Dental amalgam:

It is a special type of alloy in which mercury is one of the components. Mercury is able to react with other metals to form a plastic mass, which is conveniently packed into a prepared cavity in a tooth, and then this mass is hardened. It is the most widely used filling material for posterior teeth.

Amalgam became the dental restorative material of choice due to its low cost, ease of application, strength, and durability. However, concern for aesthetics, environmental pollution and health, composite materials diminished its popularity (toxicity of mercury have made its use increasingly controversial).

Uses of the amalgam:
1- As a permanent filling material in:
   a- Class I and class II cavities.
   b- Class V cavities where esthetic is not important.
2- In combination with retentive pins to restore a crown.
3- For making a die.
4- In retrograde root canal fillings.
5- As a core material

Advantages of dental Amalgam:
1) Reasonably easy to insert.
2) Not sensitive technique.
3) Maintain anatomical form.
4) Have reasonably adequate resistance to fracture (strength).
5) Prevent marginal leakage after a period of time in the mouth.
6) Can be used in stress bearing areas.
7) Have a relatively long service life (durability).
8) Low cost.

Disadvantages of dental amalgam:
1) The silver color does not match tooth structure.
2) They are somewhat brittle, subject to corrosion and galvanic action.
3) May demonstrate a degree of marginal breakdown.
4) Do not help retain weakened tooth structure.
5) There are regulatory concerns about amalgam being disposed in the wastewater.
Classification of Amalgam alloys

- **Based on copper content (most popular one)**
  1) Low copper alloys: (5% or less copper) it is either **irregular (lathe-cut)** or **spherical in shape**.
  2) High copper alloys: (13% to 30% copper) either
     a. Admixed or dispersion or blended alloys
     b. Single compositional or unicomposition alloys

- **Based on zinc content**
  1) Zinc containing alloys: contain more than 0.01% Zinc.
  2) Zinc Free alloys: contain less than 0.01% Zinc.

- **Based on shape of the alloy particle:**
  1) Lathe cut alloys or irregular shape.
  2) Spherical alloys.
  3) Mixture of lathe-cut and spherical particles

- **Based on number of alloyed metals:**
  1) Binary alloys, e.g. silver-tin.
  2) Ternary alloys, e.g. silver-tin-copper.
  3) Quaternary alloys, e.g. silver-tin-copper-indium.

- **Based on size of alloy particles**
  1) Microcut.
  2) Macrocut.

**Supplied as:**

Bulk powder and mercury. Alloy and mercury in disposable capsules mixed by amalgamator machine.
Composition: The amalgam alloy consists essentially of silver and tin. In lesser amounts, copper, zinc, and a trace of gold, palladium, indium, selenium.

<table>
<thead>
<tr>
<th>Amalgam type</th>
<th>Silver (Ag)</th>
<th>Tin (Sn)</th>
<th>Copper (Cu)</th>
<th>Zinc (Zn)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low copper (lathe-cut)</td>
<td>70.3 %</td>
<td>25.9%</td>
<td>2.8%</td>
<td>0.9%</td>
</tr>
<tr>
<td>Low copper (spherical)</td>
<td>72 %</td>
<td>25 %</td>
<td>3 %</td>
<td>-</td>
</tr>
<tr>
<td>High copper (admix)</td>
<td>69.5 %</td>
<td>17.7%</td>
<td>11.8%</td>
<td>1 %</td>
</tr>
<tr>
<td>High copper (spherical)</td>
<td>61%</td>
<td>26 %</td>
<td>13 %</td>
<td>-</td>
</tr>
</tbody>
</table>

**Silver (Ag):**
1. Major element in the reaction.
2. Whitens the alloy.
3. Decreases the creep.
4. Increases strength.
5. Increases expansion on setting.
6. Increases tarnish resistance in the resulting amalgam.

**Tin (Sn):**
1. Tin controls the reaction between silver and mercury.
2. Without tin the reaction would be too fast and the setting expansion would be unacceptable.
3. Reduces strength and hardness.
4. Reduces the resistance to tarnish and corrosion, hence the tin content should be controlled.

**Copper (Cu):**
1. Increases hardness and strength.
2. Increases setting expansion.
Zinc (Zn):

1. In small amounts, it does not influence the setting reaction or properties of amalgam. Zinc acts as a scavenger or deoxidizer during manufacture (prevents the oxidation of the elements like silver, copper or tin). Alloy without Zinc are more brittle, and amalgam formed by them are less plastic.
2. Zinc causes delayed expansion if the amalgam mix is contaminated with moisture during manipulation.

Mercury

- **Setting reaction**

**Low copper alloys**: The powder particles Available as: Spherical alloys or Lathe-cut alloys

When alloy powder and mercury are mixed, Mercury diffuses into the alloy particles and starts reacting with the silver and tin present in it, forming silver-mercury and tin mercury compounds and some of the unreacted Silver-tin compound. The combinations which are formed depending on which thing reacts with another thing, they are named as below,

\[ \gamma = \text{Ag}_3\text{Sn} \text{ (powder form so strongest phase)} \]
\[ \gamma_1 = \text{Ag}_2\text{Hg}_3 \text{ (Noble phase, main constituent of set amalgam)} \]
\[ \gamma_2 = \text{Sn}_8\text{Hg} \text{ (weakest phase causes tarnish and corrosion)} \]

\[ \text{Ag}_3\text{Sn} + \text{Hg} \rightarrow \text{Ag}_2\text{Hg}_3 + \text{Sn}_8\text{Hg} + \text{Ag}_3\text{Sn} \]

(\(\gamma\) gamma phase) (\(\gamma_1\) gamma one) (\(\gamma_2\) gamma two) (\(\gamma\)
**Note:** These are called as phases of setting reaction. Properties of hardened amalgam depend upon proportion of reaction phases. The $(\gamma_2)$ phase is weakest compound and is least stable to corrosion process. If more $(\gamma)$ phase is present the stronger the amalgam. The alloy particles do not react completely with mercury. About 27% of the original $\text{Ag}_3\text{Sn}$ remains as unreacted particles. Set amalgam consist of unreacted particles $(\gamma)$ surrounded by matrix of the reaction products $(\gamma_1)$ and $(\gamma_2)$.

**High copper alloy:** They are preferred because of their improved mechanical properties, resistance to corrosion, and better marginal integrity (because the weakest $(\gamma_2)$ phase is eliminated in high copper amalgam)

1. **Admixed Alloy powder:** They are made by mixing one part (1/3) silver copper eutectic alloy (high copper spherical particles) with 2 part (2/3) silver-tin alloy (low-copper, lathe-cut particles). The main role of adding eutectic alloy of copper is to avoid $\text{Sn}$ to react with $\text{Hg}$ and to react with $\text{Cu}$ itself, to avoid formation of $(\gamma_2)$ which is responsible for tarnish and corrosion, thus reducing the same property just to increase mechanical properties.

2. **Single-composition alloys:** Each particle of alloy powder has the same composition; they are called single-composition or uni-compositional alloys.

**Properties of set amalgam:**

- **Dimensional change:** freshly mixed Amalgam should neither expand nor contract as it sets after it is condensed into a cavity preparation. Expansion may result in post placement sensitivity or protrusion from the cavity. Whereas contraction would leave gaps between the restoration and the tooth prone to leakage and recurrent decay. In general most amalgams expand or contract only slightly during setting.

If there is sufficient mercury present to provide a plastic matrix, an expansion will occur when $\gamma_1$ crystals impinge. Reducing mercury in the mix will favor contraction

**Factors favoring contraction are:**

1. Low mercury/alloy ratio.
2. Higher condensation pressure (squeezes out mercury).
3. Smaller particle size (accelerate mercury consumption because of its larger surface area)
4. Longer triturating times (accelerates setting).

The dimension become nearly constant after 6 to 8 hours, and thus the values after 24 hours are final values.
- **Effect of moisture contamination (delayed expansion):**

If a zinc-containing amalgam is contaminated by moisture during condensation large expansion can take place. It usually starts after 3-5 days and may continue for months. It may reach 4% that produce pressure on the pulp and cause post-operative sensitivity; this is known as **delayed expansion or secondary expansion**.

\[
\text{H}_2\text{O} + \text{Zn} \rightarrow \text{ZnO} + \text{H}_2 \text{(gas)}
\]

The hydrogen gas does not combine with the amalgam, but collects within restoration, increasing the internal pressure to levels high enough to cause the amalgam to creep, thus producing the observed expansion. Amalgam without zinc tend to be less plastic and less workable used only for cases where it is difficult to control moisture e.g. patient having excessive salivation, sub gingival lesions, etc..

- **Strength:** Hardened amalgam has good compressive strength. But cannot withstand high tensile or bending strength. Therefore the cavity design should be such that the restoration will receive compression forces and minimize tension or shear forces in service. The factors affecting strength of the amalgam are:

1) **Effect of triturating.** Either under-trituration or over-trituration will decrease the strength.

2) **Effect of mercury content.** Sufficient mercury should be mixed with the alloy wet each particle of the alloy. Otherwise a dry, granular mix results which has rough and pitted surface that invites corrosion. Excess mercury in the mix can produce a marked reduction in strength the reason high mercury amalgam have more \(\gamma_2\) content (which is weakest phase)

3) **Effect of condensation:** in lathe cut alloy and admixed alloys the higher condensation pressure results in higher compressive strength (good condensation technique will minimize porosity and remove excess mercury from lathe cut amalgam). While the spherical amalgam condense with lighter pressures produce adequate strength (If heavy pressure is used the condenser will punch through).

4) **Effect of rate of hardening** Amalgam does not gain strength as rapidly as might be desired. Patient should be cautioned not to bite too hard for least 8 hours after placement. The time at which at least 70% of its strength is gained.

5) **Effect of cavity design:** The cavity should be designed to reduce tensile stresses. Amalgam has strength in bulk; therefore, the cavity should have adequate depth.

6) **Effect of porosity.** Voids and porosity reduce strength.

- **Creep:** permanent deformation under static loads (a time dependent plastic deformation). Creep of dental amalgam is a slow progressive permanent deformation of set amalgam which occurs under constant stress (**static creep**) or intermittent stress (**dynamic creep**). Creep is related to marginal breakdown of low copper amalgams. The higher the creep, the greater is the degree of marginal deterioration (ditching). Creep
causes the amalgam to flow over time such that unsupported amalgam protrudes at the margin of the restoration.

The highest value of creep was found for the low-copper lath cut alloy, and the lowest values were determined for the high-copper (The $\gamma_2$ phase is associated with higher creep rates). **Increase** in zinc content gives less creep.

**Effect of manipulative variables (for increase strength and low creep)**

1. Decrease the Hg\alloy ratio.
2. Maximum condensation pressure applies for lathe cut or admixed alloys.
3. Careful attention should be paid to timing of trituration and condensation. Either under or over-trituration or delayed condensation tend to increase the creep rate.

- **Tarnish and corrosion:** Amalgam restorations often tarnish, and corrode in mouth.

**Tarnish:** is the surface phenomenon that can result in a discolored restoration (loss of luster from the surface due to the formation of surface coating). With tarnish the chemical reaction between the amalgam and the oral cavity is restricted to the amalgam surface. Although tarnish may be undesirable esthetically, it will not often cause the restoration to fail (no change in the mechanical properties of the alloy).

**Corrosion:** - results from chemical reactions that penetrate into the body of the amalgam and cause the failure of the restoration. Corrosion is the progressive destruction of a metal by chemical or electrochemical reaction with its environment. The multiphase structure of amalgam makes it prone to corrosion, the different phases form the anode and cathode and saliva provides the electrolytes. Excessive corrosion can lead to increased porosity, reduced marginal integrity, loss of strength and the release of metallic product into oral environment.

**Factors increase tarnish and corrosion:**

1. High residual mercury.
2. Surface texture — small scratches and exposed voids rough surface.
3. Contact of dissimilar metals, e.g. gold, and amalgam.
4. Patients on a high sulfur diet.
5. Moisture contamination during condensation.
6) Type of alloy — low copper amalgam is more susceptible to corrosion (due to greater $\gamma_2$ content) than high copper.

7) High copper amalgam is cathode in respect to a low copper amalgam so mixed high copper and low copper restoration should be avoided.

**Corrosion of amalgam can be reduced by:**

1. Smoothing and polishing the restoration.
2. Correct Hg alloy ratio and proper manipulation.
3. Avoid dissimilar metal including mixing of high and low copper amalgams.

Corrosion has **one advantage** that corrosion products help to produce a good marginal seal at the restoration / tooth interface (seal the gap) to prevent or decrease micro leakage.

- **Technical consideration**

The clinical success of most amalgam restoration is highly dependent on the correct selection manipulation of the alloy and cavity design. If a restoration is defective, it is usually the fault of the operator and not the material.

**Manipulation of Amalgam.**

1. Proportion and Dispensers.
2. Trituration.
3. Condensation.
5. Polishing.

1. **Proportion and Dispensers:** Because proportioning is important, manufacturers have developed some simple dispensers for alloy and mercury.

**Tablets:** This is most accurate method of dispensers manufacturers compress alloy powder into tablets of controlled weight which is used with measured amount of mercury.

**Pre-proportioned capsules** (disposable amalgam capsules) containing alloy particles and mercury in compartments separated by a membrane. Before use, the membrane is ruptured by compressing the capsule, and the capsule is then placed in a mechanical amalgamator.
Proportions of alloy to mercury: Some alloy require Hg-alloy ratio in excess of 1:1, whereas other use ratio of less than 1:1. the percentage of Hg varies from 43% to 54%.

2. Triturating (Mixing of Amalgam): Triturating of amalgam alloy and mercury is done with:

1. **Hand mixing** by use mortar and pestle.
2. **Mechanical mixing**: device called an amalgamator. Spherical or irregular low-copper alloy may be triturated at low speed (low energy), but most high copper alloys require high speed (high energy).

**Advantages of mechanical triturating:**

1. Shorter mixing time.
3. Requires less mercury when compared to hand mixing technique.

**Mixing time:** There is no exact recommendation for mixing time, since amalgamators differ in speed, oscillating pattern, and capsule designs. Spherical alloys usually require less amalgamation time than do lath-cut alloys. A large mix required slightly longer mixing time than a smaller one. When amalgams with longer or shorter working times are desired, one should use amalgam alloys that are designed to react faster or slower and not attempt to achieve the change by altering the trituration time.

**Mixing Variables:** Under mixing, normal mixing, or over mixing can result from variations in the condition of trituration of the alloy and mercury. The three types have different mechanical properties, dimensional change, strength and creep.

- **Under mixed amalgam** appears dull and is crumbly. A grainy under triturated mixture; restoration made of such a mixture has low strength and poor resistance to corrosion. The mixture may appear in solid mass, but the surface remains without luster.
- **Normal mix** appears shiny and separates in a single mass from the capsule. It appears rounded with a smooth shiny surface.
- **Over mixed amalgam** appears soupy and tends to stick to the inside of the capsule. It is shinier than that of the properly triturated one the mass appears flattened by the force of trituration.

![Amalgam images](image)

**Under** | **Normal** | **Over**

3. **Condensation** The amalgam is placed in the cavity after triturating, and packed (condensed) using suitable instrument. It is adaptation of the amalgam mass to the cavity walls that controls the amount of mercury that will remain in the finished restoration. More mercury left in the mass after condensation, the weaker the alloy.

Aims of condensation:

a. To adapt it to the cavity wall.

b. Remove excess mercury.

c. Reduce voids.

Irregularly shaped alloys needs higher percentage of mercury while with spherical alloys the amount of mercury is lower. Increasing the condensation pressure results in a significant increase in compressive strength.

Condensation could be: **Manual condensation or Mechanical condensation**.

**Manual Condensation:** Circular condenser tips may prove adequate condensation. With irregularly shaped alloys small tip condenser (1 to 2) mm is use with high condensation forces in a vertical direction. While for spherical alloys one should use condensers with larger tips, almost as large as the cavity permits (particles tend to roll over one another).

**Mechanical condensation:** These devices are useful for condensing irregularly shaped alloys when high condensation forces are required. Ultrasonic condensers are not recommended because during condensation they increase the mercury vapor level.
4. **Carving:** The filling is carved to reproduce the tooth anatomy. The carving should not be started until the amalgam is hard enough to offer resistance to the cavity instrument.

**Burnishing:** After the carving, the restoration is smoothened, by burnishing the surface and margins of the restoration. Burnishing is done with a ball burnished using light stroke proceeding from the amalgam surface to the tooth surface.

5. **Polishing:** Polishing minimize corrosion and prevents adherence of plaque. the polishing should be delayed for at least 24hours after condensation. For polishing wet abrasive powder in a paste form is used.

**Mercury toxicity:** Mercury is toxic. Free mercury should not be sprayed or exposed to the atmosphere. This hazard can arise during triturating, condensation, and finishing of restoration, and also during the removal of old restoration at high speed. Mercury vapors can be inhaled; skin contact with mercury should be avoided as it can be absorbed. It also reacts with gold.

Mercury has a cumulative toxic effect. Dentists and dental assistant are at high risk. Though it can be absorbed by skin or by ingestion, the primary risk is from inhalation. The clinic should be well ventilated. All excess mercury and amalgam waste should be stored in well-sealed containers. An important aspect from a medical point of view, there is no clinical evidence to suggest that amalgam is causing illness in the general population.
Precautions:

1. The clinic should be well ventilated.
2. The mercury should be stored in well-sealed container.
3. Skin contacted with mercury should be washed with soap and water.
4. While removing the old fillings, a water spray, mouth mask, and suction should be used.
5. The use of ultrasonic amalgam condenser is not recommended as a spray of small mercury droplets is observed.
6. If the mercury contact the gold jewelry the mercury bonds permanently to the gold and ruins, but boiling it in coconut oil can fix it.
7. Annually, a (programme for handling toxic materials) is monitored for actual exposure levels.