Dental Material

Filling materials

Introduction

The materials used to replace a missing part of the tooth. Teeth may need a restoration for a variety of reasons:
1- Destruction of tooth caused by caries result in the loss of considerable quantities of enamel and dentine.
2- Destruction caused by trauma.
3- Abrasion (Diet, wrong brushing, habit)

The parts of the teeth, which require replacement, vary in size, shape and location inside the mouth of the patient.
Durability of the restoration is the life expectancy of the restoration. It depends on physical, mechanical and biological properties of the restorative material.

Requirements of an Ideal Filling Material

1- It should have satisfactory mechanical properties to withstand the force applied. Ex. Abrasion resistance, compressive and tensile strength, modulus of elasticity.
2- Ideally filling materials should be good thermal insulators, protecting the dental pulp from harmful effect of hot and cold stimuli (Low thermal Diffusivity). Also the coefficient of thermal expansion and contraction should be the same of enamel and dentine.
3- The filling materials subjected to different types of foods, drinks and medicaments. Thus the material should withstand a large variety of pH without dissolving and degradation and should not absorb saliva and other fluids and should have low electrical activity.
4- It should have sufficient working time, enable manipulation and placement of the filling materials before complete setting, and it should have dimensional stability during and after setting.
5- It should adhere well to the tooth walls and seal the margin to prevent ingress of fluid and bacteria.
6- It should be harmless to the operator and to the patient and should not irritate dental pulp and soft tissues.
7- Easily polished (like tooth in color and texture).
8- Should be bacteriostatic, and anticariogenic.
9- It should be radiopaque.
Classification of the Filling Materials

Non metallic
Polymeric
Silicate
Unfilled resin

metallic
non polymeric
amalgam
unfilled resin
filled risen
(Acrylic)
(Composite)

Other classification
1. Anterior filling materials.
2. Posterior filling materials.

Silicate Filling Material
The first introduced tooth colored restorative material by Fletcher in 1878. It has been the material of choice in anterior teeth for many years (till 1940's).

Composition
**Powder:** Sodium alumino-silicate glass with 20% calcium fluoride.
**Liquid:** 50% phosphoric acid, H₂O, Buffering agent like zinc phosphate or aluminum phosphate, (to stabilize the pH of liquid due to evaporation and condensation of water and to produce a material with control and predictable setting time. The glass react with acid to form a series of phosphate salts, it is acid base reaction.

Manipulation
The powder is mixed with liquid on cold cement slab using plastic spatula.
Why cold slab? Heat will cause evaporation of liquid, decrease setting time and this leads to decrease working time.
Why Plastic spatula? Metal spatula will be abraded by hard glass particles, the abraded metal particles will incorporate inside filling materials leads to discoloration.
Powder is added by increments to give putty mix (proper working time). Placement of filling into the prepared tooth cavity not as increments because bonding between increments is not guaranteed.

**Advantages**
1- Easy manipulated.
2- Anticariogenic: fluoride release lead to less chance for caries development.
3- Good insulator.

**Disadvantages**
1- Pulpal irritation due to low pH (5-3.5).
2- Brittle and has weak mechanical properties.
3- Shrinkage on setting.
4- Discoloration.
5- High solubility and disintegration.

**Acrylic Resin**
Acrylic resin was developed, in 1930's in Germany. During 2nd world war it was used in prosthetics, and then modified to be used in dentistry for anterior restoration in the late 1940's.

**Composition**

1- **Powder**: polymers (polymethyl methacrylate beads).
   - Initiator (benzoyl peroxide)
   - Pigments (salt of calcium or iron or organic dyes)

2- **Liquid**: Monomers (methyl methacrylate)
   - Gross linking agent (ethylene glycol dimethaerylatc)
   - Inhibitor (hydroquinone)
   - Activator (tertiary amine)

**Polymerization**: conversion of monomers into polymers.

The initiator contain weak bond. Under certain condition this weak bond (peroxide linkage) is able to split to form two identical radicals; this decomposition may be accomplished by reaction with chemical activator.
The free radical will react with monomer forming a chain, which is lead to conversion of the materials form liquid to solid state.

The cross linking agent: to improve the physical-properties, of the set material.

Inhibitor: To improve the shelf life of the liquid, (react with free radical inside liquid to stabilize them so prevent premature polymerization.)

Storage: inside cans or dark - brown bottle to prevent exposure to visible light.

**Types**
1- **Heat cure**: the first generation of acrylic constructed outside the patient, mouth. (70-100 °C) (Indirect)
2- **Self cure (cold cure)**: directly placed inside the patient mouth.
**Manipulation:**
Powder is mixed with liquid then inserted inside patient mouth by one of three techniques.

1. **Pressure technique:** the powder is mixed with liquid until reach the dough stage then inserted in the cavity holding the matrix strip firmly on the filling until it sets.

2. **Brush technique:** a hair brush is dipped into the liquid then into powder then placed into the cavity, repeat the same procedure until the cavity is filled.

3. **Lamination technique:** a thin mix is prepared and inserted in the cavity, then prepared another mix until the cavity is filled.

# finishing should be after 24 hours

# Contamination of the filling with H2O may lead to discoloration over a period of time.

# Sensitive to ultraviolet light which may cause yellow or brown color changing.

**Advantages:**
1. Less soluble than silicate over a wide range of pH.
2. Less irritant to the dental pulp than silicate but it has residual methyl methacrylate which is irritant to the pulp.
3. Less brittle than silicate.
4. Has the ability to match the color of the tooth.
5. Some products which contain fluoride (anticariogenic)

**Disadvantages**
1. Temperature rise during setting caused by highly exothermic polymerization reaction necessitate the use of protective cavity base material which is calcium hydroxide. Products containing Eugenol should be avoided. Why?
2. Undergo a considerable setting contraction (high coefficient of thermal expansion $92 \times 10^{-6}/^\circ C$). This could produce a significant marginal gap in to which the fluids can penetrate. To overcome this problem:
   A) Fill the cavity with small increments and allow contraction occur towards the walls before next increment is added,
   B) Over fill the cavity and put the setting material under strong finger pressure with a matrix strip.
   C) Water absorption (1-1.5%) leads to expansion which may improve the marginal seal.
3. Low compressive strength and hardness value (low wear resistance).
4. Porosity: air trapped during mixing or during evaporation of monomer leads to poor strength and color changes.

<table>
<thead>
<tr>
<th></th>
<th>Acrylic resin</th>
<th>Enamel</th>
<th>Dentin</th>
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<tbody>
<tr>
<td>Compressive strength (MPa)</td>
<td>70</td>
<td>250</td>
<td>280</td>
</tr>
<tr>
<td>Hardness (Vickers)</td>
<td>20</td>
<td>350</td>
<td>60</td>
</tr>
</tbody>
</table>
Temporary Filling Materials

Indications
1. During treatment of root canal fillings.
2. Inlay and onlay preparation. It should be placed after preparation until the final restoration is placed.
3. After pulp capping in case of traumatic exposure, to give time for pulp healing process and production of dentin.
4. Pedodontic practice.

Requirements
1. Should be easily removed from the cavity
2. Should have sedative effect to the tooth and promote pulp healing
3. Reasonable strength and abrasive resistance
4. Radiopaque
5. Reasonable setting time and has low flow after setting

Types
1. Zinc oxide eugenol
2. Zinc phosphate
3. Zinc silico phosphate
4. Gutta-percha

1. Zinc oxide eugenol
It's the material of choice as temporary filling.

Powder: zinc oxide, zinc acetate
Liquid: olive oil
Mixing is according to manufacture instruction or pastes.

Properties:
* It has sedative effect on the tooth; reasonable sealing of the cavity, but it has low strength, low abrasive resistance, and low flow after setting.
* The strength and abrasive resistance could be improved by adding 20-40% of fine polymer particles and treating the surface of zinc oxide particles with carboxylic acid-reinforced type.
* Sufficient powder should be added to the liquid to achieve putty consistency.

2. Zinc phosphate
It is powder and liquid.

- Has higher strength and abrasive resistance than ZOE and has relatively low solubility in oral fluids but still has low abrasive resistance in area subjected to high load of mastication.
- Higher powder/liquid is required to decrease acidity and increase strength.
- Reinforced zinc phosphate is more durable and could be used when longer time is required.
3. Zinc silico phosphate

*Powder:* zinc oxide and silicate glass  
*Liquid:* phosphoric acid

- It cause fluoride release  
- It has superior strength and more translucent than zinc phosphate  
- It not promotes healing of the pulp  
- It is used when longer time is required for temporary filling.

4. Gutta-percha

It is composed of natural gutta-percha, zinc oxide, wax, resin, metal salts to give radiopacity  
It is applied by softening the gutta-percha on the flame and put it inside the cavity.

**Disadvantages**

1. Lack the ability to seal the cavity lead to micro leakage  
2. Heat cause pain to the patient  
3. Low strength reinforced zinc phosphate is more durable and could be used when longer time is required.

**Composite Resin**

- The term composite refers to three-dimensional combination of at least two chemically different materials with a distinct interface separating the components.  
- Composite filling is a polymeric restorative material reinforced with filler particles.  
- Composite resin was developed first by Bowen in 1962 to overcome the shortening in physical properties of unfilled resin and silicate. It is the most popular tooth colored restorative materials.

**Composition**

**1- Resin Matrix**

The nature of resin may alter slightly from one product to another, essentially, they all contain dimethacrylate monomer, like Bis- GMA (Bis phenol-A & glycidyl methacrylate) or UDMA (Urethane dimethacrylate), Bis - GMA and UDMA are viscous and sticky so, TEGMA. (Triethylene glycol dimethacrylate) a low molecular weight monomer added as a dilute to control the consistency of composite paste. Bis-GMA, UDMA and TEGMA are characterized by carbon double bond the react to convert them to polymers.

**2- Fillers**

They are silicate particles in two forms crystalline forms (quartz) and non crystalline form (glass like aluminosilicates and borosilicates), the type of filler, particle size, and distribution in resin matrix are the major factors controlling properties. Zinc, Barium, Zirconium ions may be added to produce radiopacity in the filler particles.
The quartz filler is harder than glass fillers but difficult to polish to the smooth surface.

**Advantages of adding fillers**
1. Polymerization shrinkage is reduced, as compared with unfilled due to less resin is present in a composite. Although shrinkage varies from one product to another.
2. Water sorption and CTE are significantly reduced.
3. Mechanical properties such as compressive strength, tensile strength, abrasive resistance and modulus of elasticity are improved.
4. Optical properties (color match and radiopacity) are improved.

**3- Coupling agent**
Organosilanes are added to bond the filler particles to the resin matrix, so stresses are transferred to the stiffer filler particles through the weaker resin.
1. Improve the mechanical properties of the composite resin.
2. Prevent the fillers from being dislodged from the resin matrix.
3. Hydrolytic stability prevents the water from penetrating along resin - filler interface.

**4-Initiator - Activator System:**

*a) Self cured composite resin*
Two paste system: one paste contains 1% benzoic peroxide initiator second paste contain 0.5% of tertiary amine activator.
Reaction leads to formation of free radical, which will initiate polymerization.

*b) Light activated composite resin*
One paste system
The first light cures system made use ultraviolet radiation to initiate polymerization. Then UV light is then replaced with visible light cure system, which is safer, less expensive and improve ability to polymerize thicker increment up to 2 mm. Photoinitiator is added to initiate polymerization, it absorbs visible light of wavelength (400-500 nm) (blue light) forming free radical which initiate polymerization.

*c) Laser activated system*
Photochemical initiator found to initiate polymerization when subjected to Argon laser (456-495 nm) wavelength energy. This provides curing up to 10 mm form the tip over a large focusing area and it can produce a complete curing in only 8 seconds.

**5- Inhibitors**
Butylated hydroxytoluene (0.01 /wt) inhibitor is added to prevent spontaneous polymerization of monomers they have strong reactivity potential with free radicals that has been formed by brief exposure to light when the material are dispersed.

**6- Pigments**
Inorganic oxide like aluminum oxide or titanium oxides are added in small amount to provide shades that match the majority tooth shades.
System of composite resins

1- Two paste system (chemical cure)
2- One paste system (light cure)
3-Powder and liquid system:
   Powder: filler, peroxide initiator.
   Liquid: monomer, chemical activator.
4-Paste and liquid system: difficult to mix.
   Paste: monomer, filler, peroxide.
   Liquid: monomer, chemical activator.
5-Encapsulated system: filler, peroxide mixed initially and separated from monomers which contain chemical activator, on breaking the seal separating the 2 parts the reactive compounds come into contact and mixed mechanically.

Manipulation
Proper isolation to prevent bacterial infiltration, placement of protective linear or base (should not contain eugenol?)
1-Acid etching
   Since the material is not adhering to the tooth, so acid etching is used to provide micro-mechanical retention for resin restoration to the tooth surface.
   The technique is consisted of applying 30-50 % (37%) phosphoric acid to enamel for 30-60 seconds followed by thorough rinsing and drying the area. The acid solution will remove the enamel prisms lead to numerous of microscopic undercuts and irregular peaks in enamel.
   - Bonding agent applied (low viscosity monomer) flows into the minute undercuts and polymerized to form resin tags.
   - For the dentin acid etching using phosphoric acid (37%) for 10-30 seconds. Followed by application of primer (an adhesion promoting agent), hydrophilic resin, added to ensure optimum wetting and prevent collapse of collagen fibers. Then dentine bonding agent is applied.
2. Application of composite
   - For self cure: equal amount of catalyst and base (pastes) are placed on the pad first, then mixed for 30 seconds using plastic spatula till get homogenous mass. Than placed inside prepared cavity holding a matrix strip (polyester strip) till it sets.
   - For light cure select proper shade, add composite by increments each increment should not exceed 2 mm thickness; each increment should be cured with light cure for 20-60 seconds according to the manufacturer instruction.

Advantages matrix strip
A) Protect filling from air (because the filling is oxygen sensitive)
B) Pressing the filling with matrix strip to ensure flow of the material inside cavity.
C) To prevent direct contact with adjacent teeth.
Advantages of light cure
A) Color stability
B) Resistance to wear
C) No incorporation of air bubbles.
D) Longer working time.

3-Finishing:
Composite resin cured against matrix strip provides maximum smoothness.
Finishing of composite (using finishing burs) after setting to remove access material and contouring of the filling material leads to surface roughness, (the weaker resin matrix wear away leaving a filler particles protruded from the surface).
After finishing, polishing of the surface should be accomplished to reduce surface roughness because rough surface leads to plaque retention, staining and recurrent caries.

Dental Amalgam
Dental amalgam is a powder of silver-tin alloy mixed with mercury. It is the most popular filling material used till nowadays to restore posterior teeth and core build up.
- In 1833 amalgam introduced in USA by mixing silver coins with mercury, the problem was a high setting expansion of silver cause fracturing of restoring tooth. The best scientific, beginning of amalgam as a restorative material was in 1855 by using Silver-Tin- mercury of equal parts.

Composition
The composition, of alloy powder is varies from one product to another.

I) Conventional amalgam (Traditional)
Produced by early dental manufactory in. 1900.

Basic composition:
a) Silver (Ag) 65%: strength, promoting setting when mixed with mercury.
Disadvantage: high degree of setting expansion.
b- Tin (Sn) 25-29%: aids in amalgamation process of alloy with mercury at room temperature and decrease expansion within practical limit.
Large amount of tin cause decrease strength, prolong the setting time and decrease corrosion resistance of amalgam.
c- Copper (Cu) 6%: increase strength and hardness and setting expansion but decrease flow.
d- Zinc (Zn) 1-2 % max: aid in process of manufacturing by acting as a scavenger for oxygen and minimize the oxidation of other metals.
Increase in Zn cause delayed expansion.
-Alloy which contain > 0.01% Zinc- containing alloys
-Alloy which contain <0.01% non zinc (Zinc free; alloys). (Require inert atmosphere during manufacturing)

Two methods of production of alloy powder:
1- Lath - cut alloys: melting of alloys then poured into suitable mold (3-8 cm diameter and 20-25 cm in length) to form ingot, ingot is cooled relatively slowly, removed from
the mold and heated for (6-8 hrs at 400 °C to get homogenizing grain. The ingot is then reduced to filings by being cut on a lathe and ball milled. The particles are passed through a fine sieve and then ball milled to form the proper particle size. The particles are typically 60 to 120 micron in length, 10 to 70 micron in width, and 10 to 35 micron in thickness. Most products are labeled as fine-cut. The particle size and shape of lathe-cut amalgam alloys are shown in the following figures.

2- Spherical Particles: Spherical particles of low- or high-copper alloys are produced when all the desired elements are melted together. In the molten stage the metallic ingredients form the desired alloy. The liquid alloy is then sprayed, under high pressure of an inert gas, through a fine crack in a crucible into a large chamber. The shape of the sprayed particles may be spherical or somewhat irregular, as shown in Fig. The size of the spheres varies from 2 to 43 micron.

II) High copper amalgam:
The copper content is increase from 6% up to 10-30%.
a- Unicompositional system: either lathe -- cut or spherical
b- Disperse alloy (admixed): a mechanical mixture of lathe-cut alloy with spherical alloy.

**Setting Reaction**
The reaction is take place when alloy powder and mercury is mixed, mercury diffused in alloy particles. The reaction products crystallize to give new phases in the set amalgam. A considerable amount of initial alloy remains unreacted.
The reaction of conventional amalgam is given by this equation:

\[ \text{Ag}_3\text{Sn} + \text{Hg} \rightarrow \text{Ag}_2\text{Hg}_3 + \text{Sn}_7\text{Hg} + \text{Ag}_3\text{Sn} \]

\[ + \text{Hg} \rightarrow + + \]

For high copper amalgam:

\[ \text{Ag}_3\text{Sn} + \text{Cu} + \text{Hg} \rightarrow \text{Ag}_2\text{Hg}_3 + \text{Cu}_6\text{Sn}_5 + \text{Ag}_3\text{Sn} \]

\[ + \text{Cu} + \text{Hg} \rightarrow + \text{Cu}_6\text{Sn}_5 + \]

**Properties**

1- **Dimensional changes**: The setting reaction of amalgam is associated with dimensional changes.

A small contraction takes place in the first \(1/2\) hr as mercury still diffusing in alloy powder, then when crystallization begun the outward thrust of growing crystals cause expansion. The overall effect of the final set material may cause slight final expansion (curve a) or slight final contraction (curve b).

Factors which affect a final expansion or contraction:

1- Type of alloy
2- Particle size and shape.
3- Pressure used to condensed amalgam (most significant).

A standard test permit a slight expansion typically (0.2%) max. or slight contraction of 0.1% max. A large contraction would result in a marginal gap down which fluids could penetrate. A large expansion would result in the protrusion of the filling from the cavity.

*Delayed expansion*: for zinc containing amalgam when contaminated with moisture during condensation zinc will react with water, hydrogen will produced as products of such reaction, hydrogen will be collected internally, this cause pressure which may cause expansion. This occurs after 3-4 days and may be after a month (curve c). This confirms the need for adequate moisture control when using this material.
2- Strength: The strength of amalgam developed slowly it may takes 24 hrs after mixing to reach reasonable high value, and continue to increase slightly for some time after that.

Why we instruct the patient not to press on amalgam after 20-30 minutes}
Spherical alloy and high copper amalgam develop strength more rapidly than conventional lathe-cut material, in which fine grain develops strength faster than coarse grain.

High mercury affect the strength (weaken the final properties of the set material)

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>SILVER</th>
<th>TIN</th>
<th>COPPER</th>
<th>ZINC</th>
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<tbody>
<tr>
<td>Strength</td>
<td>Increases</td>
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<tr>
<td>Durability</td>
<td>Increases</td>
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<tr>
<td>Hardness</td>
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<td>Increases</td>
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<tr>
<td>Expansion</td>
<td>Increases</td>
<td>Decreases</td>
<td>Increases</td>
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<tr>
<td>Flow</td>
<td>Decreases</td>
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<td>Color</td>
<td>Imparts</td>
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<tr>
<td>Setting time</td>
<td>Decreases</td>
<td>Increases</td>
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<td>Workability</td>
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<td>Increases</td>
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<tr>
<td>Cleanliness</td>
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<td>Increases</td>
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</table>

Table 1- Properties of an amalgam restoration imparted by ingredients.

3) Creep: Is a plastic deformation of amalgam when subjected to intraoral stresses. It is measured using "Static Creep Test".
Creep causes protrusion of amalgam out of the cavity, the protruded edges are unsupported and weak and may be further weakened by corrosion, this lead to fracture, as a result a ditch will happened around the margin of amalgam restoration which will cause a gap and microleakage (Ditching of amalgam).

<table>
<thead>
<tr>
<th>amalgam</th>
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<td>onal</td>
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<td>per</td>
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A gamma 2 phase is primarily responsible for high value of creep in conventional amalgam but it is not the only factor involved, while High copper amalgam has lower value of creep because it has a little or no gamma 2 phase.

4) **Tarnish and Corrosion:**

**Tarnish:** Is a loss of luster from the surface of metal or alloy due to the formation of a surface coating. The amalgam is usually tarnished due to the formation of sulfide layer on the surface. This causes no change in the mechanical properties of the alloy.

**Corrosion:** The multiphase structure of amalgam makes it prone to corrosion. The different phases from the anode and cathode and saliva (provides the electrolytes), electrolytic cell is readily setup.

The gamma 2 phase of conventional amalgam is the most electrochemically reactive and readily forms the anode, gamma 2 will break down to tin containing corrosion products and mercury, some of mercury will combine with unreacted alloy (gamma). Small quantity of mercury will be ingested by the body.

For higher copper amalgam the Cu6Sn3 phase forms the anode but less corrosion occurs than conventional amalgam because absence of gamma 2 phase.

*The rate of corrosion is accelerated when the amalgam filling is contact with gold restoration. Why?*

*Corrosion will cause roughness of the amalgam which may lead to plaque and bacterial accumulation and inflammation of the soft tissue also will cause poor appearance of the filling surface and may affect the mechanical properties of amalgam.*

*Level of corrosion may be minimized by polishing, surface of restoration.*

*Corrosion has one advantage that corrosion products thought to be gathered at the restoration - tooth interface (seal the gap) to prevent or decrease microleakage.*

5-**Thermal Properties:**
Dental amalgam has a high value of thermal diffusivity so requires insulating material (cement base).

The Coefficient of thermal expansion and contraction is three times greater than that of dentine this cause more expansion and contraction of the restoration than the surrounding tooth when patient takes cold and hot food and drinks. This leads to microleakage around the filling. So replacement of the restoration is a must every 5 years.

<table>
<thead>
<tr>
<th>Coefficient of thermal expansion X 10^-6</th>
<th>Diffusivity X 10^-3 cm^2 S^-1</th>
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</thead>
<tbody>
<tr>
<td>Amalgam</td>
<td>25</td>
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<td></td>
<td>8</td>
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</table>

VI) Biological properties

- The mercury has a bad effect on CNS also may cause contact dermatitis.

Some studies showed a higher concentration of mercury in blood and urine in patients with amalgam fillings than those without fillings, but the levels was within acceptable limit.

- The dentist and assistants should take precautions:
  - A) Freshly mixed amalgam and mercury should not be touched by hands, because mercury will be absorbed by skin.
  - B) Dentist and assistant subjected to the vapor of mercury in atmosphere which increases with increasing temp, especially when sterilizing the instruments with mercury contamination. So Instruments should be cleaned well.
  - C) "Wearing, a mask and gloves will protect the dentist and the assistant from mercury toxicity.

Manipulation

1- Proportioning, and Dispersing '1 ~ Trituration
2- Condensation
3- Caving
4- Polishing
2- Amalgamator: A device typically has 2 hoppers, one filled with alloy and the other with mercury, the alloy/mercury ratio is set by the operator and the required amount of each component is released into a mixing chamber by pressing a button.

3- Using capsulated materials: Both alloy and mercury in proportion have been determined by the manufacturer. The two components are separated by an impermeable membrane, which is readily shattered using a capsule press or starting vibration of the capsule in a mechanical mixer which is called self-activating capsule.

2- Trituration:
1- By hand using a mortar and pestle: a glass mortar with a pestle that has a rough surface.

2- Mechanically by amalgamator: The time of mixing varies from 5-20 seconds depending on the speed of the amalgamator and the type of alloy used.

Advantages:
- a) uniform mix is produced;
- b) shorter time;
- c) less mercury/alloy ratio is used.

3- Condensation:
The material should be placed into the prepared cavity using a flat-ended steel hand instrument (amalgam condenser), and should be condensed in increments. Advantages: