Dental amalgam

Dental amalgam is an alloy produced by mixing liquid mercury with solid particles of silver, tin, copper and sometimes zinc, palladium and selenium; this combination of solid metals is known as the amalgam alloy.
In dentistry, the amalgam has been successfully used for more than a century as a restoration material for tooth decay.

{Alloy for dental amalgam A silver-tin alloy containing other metals, usually copper
and zinc, that will be mixed with mercury to form dental amalgam**}**.

Classification of amalgam alloys :

1. Based on copper content:

- ***Low copper alloys:*** **Contain less than 6% copper (*conventional alloys*).**
- ***High copper alloys:*** **Contain more than 6% copper.**

The high copper alloys are further classified as:

- ✓ **Admixed or blended or dispersion alloys.**
- ✓ **Single composition or unicomposition alloys.**

2. Based on zinc content:

- **Zinc- containing alloys: Contain more than 0.01% zinc.**
- **Zinc-free alloys: Contain less than 0.01% zinc.**

3. Based on the shape of alloy particle:

- **Lathe cut alloys: irregular shape.**
- **Spherical alloys.**

4. Based on number of alloyed metals:

- **Binary alloys: e.g. silver-tin.**
- **Tertiary alloys: e.g. silver-tin-copper.**
- **Quaternary alloys: e.g. silver-tin-copper-indium.**

Manufacture of alloy powder:

- **Lathe-cut alloy powder:** to produce lathe-cut alloys, the metal ingredients are heated and protected from oxidation until melted, then poured into a mold to form an ingot; the ingot is cooled slowly. After the ingot is completely cooled, it is heated for various period of time to produce a more homogenous distribution of Ag_3Sn. An annealed ingot of silver-tin alloy is placed in a milling machine or in a lathe and fed into a cutting tool.

Aging: a freshly cut alloy reacts too rapidly with mercury. If the alloy fillings are stored at room temperature for a few months the reactivity gradually decreases. Such alloys are said to been aged. Aging can be done quickly by boiling the fillings for 30 minutes in water. They can also be treated with acid. Aging also improves the shelf life of product.

- **Spherical alloy powder:** the spherical alloy is prepared by an atomization process. The liquid alloy is sprayed under high pressure of an inert gas through a fine crack into a large chamber. If the droplets solidify before hitting a surface, the spherical shaped is preserved. Like the lathe-cut powder, spherical powder is aged.

Composition:

Low copper	**High copper**		
	Admixed		**Unicomposition**
Lathe-cut or spherical	**Lathe-cut**	**Spherical**	**Spherical**
Silver 63-70%	40-70%	40-65%	40-60%
Tin 26-29%	26-30%	0-30%	22-30%
Copper 2-5%	2-30%	20-40%	13-30%
Zinc 0-2%	0-2%	0%	0-4%

Function of each component:

Silver

- Major element in the reaction.
- Whitens the alloy.
- Decreases the creep.
- Increases strength.
- Increases expansion on setting.
- Increases tarnish resistance in the resulting amalgam.

Tin

- Controls the reaction between silver and mercury. Without tin, the reaction would be too fast and the setting expansion would be unacceptable.
- Reduces strength and hardness.
- Reduces the résistance to tarnish and corrosion, hence the tin content should be controlled.

Copper

- Increases hardness and strength.

- Increases setting expansion.

Zinc

- Scavenger or deoxidizer, during manufacture, thus prevents the oxidation of important elements like silver, copper or tin. Oxidation of these elements would seriously affect the properties of the alloy and amalgam.
- Alloy without Zinc are more brittle, and amalgam formed by them are less plastic.
- Zinc causes delayed expansion if the amalgam mix is contaminated with moisture during manipulation.
- In small amounts, it does not influence the setting reaction or properties of amalgam.

Platinum

- Hardens the alloy and increases résistance to corrosion.

Palladium

- Hardens and whitens the alloy.

Indium

- Reduces mercury vapor, improves wetting and reduce creep.

Low copper alloys : (*Traditional,Conventional)*

- Composed of silver 63-7o%, tin 26-29%.
- Available as: *lathe-cut alloys, two types: coarse or fine grain.

  *Spherical alloys.

  *Blend of lathe-cut and spherical particles.

- **Setting reaction:** when alloy powder and mercury are triturated, mercury diffuses into the alloy particles and starts reacting with the silver and tin present in it, forming silver-mercury and tin-mercury compounds.

$$Ag_3Sn + Hg =================== Ag_2Hg_3 + Sn_8Hg + Ag_3Sn$$

(Ag_3Sn) gamma (Y) phase a silver-tin compound that forms a substantial part of the amalgam alloy
(Ag_2Hg_3) gamma 1 (Y1) phase A silver-mercury compound that is a reaction product in dental amalgam.
(Sn_8Hg) gamma 2 (Y2) phase A tin-mercury compound ***the weakest compound and is least stable to corrosion process.***

The alloy particles do not react completely with mercury; about 27% of the original Ag_3Sn remains as unreacted particles. Set amalgam consist of unreacted particles (Y) surrounded by matrix of the reaction products (Y1 & Y2). If more (Y) phase is present, the stronger the amalgam.

High copper alloy:

They are preferred because of their improved mechanical properties, resistance to corrosion and better marginal integrity (because the weakest Y2 phase is eliminated in high copper amalgam). High copper alloy are further classified as:

Admixed Alloy

- ***Made by mixing***
  - One part of *high copper spherical particles* (eutectic alloy) silver (40-56%), copper (20-40%)
  - 2 part of (low-copper, lathe-cut particles).
- **Setting reaction**

$Ag_3Sn + Ag\text{-}Cu + Hg$ ================== $Ag_2Hg_3 + Sn_8Hg + Ag_3Sn + AgCu$

$Sn_6Hg + Ag\text{-}Cu$ ======================== $Cu_6Sn_5 + Ag_2Hg_3$.

- **(Cu_6Sn_5)** - Eta phase**.**

Single-composition alloys:

- Made from particle has the same composition silver(40-60%), copper (13-30%), tin (22-30)
- ***Setting reaction***

$AgSnCu + Hg$ ------- $Cu_6Sn_5 + Ag_2Hg_3 + AgSnCu$

(Y + ε)

- No gamma 2 (Sn_8Hg) will appear in any stage of reaction.

Properties of amalgam:

Dimensional change: amalgam may expand or contract depending on its manipulation. Ideally; dimensional changes should be small. ADA specification No. 1 requires that amalgam should not expand or contract more than 20mm/cm at 37C°, between 5 & 24 hours from the beginning of triturating. The initial contraction after short time (the first 20 minutes) is believed to be associated with the solution of mercury in alloy particles. After this period an expansion occurs (although the total change remains negative) which is believed to be result of reaction of the mercury with silver and tin and the formation of the intermetallic compounds. The Y1 crystals as they grow, impinge against one another; produce an outward pressure tending to oppose contraction. If there is sufficient mercury present to provide a plastic matrix, an expansion will occur when Y1 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).
4. Longer trituration times (accelerate setting).

Modern amalgams show a net contraction; whereas older amalgams always showed expansion.

Two reasons for this difference:

1. Older amalgams contained larger alloy particles and were mixed with higher mercury/alloy ratios.
2. Hand trituration was used before; modern amalgams are mixed with high speed amalgamators.

The dimension becomes nearly constant after 6-8 hours, and thus the values after 24 hours are final values. The only exception to this statement is the excessive delay dimensional change resulting from contamination of zinc containing alloy with water during trituration or condensation. It is usually starts after 3-5 days and may continue for months. This is known as delayed or secondary expansion.

$H_2O + Zn$ -------- $ZnO + H_2$ (gas)

The hydrogen gas does not combine with the amalgam, but collects within restoration; creating internal pressure and expansion of the mass.

Amalgam without zinc tends to be less plastic and less workable; used only for cases where it is difficult to control moisture, e.g.: patients having excessive salivation, subgingival lesions, etc.

<u>strength</u>

- Hardened amalgam has good compressive strength but low 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.

Factors affecting strength:

1. Trituration affect: either under or over trituration will decrease the strength for both low and high copper amalgam.
2. Mercury content affect: sufficient mercury should be mixed with the alloy to 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.
3. Condensation affect: higher condensation pressure results in higher compressive strength (only for lathe-cut alloy). Good condensation technique will minimize porosity and remove excess mercury from lathe-cut amalgam. If heavy pressure is used in spherical amalgam, the condenser will punch through; however spherical condensed with light pressure produce adequate strength.
4. Porosity affect: voids and porosity reduce strength. **Porosity is caused by:**
   - **A.** Decrease plasticity of the mix: caused by: low and high Hg/alloy ratio & over and under trituration.
   - **B.** Inadequate condensation pressure.
   - **C.** Irregularly shaped particles of alloy powder.
   - **D.** Insertion of too large increments.

   Increase condensation pressure improves adaptation at margins and decreases the number of voids. Fortunately, **voids are not problem with spherical alloys.**
5. Rate of hardening affect: strength increase with time. Amalgam do not gain strength as rapidly as might be desired. The ADA stipulates a minimum of 80 mpa at 1 hour. Patient

should be continued not to bite too hard for at least 8 hours after placement; the time at which at least **70%** of strength is gained.

6. Cavity design affect: the cavity should be designed to reduce tensile stresses. Amalgam has strength in bulk; therefore increase thikness will increase strength, the cavity should has adequate depth.

….. ***Creep***

- Creep is defined as a time dependant 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).
- It is related to marginal breakdown of low copper amalgam. The higher the creep, the greater is the degree of marginal deterioration (ditching).
- Low copper amalgam creep= 0.8-8.0%.
- High copper amalgam creep= 0.4-0.1%.
- According to ADA specification No.1 creep should be below 3%.
- The Y2 phase is associated with higher creep rates.
- Increase in zinc content gives less creep.

Effect of manipulative variables (for increase strength & low creep):

- ✓ Hg/alloy ratio should be minimum.
- ✓ Condensation pressure should be maximum for lathe-cut or admixed alloys.
- ✓ 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

- Tarnish: means loss of luster from the surface of metal or alloy due to the formation of a surface coating.
- Cause no change in the mechanical properties of the alloy.
- Amalgam is usually tarnish due to the formation of sulphide layer on the surface.
- Tarnish increase in patients on a high sulfur diet.
- Rough surface and moisture contamination during condensation increase tarnish.

Corrosion

- The multiphase structure of amalgam makes it prone to corrosion.
- Corrosion is the progressive destruction of a metal by chemical or electrochemical reaction with its enviorment.
- Excessive corrosion can lead to increased porosity, reduced marginai integrity, loss of strength, and the release of metallic product into oral invironment.

Factors related to excess tarnish and corrosion:

- High residual mercury increase corrosion.
- Contact of dissimilar metals, e.g gold, and amalgam increase **galvanic** corrosion.
- High copper amalgam is cathodic in respect to a low copper amalgam so mixed high copper and low copper restoration increase **galvanic** corrosion (should be avoided).

- Rough surface texture, small scratches and exposed voids increase corrosion.
- Moisture contamination during condensation.
- Patients on a high sulfur diet.

Corrosion of amalgam can be reduced by:

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

Corrosion has one advantage that corrosion products gathered at the restoration - tooth interface (seal the gap) to prevent or decrease micro leakage.

Thermal properties:

- Amalgam has a relatively high value of *thermal diffusivity*. In large cavities it is necessary to line the base of the cavity with an insulating, cavity lining material prior to condensing the amalgam. This reduces the harmful effects of thermal stimuli on the pulp.

The *coefficient of thermal expansion* value for amalgam is about three times greater than that for dentine.

Biological properties

- Certain mercury compounds are known to have a harmful effect on the central nervous system. The patient is briefly subjected to relatively high doses of mercury during placement, contouring and removal of amalgam fillings. A lower, but continuing, dose results from ingestion of corrosion products. Properly handled dental amalgam should be regarded as safe for general use as a direct restorative material.
- Mercury is toxic, free mercury should not be sprayed or exposed to the atmosphere. This hazard can be arising during trituration, condensation and finishing of restoration; 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. Mercury has accumulative toxic affect. Dentists and dental assistants 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.

Manpulation of Amalgam

Amalgam alloy results when mercury is combined with a silver alloy and that is initially a plastic mass by amalgamation (Reaction that occurs between mercury and an amalgam alloy). The manipulation of amalgam involves the following sequence of events.

(1) Proportioning and dispensing;
(2) Trituration;
(3) Condensation;
(4) Carving;
(5) Polishing.

Proportioning

- Alloy/mercury ratios vary between 5: 8 'wetter' are generally used with hand mixing and 10: 8. 'Drier' used with mechanical mixing.
- For any given alloy/mercury ratio, the nature of the mix may vary depending upon the size and shape of the alloy particles. Spherical particle alloys, for example, require less mercury to produce a workable mix.
- 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%-54%.

Dispensing

- The simplest type volume dispenser releases a known volume of either mercury or alloy. Dispenser by volume is unreliable because it is affected by particle size and the degree of packing (trapped air and voids) in dispenser.
- Semi-automatic dispensers have two hoppers. One is filled with alloy, the other with mercury which also carries out the mixing.
- Tablets: manufactures compress alloy powder into tablets of controlled weight which is used with measured amount of mercury.
- Pre-proportioned Capsule contains both alloy and mercury in proportions which have been determined by the manufacturer. The two components are initially separated by an impermeable membrane. Before use, the membrane is ruptured by compressing the capsule; then the capsule is placed in mechanical amalgamator.

***Trituration**:*

- The mixing or Trituration of amalgam may be carried out by hand; using a mortar and pestle, or in an electrically powered machine (mechanical mixing device called amalgamator) which vibrates a capsule containing the mercury and alloy.
- The Trituration time will vary according to the nature of the alloy and the alloy: mercury ratio. Spherical or irregular low copper alloy may be triturated at low speed (low energy); but most high copper alloys required high speed (high energy).
- The advantages of mechanical trituration are:
- ✓ A uniform and reproducible mix is produced.
- ✓ A shorter trituration time can be used.
- ✓ A greater alloy/mercury ratio can be used (requires less mercury when compared with hand mixing technique).
- 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 lathe-cut alloys. A large mix required slightly longer mixing time than a smaller one.

Condensation;

- The most widely used method of condensation is with a hand instrument called an amalgam condenser.
- Ultrasonic vibration and mechanical condensing tools can be used also.
- Amalgam gun is the device used to transfer the material from the mixing vessel to the prepared cavity. **During condensation:**
- The amalgam is packed in increments, each increment being equivalent to the volume of material which can be carried in an amalgam 'gun' (carrier).
- During condensation, a fluid, mercury-rich layer is formed on the surface of each incremental layer. The cavity is overfilled and the mercury-rich layer carved away from the

surface. This effectively reduces the mercury content of the filling thus improving its mechanical properties.

- The technique chosen for condensation must ensure the following:
- ✓ Adequate adaptation of the material to all parts of the cavity base and walls.
- ✓ Good bonding between the incremental layers of amalgam.
- ✓ Optimal mechanical properties in the set amalgam by minimizing porosity, voids and achieving low final mercury.

Carving:

- The objectives of carving an amalgam restoration are to remove the mercury-rich layer on the amalgam surface and to rebuild the anatomy of the tooth.
- Carving should be carried out when the material has reached a certain degree of set.
- Spherical amalgams are easier to carve than lathe-cut materials and fine-grain products easier than coarse-grain.
- After the carving, the restoration is smoothened by burnishing the surface and margins of the restoration. Burnishing is done with a ball burnisher using light stroke proceeding from the amalgam surface to the tooth surface.

Polishing

- Polishing is carried out in order to achieve a lustrous surface having a more acceptable appearance and better corrosion resistance and prevent adherence of plaque.
- The fillings should not be polished until the material has achieved a certain level of mechanical strength, at least 24 hours after condensation otherwise there is a danger of fracture, particularly at the margins.
- For polishing; wet abrasive powder in a paste form is used.

Application of amalgam

- Permanent filling material.
- For making dies.
- In retrograde root canal filling.
- As a core materials.