DENTAL AMALGAM
Amalgam:
Mixture of a metal or an alloy with Hg.

Dental amalgam alloy:
Special dental alloy of Ag, Sn and Cu, and may contain other minor metals as zinc.

Dental amalgam:
It is a mixture of special dental alloy with highly purified Hg at room temperature to give a plastic mass can be packed into the prepared cavity.
USES:-

1. Filling class I, II, V posterior
2. Cusp rebuilding.
3. Core build-up material.
4. Retrograde filling material.

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ADVANTAGES

1. Easy to be insert.
2. Not technique sensitive
3. Have adequate compressive strength
4. Decreasing marginal leakage
5. Have a relatively long service life
6. Adequate wear resistance.
7. Cost effectiveness.

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DISADVANTAGES

1. Silver color (main disadvantage)
2. Suffer from creep
3. Corrosion & galvanism
4. Good thermal conductor
5. Brittle
7. No bonding to tooth structure.
ROLE OF CONSTITUENT ELEMENTS:

Silver (Ag)

- Decrease creep.
- Increase strength and hardness.
- Increase setting expansion.
- Increase tarnish and corrosion resistance and reactivity with mercury.
Tin (Sn)
- Increase plasticity of amalgam mass during condensation
- Increase the rate of amalgamation
- Decrease corrosion resistance
- Increase creep
- Decrease strength
- Decrease setting expansion
Copper (Cu)
- Increase corrosion resistance
- Increase strength,
- Increase setting expansion
- Decrease creep

Zinc (Zn)
- Deoxidizer (scavenger).
- Increase plasticity of amalgam during condensation.
- Cause delayed expansion if contaminated with moisture during insertion of amalgam inside the prepared cavity due to formation of zinc hydroxide and liberation of hydrogen gas
Mercury

- Use high purified mercury (triple distilled)
- Increase creep.
- Decrease strength and hardness.
- Decrease tarnish and corrosion resistance

*Indium (In), Palladium (Pd)*

- Enhance mechanical properties
- Increase tarnish and corrosion resistance.
Ag$_3$Sn ($\gamma$) is intermetallic compound produced from 73 %Ag and 27 % Sn below 480°C. If Sn < 26% Production of phase (Solid solution of Sn in Ag) which is a totally different than $\gamma$ phase. If Sn > 30% $\Rightarrow$ decrease strength, Increase setting expansion and Increase tarnish and corrosion.
MANUFACTURE OF ALLOY POWDER

- Ingot production
- Homogenization of the ingots
- Production of the powder (Lathe cut or ball milling or spherical particles or spheroidal particles)
- Aging or annealing (for lathe cut or ball milling)
1- Ingots production:
The constituent elements of the alloy powder are melted then slowly cooled below 480°C. The liquid alloy is cast into ingots (3.8 cm in diameter and 20-25 cm in length).
It’s a cored structure.

2- Homogenization of the ingot:
Is done by heating the ingot at 400°C for 24 hr then quenching to
- Ensures that powder particles have similar composition
- Increase tarnish and corrosion resistance of the final amalgam
3- Powder Production:

A- Production of lath cut alloy powder
- By machining of the ingot
- Disadvantage is inducing internal stresses in the alloy particles.

B- Production of spherical and spheroidal alloy powder:
- Is formed by melting the alloy ingredients together and then sprayed into a closed chamber filled with inert gas (Spherical particles) or atomizing the liquid alloy in water (spheroidal particles)
4- Aging or annealing:
   Is done in order to eliminate the internal stresses before amalgamation.
   Aging is done either by
   - Heating the lathe-cut powder at 100°C for 6-8 hr.
   - Storage powder at room temp. for several months.

NB: Spherical & spheroidal powders require homogenization to element coring but don't annealing!!!!!!Why?
AMALGAMATION (SETTING) REACTION:

When the mercury is mixed with the alloy powder the following subsequent stages occur

- **Wetting:** mercury wets the surface of $\gamma$-$\text{Ag}_3\text{Sn}$ particles.
- **Diffusion:** The mercury diffuses into the alloy particles.
- **Surface reaction:** A surface chemical reaction occurs during which two new phases are formed.

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CLASSIFICATIONS OF DENTAL AMALGAM

According to:-

- Copper content
- Zinc content
- Particle shape
- Particle size
Classifications of dental amalgams

- **Cu content**
  - Low Cu
  - High Cu
    - Admixed
      - Unicompositional

- **Zn content**
  - Zn containing
  - Zn free
    - Spherical (Regular)
    - Lathe cut (Irregular)
    - Mixed (blended)

- **Particles shape**
  - Coarse cut (Large)
  - Fine cut (Small)
1. **low copper conventional amalgam** (Cu<6%)

2. **High copper amalgam** (Cu>6%)
   1. Admixed high copper amalgam
   2. Uni-compositional high copper amalgam
1. Conventional amalgam:

<table>
<thead>
<tr>
<th>Phase</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ag₃Sn (γ)</td>
<td>Strongest + Most corrosion resistant.</td>
</tr>
<tr>
<td>Ag₂Hg₃ (γ₁)</td>
<td>Lower strength + Lower corrosion resistance due to presence of some Sn as impurity (Pure γ₁ has the highest corrosion resistance)</td>
</tr>
<tr>
<td>Sn₈Hg (γ₂)</td>
<td>Weakest + Most corrodbile phase</td>
</tr>
</tbody>
</table>

Completion of Reaction → Days to weeks. → ↓ γ + ↑γ₁ γ₂
So ↑ Hg → ↓ Strength.
  ↓ Corrosion resistance.
  ↑ Setting expansion.
  ↑ Creep.
So the amount of Hg should be kept at minimum that required for the reaction.
2. Admixed amalgam:

\[ \text{Ag}_3\text{Sn} (\gamma) + \text{Ag-Cu (eutectic)} + \text{Hg} \rightarrow \text{Ag}_2\text{Hg}_3 (\gamma_1) + \text{Sn}_8\text{Hg} (\gamma_2) + \text{Ag}_3\text{Sn} (\gamma) + \text{Ag-Cu (eutectic)} \]

\[ \text{Sn}_8\text{Hg} (\gamma_2) + \text{Ag-Cu (eutectic)} \rightarrow \text{Cu}_6\text{Sn}_5 (\eta) + \text{Ag}_2\text{Hg}_3 (\gamma_1) + \text{Ag-Cu (eutectic)} + \text{Voids} \]

Advantageous: \( \rightarrow \) No \( \gamma_2 \) phase \( \rightarrow \) \( \uparrow \) Strength, \( \downarrow \) Corrosion resistance, \( \downarrow \) Creep.

Disadvantageous: \( \rightarrow \) Presence of two Different particle shapes and composition lead to sedimentation of one particle type. \( \rightarrow \) Surface oxidation of Ag-Cu particles
UNICOMPOSITIONAL AMALGAM:

\[
\begin{align*}
\text{Ag}_3\text{Sn} \ (\gamma) + \text{Cu}_3\text{Sn} \ (\varepsilon) + \text{Hg} & \rightarrow \text{Ag}_2\text{Hg}_3 \ (\gamma_1) + \text{Cu}_6\text{Sn}_5 \ (\eta) + \text{Ag}_3\text{Sn} \ (\gamma) \text{ Unreacted} + \text{Cu}_3\text{Sn} \ (\varepsilon) \text{ Unreacted} \\
\end{align*}
\]

When the powder particles having the composition of \(\text{Ag}_3\text{Sn} \ (\gamma) + \text{Cu}_3\text{Sn} \ (\varepsilon)\) are mixed with \(\text{Hg}\), one-step reaction takes place to produce \((\gamma_2)\) free set amalgam.

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1. Conventional amalgam:
\[ \text{Ag}_3\text{Sn (γ)} + \text{Hg} \rightarrow \text{Ag}_2\text{Hg}_3 (γ_1) + \text{Sn}_8\text{Hg (γ}_2) + \text{Ag}_3\text{Sn (γ)} + \text{Voids} \]

2. Admixed amalgam:
\[ \text{Ag}_3\text{Sn (γ)} + \text{Ag-Cu (eutectic)} + \text{Hg} \rightarrow \text{Ag}_2\text{Hg}_3 (γ_1) + \text{Sn}_8\text{Hg (γ}_2) + \text{Ag}_3\text{Sn (γ)} + \text{Ag-Cu (eutectic)} \]
\[ \text{Sn}_8\text{Hg (γ}_2) + \text{Ag-Cu (eutectic)} \rightarrow \text{Cu}_6\text{Sn}_5 (η) (\text{eta}) + \text{Ag}_2\text{Hg}_3 (γ_1) + \text{Ag-Cu (eutectic)} + \text{Voids} \]

3. Unicompositional amalgam
\[ \text{(Ag}_3\text{Sn (γ) + Cu}_3\text{Sn (ε)) + Hg} \rightarrow \text{Ag}_2\text{Hg}_3 (γ_1) + \text{Cu}_6\text{Sn}_5 (η) + \text{Ag}_3\text{Sn (γ) Unreacted} + \text{Cu}_3\text{Sn (ε) Unreacted} + \text{Voids} \]
Conventional amalgam

Admixed amalgam

Unicompositional amalgam

Voids

Ag-Cu eutectic voids

$\gamma$

$\gamma_1$

$\gamma_2$

$\eta$

$\eta_1$

$\gamma + \varepsilon$
high copper Cu >6 wt% amalgam is preferred than low copper amalgam due to:-

- No γ₂ phase.
- High early strength.
- Higher mechanical properties.
- Lower creep values.
- Higher corrosion resistance.
- Good resistance to marginal breakage.
According to Zinc Content

- containing Zn ≤ 0.01% → “zinc free”
- containing Zn > 0.01% → “Zinc Containing”

Moisture contamination of zinc containing amalgam during initial setting lead to

i. Porous amalgam:
incorporation of droplet in possessing → inferior mechanical prop.

ii. Delayed (secondary) expansion
after 2-3 day → value greater than 400µ/cm due to

\[
Zn + H_2O \rightarrow ZnO + H_2↑↑
\]

lead to
postoperative pain
restoration extrude from cavity → marginal ditch →
discoloration → recurrent carries
corrosion to the restoration
gingival inflammation

iii. Blistering: H₂ near the surface → fracture → food accumulation → corrosion

Zn Free amalgam used whenever water contamination could not be avoided as in young children and class V caries

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ACCORDING TO PARTICLES SHAPE

i. Lathe - cut (irregular shape)
ii. Spherical particles (regular shape)
iii. Mixed (blended) type particles
iv. Spheroidal particles

**Lathe cut**

1- \( \uparrow \) Surface area due to irregular shape → \( \uparrow \) Needed Hg for wetting → Excess Hg → \( \uparrow \) \( \gamma_1 \) & \( \uparrow \) \( \gamma_2 \) in low cupper amalgam & \( \downarrow \) \( \gamma \)
   \( \uparrow \) Setting exp.
   \( \uparrow \) Setting time.
   \( \uparrow \) T & Cr.
   \( \uparrow \) Creep.
   \( \downarrow \) Strength.

2- \( \uparrow \) Friction between particles → \( \uparrow \) Needs condensation pressure → more voids and \( \downarrow \) Density of restoration

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Spherical

1. -↓ Surface area → ↓ Hg
2. -↓ Friction → ↓ condensation pressure → ↑ Density
3. Fast setting
4. high early strength
5. Smoother surface during carving and finishing

Disadvantages:

-↑ Setting contraction → Large marginal gap

Mixed (blended) type particles

Composed of both lathe cut and spherical particles to utilize the positive characteristics of both

Spheroidal particles

Characteristics are same to mixed type
i. Fine - cut (large particle size): (15-35µ)

ii. Coarse - cut (large particle size): (100-200 µ)

**Fine size amalgam is characterized by (15-35µ)**

1- High reaction rate with mercury

smaller particles has high surface energy. & More rapidly developed hardness

2- greater **early strength**

matrix phase that hold the mass to gather produced faster

3- greater strength in general

less Hg is need for the reaction

4- **Adapt** better to prepared cavity.

5- Produce **smoother surface** during carving and finishing.

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Very fine particles less than $3\mu$.

1- $\uparrow$ total surface area $\rightarrow \uparrow$ mercury to complete wetting of the alloy particles.

2- $\uparrow$ mercury content $\rightarrow \downarrow \gamma$

$\uparrow \gamma_1$ and $\gamma_2$

$\uparrow$ T & Cr.

$\uparrow$ Creep.

$\downarrow$ Strength.

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Coarse - cut (100-200 μ)

1-Difficult in amalgamations low reactivity of the coarse particles.

2-Inferior properties as they react with more Hg.

3-Produce a rough surface → increase corrosion
PROPERTIES OF DENTAL AMALGAM

Physical properties
- Dimensional Change
- Conductivity & $\alpha$

Mechanical properties
- Corrosion
- Strength (compressive, tensile & transverse)
- Modulus of elasticity
- Creep
- Corrosion

Biocompatibility
l-Physical properties:
- Good thermal and electrical conductivity
- Coefficient of thermal expansion near that of tooth structure
- Opaque with dark metallic color
**Dimensional changes**

- In the first 24 hours should be within the range of ± 20 um/cm.
- It's affected by **manipulative variables** as method of mixing and Hg content.
- **Contraction** appear when use **Spherical alloy**, **Low Hg** and **Mechanical amalgamation**.
- Marginal adaptation is improved by **Condensation**, **Self-seal property** due to corrosion (2-3 months) and Amalgam bonding.
- **High Hg content** lead to **Excessive formation of new phases** causing **Expansion**.
Zn containing amalgam may lead what is known as delayed expansion if contaminated with water or during mixing or condensation.

Higher contraction can lead to marginal leakage and recurrent caries.

Higher expansion can lead to pressure on the pulp cause post operative sensitivity and Protrusion of the restoration lead to Overhanging & ditching.
II- MECHANICAL PROPERTIES:

1- High compressive strength
2- Relatively low tensile strength
   - Clinical importance:
   Cavity preparation should maximize the compressive forces and minimizes the tensile stresses and shear stresses
3- FLOW AND CREEP

**Flow:** is a time dependent plastic deformation before complete setting of the material.

**Creep:** is a time dependent plastic deformation after complete setting of the material.

**Effect of creep:**
- Marginal breakdown (ditching)
- Flattening of contact points over
- Hanging margins.

- Maximum accepted Creep according to ANSI/ADA is 3% after 7 days

- Creep occurs because amalgam is a visco-elastic material. The viscous portion is due to Hg containing phases [Ag$_2$Hg$_3$ ($\gamma$1) & Sn$_8$Hg ($\gamma$2)], while the elastic portion is due to Hg free phases [Ag$_3$Sn ($\gamma$) & Cu$_6$Sn$_5$ ($\eta$)].
Young’s modulus of High Cu amalgam is higher than Low Cu amalgam.

- Clinical importance:
  In deep cavities the cement base under amalgam should have high $E$ to prevents bending of amalgam and development of tensile forces at amalgam cement interface which lead to fracture of amalgam.
III-BIOLOGICAL PROPERTIES

1- Mercury toxicity.
- Mercury is toxic and its most risky form is its vapor.
- It has a little effect on patient but on dental personnel due to Prolonged exposure to Mercury vapor serious effects can happened. Vapor is absorbed through lungs to Blood stream, Central nervous system and Kidneys.
- The use of pre-capsulated amalgam limits handling of liquid mercury and reduces the possibility of its inhalation.

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The controversy about mercury toxicity is dental amalgam is finished and the conclusion is:

- In the set materials mercury amalgam has no toxic effect.
- The amount of mercury present in nine filled teeth is equivalent to the amount ingested in two tuna meals per week so its concentration is insignificant.
- **Mercury hygiene:** Is the process of handling mercury to minimize health risks.
2- Thermal irritation due to amalgam is conductor

3- Corrosion: Either due to
   a- Galvanic corrosion which is due to Heterogeneity of the amalgam or Contact with other metallic restorations
   b- Or Concentration cell corrosion which is due to Roughness of unfinished amalgam

- The Most corrodbile phase in amalgam is Sn₈Hg (γ₂) phase so High Cu amalgam has higher corrosion resistant than Low Cu amalgam.
- Amalgam corrosion lead to deterioration of the restoration bulk, decrease Strength and Release of metallic products.
- Corrosion can be minimized by decrease the Mercury content and adequate Finishing & polishing of the restoration.

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MANIPULATION OF AMALGAM

1. Selection of Alloy
2. Proportions of Alloy to Hg
3. Mixing of Amalgam
4. Condensation of Amalgam
5. Carving & Finishing Amalgam Restoration
In selecting the alloy we should consider:
- Amount of copper content,
- particle shape,
- Particles size,
- Zn content.
Proper proportioning should be maintained:

**Excess Hg:** →↑ $\gamma_1$ &↑ $\gamma_2$ in low cupper amalgam &↓ $\gamma$

↑ Setting exp.
↑ Setting time.
↑ T & Cr.
↑ Creep.
↓ Strength.

**Less Hg:** →↓ Wetting of Hg to powder → Friable mix

↓

↑ Voids.
↑ T & Cr.

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PROPORTIONING TECHNIQUES:

1. **Wet techniques:**
   Hg : Alloy ratio is slightly $> 1 : 1$.
   irregular particles , hand mixing

2. **Minimal mercury (Eam’s) tech.:**
   Hg : Alloy ratio is slightly $< 1 : 1$
   -spherical & spheroidal , mechanical mix

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Proportioning methods:
1. Volumetric dispenser.
2. Weight (more accurate)

- Specific measure (spoon) of alloy with drops of mercury
- Amalgam tablet with mechanical dispenser for mercury
- Pre-capsulated amalgam
TRITURATION
mixing of the alloy and mercury

Aim  wet the alloy particles with Hg until a homogenous plastic mass is obtained
1. **Manual trituration**: Using Mortar & Pestle uniformity between the different mixes may not be obtained.

2. **Mechanical trituration**: Using Amalgamator “Triturator”.

**Mechanical mixing is preferred:**
1. Uniform and reproducible mix.
2. Shorter time.
3. Low Hg : Alloy ratio.
4. Less risk of exposure to Hg vapor.
Trituration is critical step that affect the properties of the final amalgam mass

<table>
<thead>
<tr>
<th>Over Trituration</th>
<th>Under Trituration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Tends to stick to the capsule.</td>
<td>Excess Hg remain in the mix lead to</td>
</tr>
<tr>
<td>2. It has low corrosion resistance, due to over formation of $\gamma_1$ and $\eta$ products.</td>
<td>1-↑ setting expansion</td>
</tr>
<tr>
<td>3. Decreases working time, slightly higher contraction</td>
<td>2. high creep</td>
</tr>
<tr>
<td></td>
<td>3. Decrease tarnish and corrosion resistance</td>
</tr>
<tr>
<td></td>
<td>4. Lower compressive and tensile strength</td>
</tr>
<tr>
<td></td>
<td>5. Dull dry crumbly appearance.</td>
</tr>
</tbody>
</table>

N.B:- Low-Cu alloys may be triturated at low speed, and High-Cu alloys require high speed.

Properly triturated amalgam makes it shinny and have some resistance to condensation.
Rubbed between the finger (mulling) produces a more homogeneous and plastic smooth mix.

If the wet technique was used, it's recommended that the excess Hg is removed after trituration by **squeezing the mass** in squeezing cloth or gauze before condensation.
CONSENSATION OF AMALGAM

Packing of amalgam into the prepared cavity using condencer.

Aims:
1. ↑ Adaptation of amalgam to cavity wall.
2. ↓ Hg content of the condensed mass
3. ↓ Porosity → ↑ Density → ↑ strength.

Delayed condensation leads to: (amalgum partially set before being transferred to the prepared cavity)
1. Breaking down of formed matrix → ↓ Strength.
2. ↑ Hg content (partially set mass will containing excess mercury.
3. ↓ Adaptation (reduction of plasticity of the amalgam)
4. ↑ Porosity
5. ↑ Creep.
6. ↓ Corrosion resistance.
7. Poor bonding between increment
Amalgam should not be used after 3 minute of trituration

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5. CARVING, FINISHING & POLISHING:

- **Carving**
amalgam carved To give proper **tooth anatomy** and remove **excess Hg** usually after 5 minute
Carving should be done in the **direction** from tooth to the restoration to avoid ditching
Finishing:
aim to remove surface irregularities, done using finishing burs

Polishing:
produced smooth Lustrous surface. Better appearance & high Cr. resist. Its done by using rubber cubes and soft brushes with pumice & glycerin or fine slurry of tin oxide
- Low Cu amalgam Weak: Polishing after 24 hours from insertion.
- High Cu amalgam Strong: (raped gaining to strength) Polishing immediately.

N:B avoid overheating of the restoration to prevent rising the Hg to the surface
Thank you