds until a uniform color is achieved. Place the cement in the deepest portion of cavity.

Uses of Calcium Hydroxide

- As liner and sub-base
- For direct and indirect pulp capping
- In pulpotomy
- For apexification
- As root canal sealer.

ZINC POLYCARBOXYLATE CEMENT/ZINC POLYACRYLATE CEMENT (FIG. 4.6)

It was one of the first chemically adhesive dental materials introduced in the 1960s. It bonds to tooth structure because of chelation reaction between carboxyl groups of cement and calcium present in tooth structure.

Its ADA specification number is 96.

Composition of Zinc Polycarboxylate Cement/Zinc Polyacrylate Cement

Sl. No.	*Component*	*Percentage (%)*	*Purpose*
1.	Zinc oxide	85–96%	Main reactive ingredient
2.	Stannous fluoride	4%	Improves the set, leaches fluoride— anticariogenic
3.	Magnesium oxide	4–10%	Preserves white color
4.	Silica	0–2%	Improves sintering process
5.	Alumina	<5%	Forms complexes with acid

Composition of Liquid

Sl. No.	*Component*	*Percentage (%)*	*Purpose*
1.	Polyacrylic acid	32–43%	Main ingredient
2.	Itaconic acid/maleic acid	32–43%	



FIGURE 4.6: Zinc polycarboxylate cement.

(*Courtesy:* Dentsply)

Manipulation of Zinc Polycarboxylate Cement

- Liquid is dispensed just before mixing of the cement as the loss of water from liquid can result in increase in its viscosity. While dispensing the liquid bottle should be held vertical, so that liquid comes out under its own weight
- Mix first-half of powder to liquid to obtain the maximum length of working time. Mixed cement should be adapted to tooth till it is glossy in appearance. It shows presence of unreacted acid groups which are available for bonding.

Setting Reaction

When the zinc oxide and polyacrylic acid come into contact, a salt (zinc polyacrylate) matrix is formed only on the surface of the zinc oxide particles. Polyacrylic acid chains cross-link through the zinc ions of the zinc oxide. The set material has cores of zinc oxide within the zinc polyacrylate matrix binding the unreacted zinc oxide cores together.

The mixed cement goes through a rubbery phase as it is setting and it should not be disturbed during this phase because otherwise adhesive bond of the cement will be

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ruptured. This can cause microleakage if cement is pulled away from the tooth surface. The cement should not be disturbed until it can be removed cleanly from the margin of a cemented restoration.

Properties

- ***Working time and setting time***:
  - Working time ~ 2.5 minutes
  - Setting time ~ 6–9 minutes.
- ***Adhesive to tooth structure***:
  - Polyacrylic acid bonds with calcium ion via the carboxyl group. Adhesion depends on the unreacted carboxyl group.
- ***Mechanical properties***:
  - Compressive strength is less than zinc phosphate cement ~ 55–67 MPa
  - Tensile strength ~ 2.4–4.4 MPa
  - Low modulus and is, therefore, slightly more elastic and less likely to fracture under heavy load.
- ***Solubility***: It is low in water. But in acidic environment with pH of less than 4.5, solubility increases. Reduction in P:L ratio also increases solubility
- ***Biological considerations***: pH of the liquid is 1.7 but increases rapidly after mixing. Zinc polycarboxylate is biocompatible because of the following reasons:
  - Size of polyacrylic acid molecule is bigger, this makes it difficult to enter into dentinal tubules.
  - pH of the cement rises more rapidly when compared to that of zinc phosphate.

Advantages	*Disadvantages*
■ Adhesion to tooth structure ■ Rapid rise in pH upon cementation ■ Biocompatible	■ Short working time (2–3 minutes) ■ Does not resist plastic deformation under high masticatory stresses

GLASS IONOMER CEMENTS

Glass ionomer cement (GIC) was introduced to dentistry in 1972 by Wilson and Kent. It is described as hybrid of dental silicate cements and zinc polycarboxylates where phosphoric acid of silicate cements is replaced by polyacrylic acid of zinc polycarboxylates.

Classification According to Skinners

- ***Type I:*** Luting cements
- ***Type II:*** Restorative cements
- ***Type III:*** Liner or base.

COMPOSITION

Conventional GIC

Glass ionomer is an acid-soluble calcium fluoroalumino-silicate glass, i.e., an ion leachable glass.

Composition of Glass Ionomer Powder

Sl. No.	*Component*	*Percentage (%)*	*Purpose*
1.	Silica	29	Forms mass of the cement
2.	Alumina	16	
3.	Aluminum fluoride	5	i. Acts as flux and decreases fusion temperature ii. Improves translucency iii. Improves strength and wearing characteristics
4.	Calcium fluoride	34	
5.	Sodium aluminum fluoride	5	
6.	Aluminum phosphate	9.9	i. Improves translucency ii. Adds body to mix cement
7.	Lanthanum, barium, and strontium	Traces	Radiopacifiers

Composition of Liquid

1.	Polyacrylic acid	45	Main component—contributing for formation of cement matrix
2.	Water	50	Reaction medium-essential part of cement structure helps in ionic exchange reaction
3.	Modifiers like: Itaconic acid, maleic acid	5	Prevents gelation of liquid which is formed due to hydrogen bond of two polyacrylic chains

These raw materials are fused at a temperature of 1,100–1,500°C to form uniform glass. This glass is then ground to powder having particle size of 15–50 μm.

Metal Reinforced Glass Ionomer Cements (Fig. 4.7)

Silver Alloy Admix Glass Ionomer Cement

In this, silver amalgam alloy is mixed with glass powder in ratio of 1:7. This cement has improved strength but poor resistance to abrasion and poor esthetics.

Cermet Cement

Cermet is manufactured by sintering and grinding of silver powder and glass ionomer powder at temperature of 800°C. It has improved compressive and tensile strength, greater abrasion resistance, and radiopacity when compared to conventional GICs, e.g., ketac silver.

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FIGURE 4.7: Miracle mix.



FIGURE 4.8: Resin-modified glass ionomer cement.

Resin-modified Glass Ionomer Cement (Fig. 4.8)

Powder

Fluoroaluminosilicate glass particles along with photoinitiator or chemical initiator.

Liquid

- Polyacrylic acid modified with methacrylate groups and HEMA monomers (15–25%)
- Water.

Advantages

- Improved physical properties
- Less technique sensitive
- Improved handling.

Manipulation of the Cement

- For mixing, dispense powder and liquid on mixing paper pad **(Fig. 4.9A)**. Always dispense powder before liquid to minimize loss of water due to evaporation
- Hold the bottle upright to ensure consistent sized drops while dispensing the liquid **(Fig. 4.9B)**
- Divide the powder into two equal portions **(Fig. 4.9C)**
- Mix first portion of powder with liquid for 10–15 seconds, then add 2nd half of powder and mix for another 15–20 seconds in folding motion by gently but rapidly folding powder into the liquid **(Fig. 4.9D)**
- The objective is to wet the particles, and not dissolving them. Mixing should be completed within 40–60 seconds
- Working time for glass ionomer cement is 60–90 seconds
- For restoration, bring the mix together. One should be able to pick up the mix without sticking to the instrument **(Fig. 4.9E)**
- For luting consistency, "1 inch" string should be formed when flat surface of spatula is pulled from the mixed cement **(Fig. 4.9F)**.

Loss of gloss/slump test: Final mixed cement should have glossy appearance. Loss of gloss shows end of working time. It is 60–90 seconds for conventional cement.

SETTING REACTION OF GLASS IONOMER CEMENT

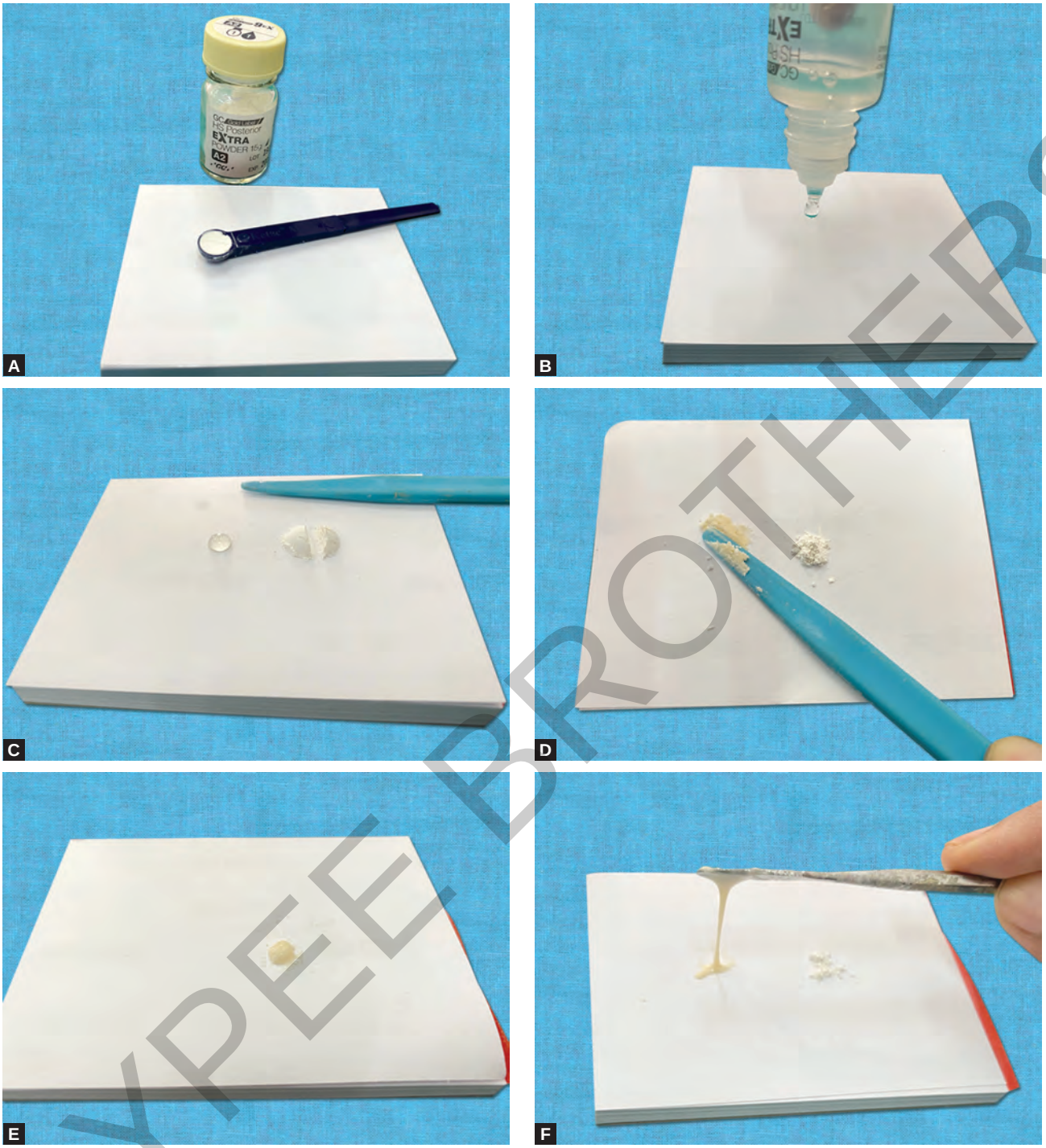
Setting Reaction of Autocure Glass Ionomer Cement

It is an acid–base reaction between powder and liquid **(Fig. 4.10)**.

- Powder and liquid are mixed
- Surface of glass ionomers is attacked by H^+ ions
- Polyacid attacks the glass particles to release Ca^{2+} and Al^{3+}, F^- and Na^+
- Initially, calcium ions and later aluminum ions cross-link with polyacrylic acid to form calcium and aluminum polysalts
- Acid attacks Ca^- rich sites and metal ions migrate into aqueous phase of cement towards polyacrylic acid chains
- Cross linking of chains occur resulting in gelation and formation of calcium polyacrylate
- The salts hydrate to form gel matrix and surround the unreacted part of glass particles
- Final set cement consists of unreacted glass surrounded by silica gel bound together by matrix of hydrated calcium and aluminum polysalts.

Advantages	*Disadvantages*
■ Adhesion to tooth structure because of chemical bonding to enamel and dentin through ion exchange ■ Biocompatible because large-sized polyacrylic acid molecules prevent the acid from producing pulpal response ■ Anticariogenic because of fluoride release ■ Good color matching and translucency makes it esthetic ■ Glass ionomers show less solubility than other cements	■ Brittle and have low fracture resistance when compared to composite restorations ■ Low wear resistance when compared to composite restorations ■ Sensitive to moisture contamination and desiccation soon after placement, which can affect physical properties and esthetics

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FIGURES 4.9A TO F: (A) For mixing, dispense powder and liquid on mixing paper pad; (B) Hold the bottle upright to ensure consistent sized drops while dispensing the liquid; (C) Divide the powder into two equal portions; (D) Mix first portion of powder with liquid for 10–15 seconds, then add 2nd half of powder and mix for another 15–20 seconds in folding motion; (E) For restoration, one should be able to pick up the mix without sticking to the instrument; (F) For luting consistency, "1 inch" string should be formed when flat surface of spatula is pulled from the mixed cement.

Indications	*Contraindications*
■ As pit and fissure sealants ■ As liners and bases ■ As luting agents ■ For restorations of small class I (buccal and palatal pits), III and V Lesions ■ In high caries risk patients	■ In stress-bearing areas like class I, class II, and class IV preparations because glass ionomers lack fracture toughness ■ In patients with xerostomia because restorations can become opaque, brittle, and disintegrate over a short period of time ■ In mouth breathers because restoration may become opaque, brittle, and may fracture over time ■ In areas requiring esthetics like veneering of anterior teeth

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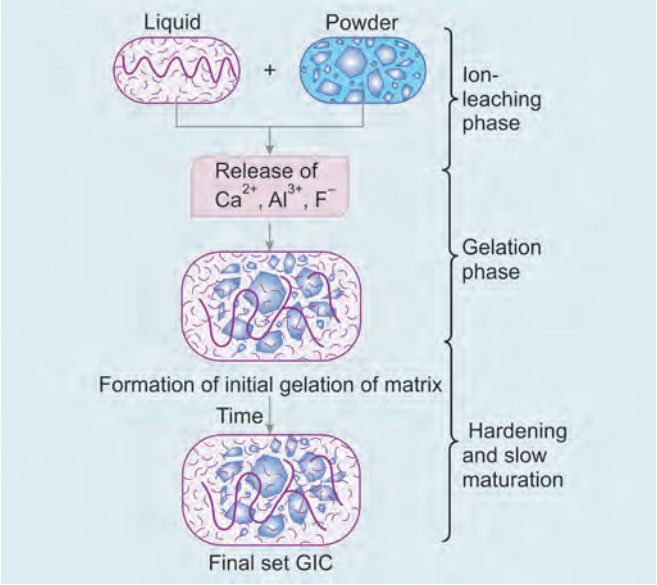


FIGURE 4.10: Setting reaction of glass ionomer cement.

DENTAL AMALGAM

- **Alloy:** Alloy is a union of two or more metals
- **Amalgam:** Amalgam is an alloy of mercury with any other metal
- **Dental amalgam:** Dental amalgam is an alloy of mercury with silver, tin, and varying amounts of copper, zinc, and other minor constituents
- **Dental amalgam alloys:** Dental amalgam alloys are silver-tin alloys with varying amounts of copper, zinc, and other metals.

Classification of Dental Amalgam

- **Based on shape of particles**
  - ***Irregular:*** In this, shape of particles is irregular, and may be in the shape of spindles or shavings
  - ***Spherical:*** In this, shape of particle is spherical with smooth surface
  - ***Spheroidal:*** In this, shape of particle is spheroidal with irregular surface
- **Based on copper content**
  - ***Low copper alloy:*** Contains copper in range of 2 to 6%
  - ***High copper alloy:*** Contains copper in the range of 12 to 30%.
- **Based on zinc content**
  - ***Zinc-containing alloys:*** In these, zinc is in range of 0.01–1%
  - ***Zinc-free alloys:*** Contain less than 0.01% of zinc.
- **Based on the presence of alloyed metals**
  - ***Binary alloys:*** Contain two metals, i.e., silver and tin
  - ***Ternary alloys:*** Contain three metals, i.e., silver, tin, and copper
  - ***Quaternary alloys:*** Contain four metals, i.e. silver, tin, copper, and zinc

  Out of these, quaternary alloys are most acceptable.
- **Based on whether alloy is unicompositional or admixed**
  - ***Single composition or unicompositional:*** Each particle of alloy has same chemical composition
  - ***Admixed alloys:*** These are physical blend of lathe-cut and spherical particles.

Composition of Dental Amalgam

Amalgam consists of amalgam alloy and mercury. Amalgam alloy is composed of silver-tin alloy with varying amounts of copper, zinc, indium, and palladium.

Table 4.1 shows the Composition of amalgam alloys. **Table 4.2** summarizes the differences between high and low copper amalgam alloys.

In general, amalgam alloy consists of silver 40% (minimum), tin 32% (maximum), copper 30% (maximum), zinc 2% (maximum), and traces of indium or palladium. In ***preamalgamated alloys,*** 3% mercury is used, which reacts more rapidly when mixed with silver-tin alloy.

Mercury used for dental amalgam is purified by distillation. **Table 4.3** is showing the effects of constituent metals on properties of amalgam.

TABLE 4.1: Composition of amalgam alloys (percentage of elements by weight).

Alloy	*Silver %*	*Tin %*	*Copper %*	*Zinc %*	*Indium %*	*Palladium %*
Low copper	65–70	26–28	2–5	0–2	0	0
High copper						
i. Admixed	40–70	26–30	13–30	0–1	0	0
ii. Unicompositional	40–60	0–30	13–30	0	0–1	0–1

TABLE 4.2: Difference between high copper and low copper alloys.

	High copper alloys	*Low copper alloys*
Copper content	12–30%	<6%
Mercury required for amalgamation	Less	More
Dormant phase	It is Cu_6Sn_5, i.e., η phase	It is Ag_2Hg_3, i.e., γ1 phase
Tarnish and corrosion	It is due to copper-rich phase, i.e., Cu_6Sn_5(η)	It is due to gamma-2 phase, i.e., Sn_8Hg(γ2)

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TABLE 4.3: Effects of constituent metals on properties of amalgam.

Silver	*Tin*	*Copper*	*Zinc*	*Palladium*	*Indium*
■ Increases strength and setting expansion ■ Reduces setting time ■ Decreases flow	■ Increases setting time ■ Reduces strength, hardness, and setting expansion	■ Reduces tarnish and corrosion ■ Strengthening effect on the set amalgam	■ Scavenges the available oxygen to prevent oxidization of alloy during manufacturing ■ On contamination with moisture, delayed or secondary expansion occurs	Improves the corrosion resistance and mechanical properties	Decreases amount of mercury required to wet alloy particles

Types of Amalgam Alloy Powder

Lathe-cut is made by cutting of alloy from a pre- homogenized ingot, which was heat treated at 420°C for many hours. Fillings are then reheated at 100°C for 1 hour for aging of the alloy.

Spherical (spheroidal) alloy is formed when molten alloy is sprayed into a column filled with inert gas; this molten metal solidifies as fine droplets of alloy.

Admixed alloy is when different size or shape of amalgam powder particles are mixed together to increase filling efficiency.

Single composition is that alloy in which every particle of alloy is having same shape, size, and composition.

Dispersion modified, high copper alloys are that, in which high copper alloy is mixed with conventional alloy.

Setting Reaction/Amalgamation Reaction

Lathe-cut Low Copper Alloys

On mixing amalgam alloy with mercury, the alloy particles get dissolved in the mercury. Mercury reacts with alloy particles to form two products, i.e., the silver-mercury phase and tin-mercury phase. After this reaction, the unreacted particles are embedded in the matrix of reaction products with mercury. The reaction is as follows:

$$\underset{(\gamma)}{Ag_3Sn} + Hg \longrightarrow \underset{(\gamma_1)}{Ag_2Hg_3} + \underset{(\gamma_2)}{Sn_8Hg} + \text{unreacted } \underset{(\gamma)}{Ag_3Sn}$$

In lathe-cut low copper amalgams both γ_1 and γ_2 form a continuous network. Since γ_2 phase is least corrosion-resistant phase, its distribution in reaction product is important.

Admixed High Copper Alloys

For high copper alloys, the reaction is different. It occurs in two phases. The initial reaction is similar to that of low copper alloys, i.e.,

$$(\gamma)\ Ag_3Sn + Ag\text{-}Cu + Hg \longrightarrow (\gamma_1)\ Ag_2Hg_3 + (\gamma)\ Sn_8Hg + \text{unreacted } Ag_3Sn + Ag\text{-}Cu$$

Second phase of reaction involves the silver–copper phase (Ag-Cu).

It reacts with g (Ag_3Sn) and mercury to form Ag_2Hg_3, Sn_8Hg and Cu_6Sn_5 phase. The mercury released from Sn_8Hg (g_2 phase) reacts with silver to form Ag_2Hg_3 (g1) phase.

$$\underset{(\gamma)}{Sn_8Hg} + Ag\text{-}Cu \longrightarrow \underset{(\eta_1)}{Cu_6Sn_5} + \underset{(\gamma_1)}{Ag_2Hg_3} + \underset{(\gamma)}{Ag_3Sn}$$

This reaction goes on. After one week, the g_2 phase reacts completely with eutectic and replaces all the g_2 phase by g and g_1 phase.

Unicompositional High Copper Alloy

Difference in admix type and the unicompositional alloys is that, in latter, the eutectic phase, i.e., Ag-Cu phase is absent and the reaction is directly with silver, copper and tin phases. In these, only silver reacts with mercury and the tin remains bound to copper.

$$\underset{(\gamma)}{Ag_3Sn} + \underset{(\varepsilon)}{Cu_3Sn} + Hg \longrightarrow \underset{(\eta)}{Cu_6Sn_5} + \underset{(\gamma_1)}{Ag_2Hg_3}$$

Final phase formed is Cu_6Sn_5 (γ). There is no Sn_8Hg (γ_2) phase.

Table 4.4 shows different phases of silver amalgam setting reaction.

TABLE 4.4: Phases of silver amalgam.

Code	*Component*
(γ) gamma	Ag_3Sn (Silver–tin phase) strongest phase
(γ1) gamma 1	Ag_2Hg_3(Silver–mercury phase) noblest phase
(γ2) gamma 2	Sn_8Hg (Tin–mercury phase): Least resistant to tarnish and corrosion and weakest phase
(ε) epsilon	Cu_3Sn (Copper–tin phase)
(η) eta	Cu_6Sn_5 (Copper–tin phase) More corrosion resistant and stronger than gamma-2 phase

Indications	*Contraindications*
■ In moderate to large class I and II preparations ■ For restoration of class V lesions where esthetic is not required ■ As a postendodontic restoration to restore the access cavity ■ To restore fractured cusp using pin and slot	■ When esthetics is main concern ■ Small class I and class II preparations ■ Grossly decayed teeth

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Advantages	Disadvantages
■ Easy to manipulate and less technique sensitive ■ Self sealing of interface of amalgam and tooth due to formation of corrosion products ■ High compressive strength ■ Biocompatible ■ Good wear resistance ■ Economical	■ Unesthetic ■ Requires extensive tooth preparation ■ Corrosion and tarnish causing discoloration of tooth ■ Being metallic restoration, it transmits thermal sensation to the pulp ■ Marginal degradation is seen in low copper alloys ■ Amalgam has poor tensile strength thus making it a brittle material ■ Results in galvanic current in association with gold restoration or even in same restoration with non-uniform condensation

Manipulation of Amalgam Restoration

Mercury-alloy Ratio

Mercury-alloy ratio should be according to type of alloy used. Eames preferred 1:1 ratio of alloy/mercury for best results. Lathe-cut amalgam alloys require more (45%) of mercury to wet than the spherical alloys (40%).

Trituration

Purpose of trituration is to remove oxide layers from alloy particles so as to coat each alloy particle with mercury, resulting in a homogeneous mass for condensation. Trituration can be done by hand or mechanical means. Mechanical method is done with the help of automatic amalgamator **(Fig. 4.11A)** and hand method of trituration is done with the mortar and pestle **(Fig. 4.11B)**.

Time for which the trituration is done, speed, and force applied for trituration, affect the quality of trituration. Trituration can produce following three types of mixes **(Figs. 4.12A to C)**:

1. ***Normal triturated mix:*** This is a shiny mix which is plastic in consistency, appears as homogeneous mass and convenient to handle.
2. ***Over-triturated mix:*** This mix is "warm", shiny, and hard due to premature setting of amalgam. This mix is difficult to condense in prepared cavity.
3. ***Under-triturated mix:*** This mix is dry and crumbly which is very weak and dull in appearance and difficult to manipulate.

Mulling

Mulling of the amalgam can be done manually or mechanically. By hand, it can be done by squeezing the freshly mixed amalgam collected in the chamois skin. Mechanical mulling is done in the amalgamator by triturating it for 2–3 seconds.

Insertion of Amalgam

Use amalgam carrier to carry amalgam alloy into the preparation and condense it with flat surface of condenser



FIGURES 4.11A AND B: (A) Amalgamator; (B) Mortar and pestle.



FIGURES 4.12A TO C: (A) Normal triturated is shiny homogenous mass with plastic consistency; (B) Overtriturated mix is shiny and hard due to premature setting of amalgam; (C) Undertriturated mix is dry, crumbly and dull in appearance.

After it, add next increment and again condense it till level of amalgam reaches preparation margins **(Figs. 4.13A to E)**

Condensation

Condensation is done by using different shapes of condensers like round, elliptical, trapezoid, and parallelogram. Working end of condenser should be serrated so as to avoid slipping away of amalgam while manipulation.

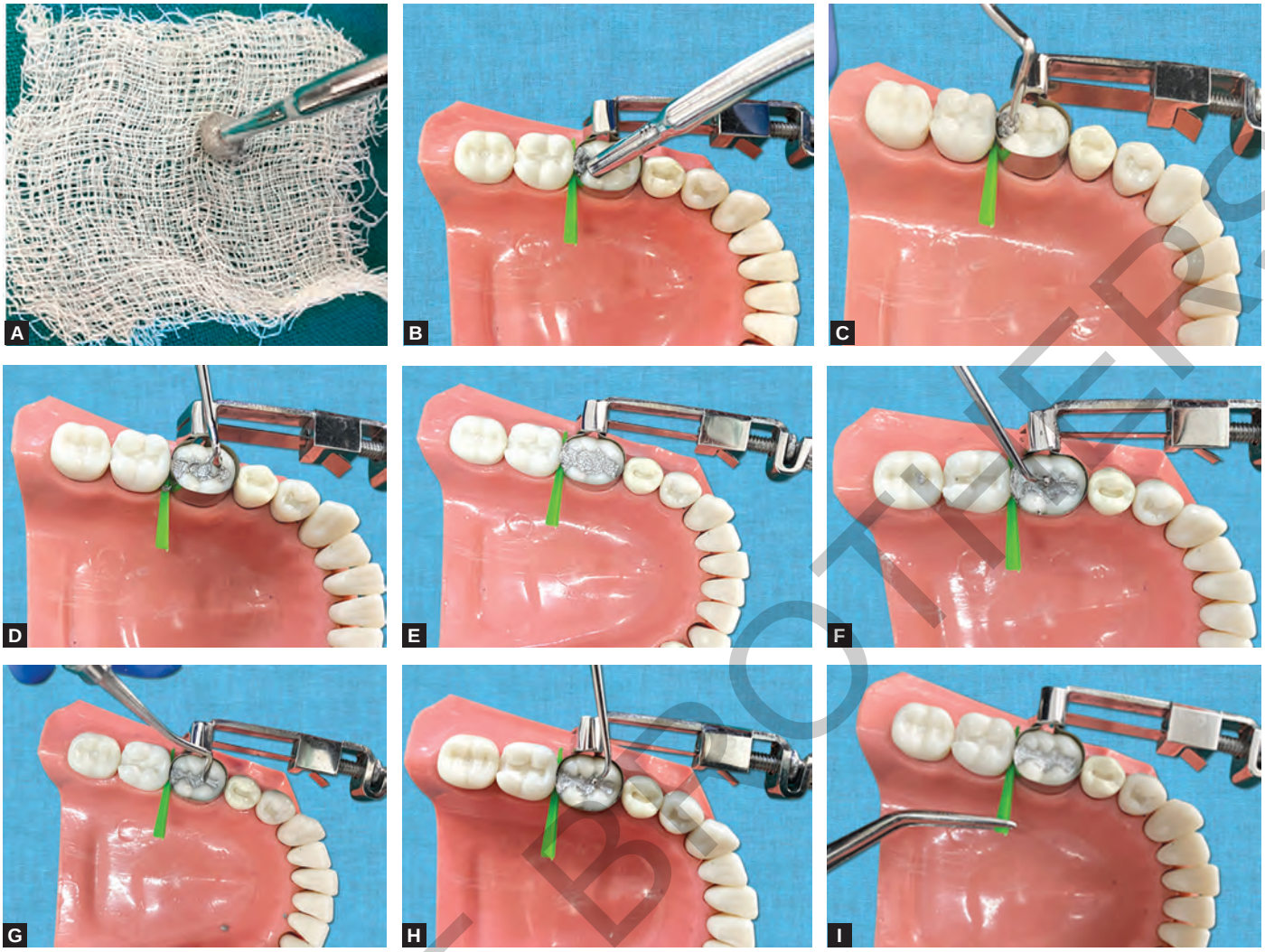
Precarve Burnishing (Fig. 4.13F)

Precarve burnishing is done soon after condensation to improve the marginal integrity of restoration and reduce the mercuric content of amalgam.

Carving (Fig. 4.13G)

Carving is done to produce anatomical contours and functional occlusion for the restoration. Commonly used

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FIGURES 4.13A TO I: (A and B) Use amalgam carrier to carry amalgam alloy into the preparation; (C) Condense it with flat surface of condenser; (D and E) After it, add next increment and again condense it till level of amalgam reaches preparation margins; (F) Precarve burnishing; (G) Carving; (H) Postcarve burnishing; (I) Finished amalgam restoration.

carvers are Hollenback carver, Frahm's carver (diamond-shaped) and cleoid-discoid carver.

Postcarve Burnishing (Fig. 4.13H)

It is done after completion of carving to reduce surface roughness and improve marginal seal.

Finishing and Polishing (Fig. 4.13I)

Finishing and polishing should be done after 24 hours of placement of amalgam restoration. Premature finishing and polishing will interfere with crystalline structure of hardening amalgam, resulting in weakening of the restoration.

CLINICAL CONSIDERATIONS

Plastic Deformation (Creep)

- Creep is time-dependent response of an already set material to stress in form of plastic deformation
- Creep is undesirable because it causes amalgam to flow out over the margins resulting in marginal deterioration and fracture
- Increased condensation pressure reduces creep because it reduces residual mercury level.

Tarnish and Corrosion

Tarnish is the surface discoloration of metal or alteration of surface finish or luster. Corrosion is actual deterioration of a metal by reaction with its environment.

When amalgam comes in contact with dissimilar metal (gold restoration), amalgam undergoes ***galvanic corrosion*** due to large difference in electromotive force of two materials.

Thermal Conductivity

Because of good thermal conductivity, amalgam can transmit temperature changes readily to the pulp. Therefore, it should be placed in tooth after adequate pulp protection like sealing dentinal tubules by applying varnish to walls or placing base on pulpal floor.

Marginal Ditching (Fig. 4.14)

Marginal ditching is breakdown of amalgam at the margins due to fracture or poor seal because of improper cavity margins.

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