Dental materials and physical properties

The advancement of dentistry and the quality of dental treatment are dependent on knowledge of the basic sciences .Certainly no basic science could be more relevant to dentistry and dental treatment than materials used in dentistry ,so, It is the science which deals with materials used in dentistry ,their physical and mechanical properties and their manipulation as such properties are related to the proper selection and use by the dentist .In the past the gold bands and wires were used for the construction of partial dentures .In the middle of the nineteenth century, research studies on amalgam were done by G.V. black .After that the **American dental association** determined the physical and chemical properties of dental materials and the development of new dental materials instruments and test methods.

The primary objective of it is to formulate standards or specification for dental materials and to certify the products which meet those requirements. The study of dental material enables the dentist to understand the behavior of these materials and how to use them to their best advantage .The service that a restoration or appliance gives to the patient is largely determined by the proper selection and use by the dentist .The objective for this course is to learn the physical ,chemical and mechanical properties of some of dental materials and their manipulation.

Biological requirements of dental material: A dental material should be :

1-Be non toxic to the body.

2-Be non- irritant to the oral or other tissues.

3-Not produce allergic reactions and ,not be mutagenic or carcinogenic.

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General properties of dental materials :there two main types of properties1- physical 2-mechanical,physical properties like color ,solubility ,density dimensional stability and others .Mechanical properties like hardness ,strength and others .There is no material until now have ideal properties which is either mechanical or physical, so the property which is good in one material may be bad in another material.

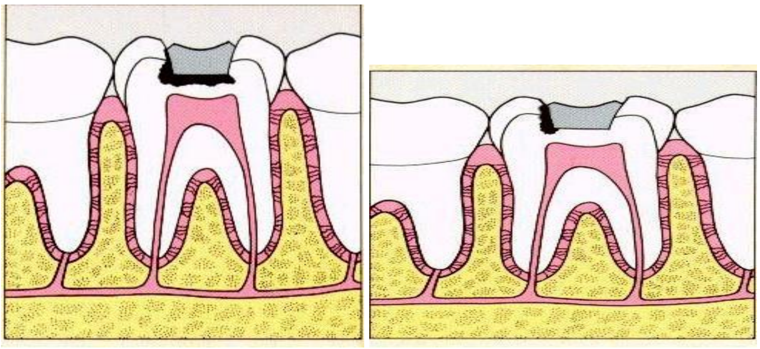
Physical properties: the following properties which are important in the study of dental material:

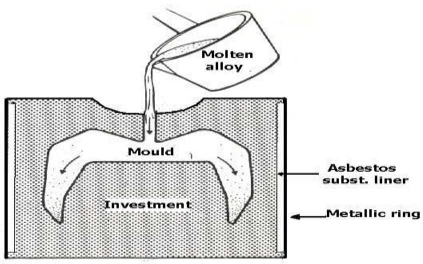
1-Color : Esthetics is critically important in dealing with dental material .For good esthetics ,the interaction of light with restorative materials must mimic the interaction of light with natural teeth. The dental restorative materials should be translucent in order to look like a natural teeth, and also should not be stained or changed the color by time ;ex anterior filling and artificial teeth.

Translucence :is the optical property that allows the light to go short way in the material before being reflected out again .Also should look like natural tooth substance at different light conditions ,such as day light and artificial light ,ex .an artificial tooth may be acceptable in ordinary light but may be discovered the relative darkness of the material in fluorescent light .For dentures ,the material should have the same appearance of natural gum .Acrylic material can be made with various shades of pink to look as normal gum.

2-linear coefficient of thermal expansion and contraction: Thermal expansion of the material occurs after increasing the temperature is due to increase the kinetic energy of the atoms and increase the vibration lead to increase the inter atomic spacing ,as a result the material expand grossly .After cooling the material contract, these changes measured by the linear coefficient of thermal expansion and contraction which is the change in length per unit length for 1 C^0 temperature change. a=final length-original length/original length*temp change (cm/cm .C^0).Hard tooth structure has the smallest coefficient, metals are intermediate ,and polymers have the largest .Tooth : $11*10^{-6}$ cm/cm.C^0 ,Gold: $14*10^{-6}$ cm/cm.C^0 ,impression compound :$250*10^{-6}$cm /cm. C^0, Acrylic resin: $76*10^{-6}$ cm/cm.C^0, Composits : $14-50*10^{-6}$ cm/cm .C^0. Filling materials should have the same coefficient as the tooth, if it does not, it will press too hard against the cavity wall on expansion and may cause pressure on the pulp, or pull away from the wall when chilled by cold water. The later effect will cause the filling to leak temporarily ,which may lead to further caries .

Gold alloy is used to cast crown or bridge .After cooling of the gold from the melting temperature ,it will contract and so the crown will be smaller. To compensate for this contraction ,we use certain type of investment, which expand in the same amount.





3-Dimensional stability: many material change shapes when they set or harden. Impression materials should not change dimensions when set .Also , dental materials should have no dimensional changes after setting .Amalgam is filling material for posterior teeth ; it may expand or contract, depending on its manipulation .Ideally, dimensional changes should be small. Excessive contraction can lead to micro leakage and secondary caries .Excessive expansion can produce pressure on the pulp and post operative sensitivity. On the other hand , the investment material that forms the mold for casting should expand for certain amount to compensate for the contraction of the molten metal after it is cooled from the molten stage

.Expansion of investment is about 1-2%, contraction of alginate is about 3%.

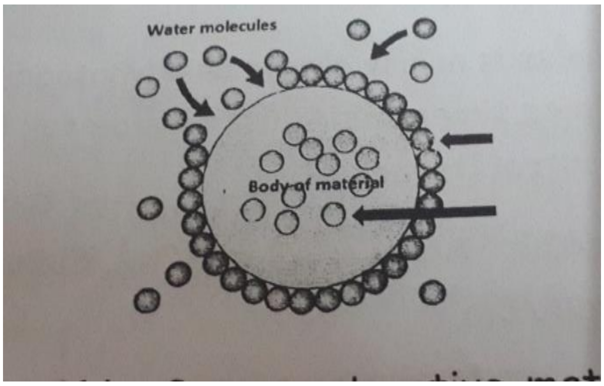
4-Density :Lightness is nearly always an advantage in restorative materials, but sometimes tin or lead is used inside full lower denture to make it heavy to control its mobility .Density of gold:14 gm/cm^3. Acrylic :1.2 gm/cm^3. Chromium / cobalt: 8.3 gm/cm^3. Water : 1gm/cm^3. **5-**

Complete Denture

Solubility :Restorative materials should not dissolve in the mouth, and if it dissolves, it should not release toxic substances .Its measured in Mg/mm^2. Solubility of composite:

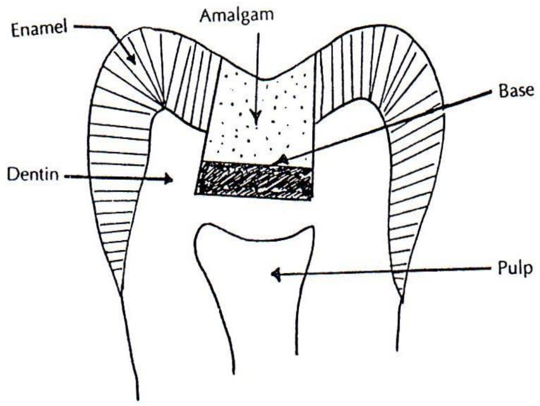
0.01Mg/mm^2. Solubility of resin cement maximum :7.5 Mg/mm^2.

6- Absorption of fluids : Some materials will absorb water or other fluids. If it is too much or continued for long time ,this will result in serious dimensional changes and the material would also be unhygienic .On the other , some materials like acrylic will absorb water for a day and stops after that , so it is acceptable .Water absorption of composites 40Mg/mm^2



7- **Tissue reaction** :some restorative materials are damaging to the living tissue which is in contact with ,like silicate filling and zinc phosphate cement which is acid and may kill the dental pulp unless a protective lining is used .Dental material should not show any allergic reaction to the tissue and also should not provide good culture to the growth of bacteria and Candida albican to grow and cause infection, like soft lining materials.

8- **Thermal conductivity** :Is the physical property that deals with heat transfer through a material by conductive flow .It is defined as the quantity of heat in calories per second passing through a material 1 cm thick with cross section of 1cm^2 having a temperature difference of 1C^0.Generally, metals are better heat conductors than non- metals. Metal filling material like amalgam, sometimes cause pulp pain by transmitting heat or cold more than natural tooth especially in deep cavities .Thus they require heat insulating layer between the filling and the pulp , here it is un desirable property. On the other hand, the thermal conductivity of metallic denture base material is an advantage as it gives feeling closer to the normal condition and the patient will feel normal also it will protect him from drinking very hot drinks which may burn his mouth.Silver:1cal/sec/cm ^{2}.Amalgam: 0.055 Cal/sec/cm^2 .Zinc oxide eugenol :0.011 Cal/sec/cm^2 .Enamel:0.0022Cal/sec/cm^2.



9-Thermal diffusivity :is the measure of the speed with which a temperature change will spread through an object when one surface is heated. It is calculated from the thermal conductivity divided by the product of density and heat capacity: **$h=K/C_P*$**

10-Electrical Activity : It is the ability of metals to ionize by losing electrons .If there is a high difference in the electrode potentials of two metals in contact with the same solution like gold and aluminum, an electrolytic cell may develop and the patient may feel discomfort.Enamel:$2.9*10^6$ Ohm.cm. Zinc oxide eugenol :10^9-10^{10}Ohm.cm

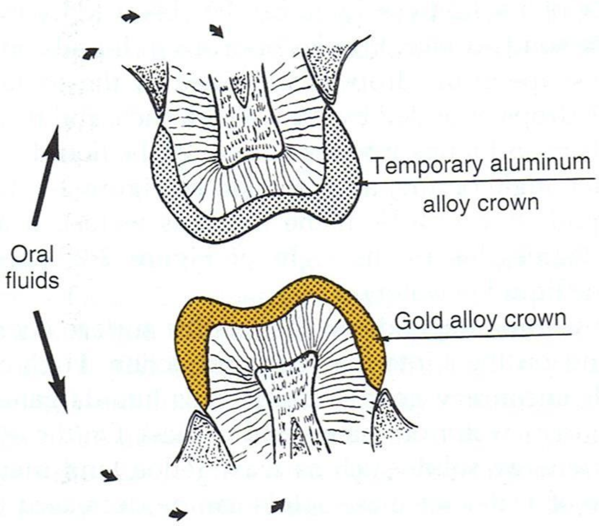


FIGURE 2–1 Diagrammatic sketch of opposing teeth with a gold crown and a temporary aluminum alloy crown indicating how galvanism can occur.

Electrochemical properties: The use of wide variety of metals for restorations and prosthetic devices the successful clinical performance and long term durability which require adequate corrosion resistance in the oral environment .

Corrosion :is the electrochemical process and is dependent on the ability to conduct electrical current either by means of free electrons in metals or via ions in solutions.

Tarnish: is a surface discoloration on a metal or a slight loss or alteration of the surface finish or luster.

11-Adhesion and cohesion : Adhesion is the force which causes two or more different substances to attach when they are brought in contact with one another .When the molecules of the same substances hold together ,the forces are said to be cohesion.

Biocompatibility: is formally defined as the ability of a material to elicit an appropriate biological response in a given application in the body .Inherent in this definition is the idea that a single material may not be biologically acceptable in all applications. For example, a material that is acceptable as a full cast crown may not be acceptable as a dental implant. Also implicit in this definition is an expectation for the biological performance of the material. In a bone implant, the expectation is that the material will allow the bone to integrate with the implant. Thus an appropriate biological response for the implant is osseointegration. In a full cast crown, the expectation is that the material will not cause inflammation of pulpal or periodontal tissues, but osseointegration is not an expectation. Whether or not a material is biocompatible therefore depends on the physical function for which the material will be used and the biological response that will be required from it.

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Mechanical properties of dental material

Mechanical properties: describe the ability of the material to resist forces and their effects on the bodies. Examples of the mechanical properties are stress, strain, strength and stiffness.

One of the most important properties of dental material is the ability to withstand the various mechanical forces placed during their use. Mechanical properties are important in understanding and predicting the behavior of a material under load, such as the restorative materials must withstand forces either during fabrication or mastication.

- Whenever force acts on a body tending to produce deformation, a resistance that is developed to the external force application. The internal reaction is equal in intensity and opposite in direction to the applied external force and is called as **stress.**

Stress: is the force per unit area induced in a body in response to some externally applied force.

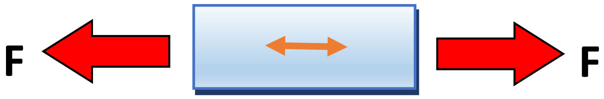
$$\text{Stress } (\sigma) = \frac{\text{Force}}{\text{Unit area}}$$

several types of stress may result when a force is applied to the material, these forces are compressive, tensile, shear, twisting movement and bending movement (flexure). Each type of stress is accompanied by the same type of strain.

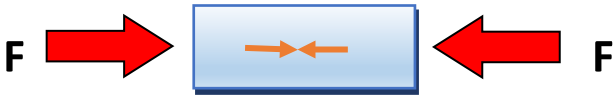
The unit of stress is the unit of force {Newton (N)} divided by a unit of area, and is commonly expressed as Pascal (1 Pa = 1 N/m^2 = 1 MN/mm^2).

Types Of Stress:

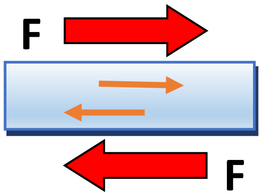
1. **Tensile stress:** it results from two sets of forces directed away from each other in the same straight line or when one end is constrained and the other end is subjected to a force directed away from the constraint; it is accompanied by tensile strain. Examples: enamel: 10 Mpa, dentin: 106 Mpa, amalgam: 32 Mpa.



2. **Compressive stress:** It results from two sets of forces directed toward each other in the same straight line or when one surface is constrained and the other is subjected to a force directed toward the constraint. lt is accompanied by compressive strain. Investment material, restorative materials and models should have high compressive strength. Examples: enamel: 384 Mpa, dentin: 297 Mpa, amalgam: 388Mpa.



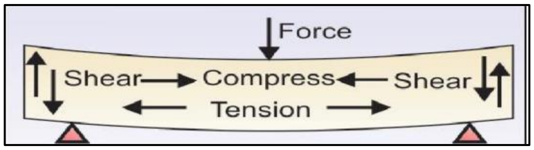
3. **Shear stress:** Shear is the result of two sets of forces directed parallel to each other (not along the same straight line) which is applied to one part of the body in one direction, and the rest is being pushed in the opposite direction. The result is sliding of the molecules over each other. It is accompanied by shear strain . Examples: enamel: 90 Mpa, dentin: 138 Mpa, amalgam: 188 Mpa.



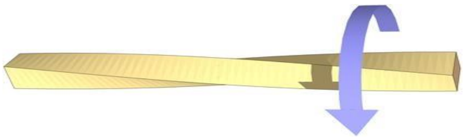
Shear force is the force which causes tearing a paper or a card. If one part of the crown is in occlusion while the rest is not, shear stress will develop.

4. **Flexural stress (bending stress):** it is the force per unit area of a material that is subjected to flexural loading.it results from an applied bending moment.

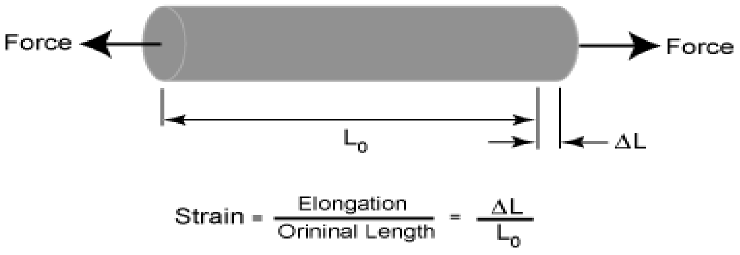
Usually, three types of stresses occur at the same time If a piece of metal is being bending it will exhibit tensile stress on the outer surface, compressive on the inner and shear stress in the middle.



5. **Torsion stress:** Force per unit area of a material that is subjected to twisting of a body.



- When external force or load is applied to a material the phenomena of **strain** occurs; i.e. the change in the dimensions of the material.



Strain (Ɛ): is the change in length (dimension) or deformation per unit length (dimension) caused by externally applied force. Strain is denoted as ‘ε’. It has no unit of measurement. Examples of some dental materials strain are: acrylic: 1.5%, Co/Cr: 4%, stainless steel: 35%.

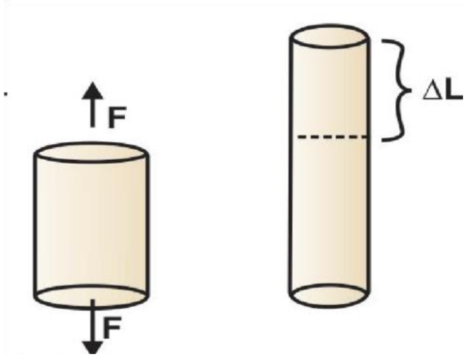
$$\text{Strain} = \frac{\text{Change in length } (\Delta L)}{\text{Original length } (Lo)} = \frac{L - Lo}{Lo} = \frac{\Delta L}{Lo}$$

L=final length

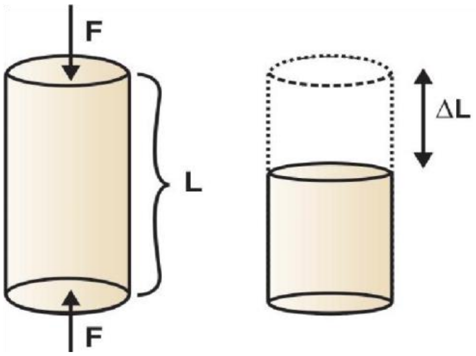
Lo= original length

Strain under tensile stress is an **elongation** in the direction of loading.

- Strain under compression is **shortening** of the body in the direction of loading.



Elongation



Shortening

- **Elongation:** The deformation that results from the application of tensile stress. An alloy with high percent of elongation can be bent or adjusted without danger of fracture.

$$elongation = \frac{increase\ in\ length}{orignal\ length} \times 100$$

Types of the strain

1. **Temporary of elastic or recoverable strain:** the material is returned to its original length after removal of the applied force.
2. **Permanent or plastic or unrecoverable strain:** the material is **not** returned to its original length after removal of the applied force. The material may remain deformed.

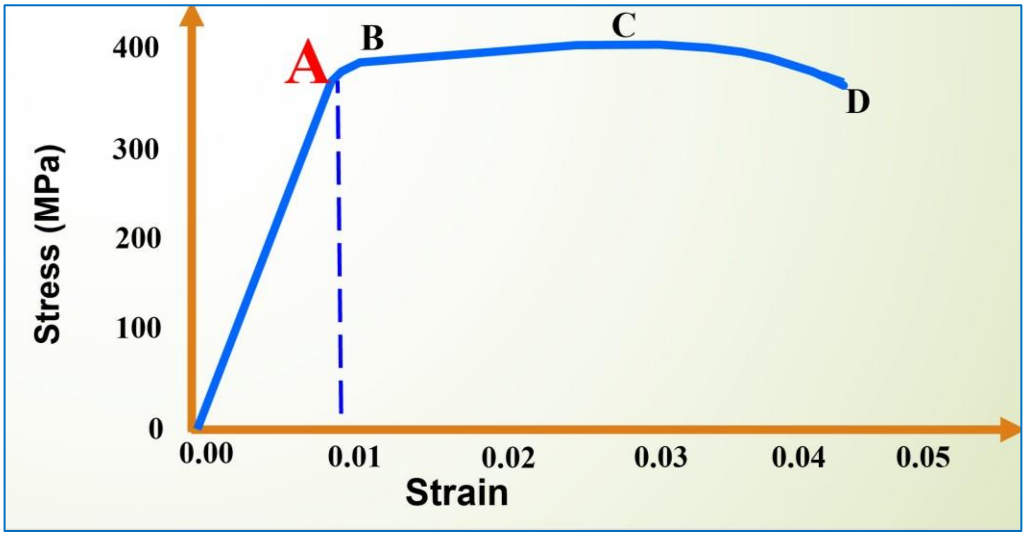
Stress —Strain Curve (S-S curve)

A convenient means of comparing the mechanical properties of materials is to apply various forces to material to determine the corresponding values of stress and strain. A plot of the corresponding values of stress and strain is referred to as “s-s curve". The relationship between stress and strain is used to study the mechanical properties of dental materials. The stress is plotted vertically and the strain is plotted horizontally. As the stress is increased the strain is increased.

Proportional limit (point A)**:** The greatest stress that a material will sustain without a deviation from the proportionality of stress to strain.

- **Elastic limit** (point A)**:** The greatest stress to which the material can be subjected such that it will return to its original shape and dimension when the stress is removed (maximum stress that a material will sustain without permanent deformation).

Elastic limit deals only with the elasticity of the material, but proportional limit deals with proportionality stress and strain. Theoretically, the values will be same.

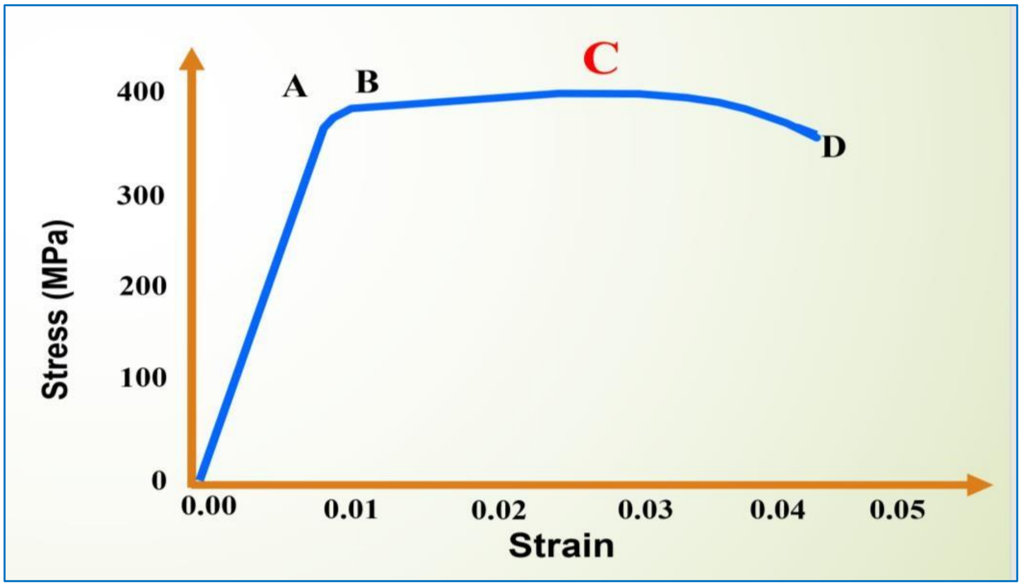


- The region of the s-s curve before the proportional limit is called the **"elastic region"** (from 0 to A).
- The region of the curve beyond this proportional limit is called as **"plastic region"** (from A to D).

If the stress is increased beyond the elastic limit or the proportional limit, the material will deform and if we remove the stress the material will **not** return to its dimension.

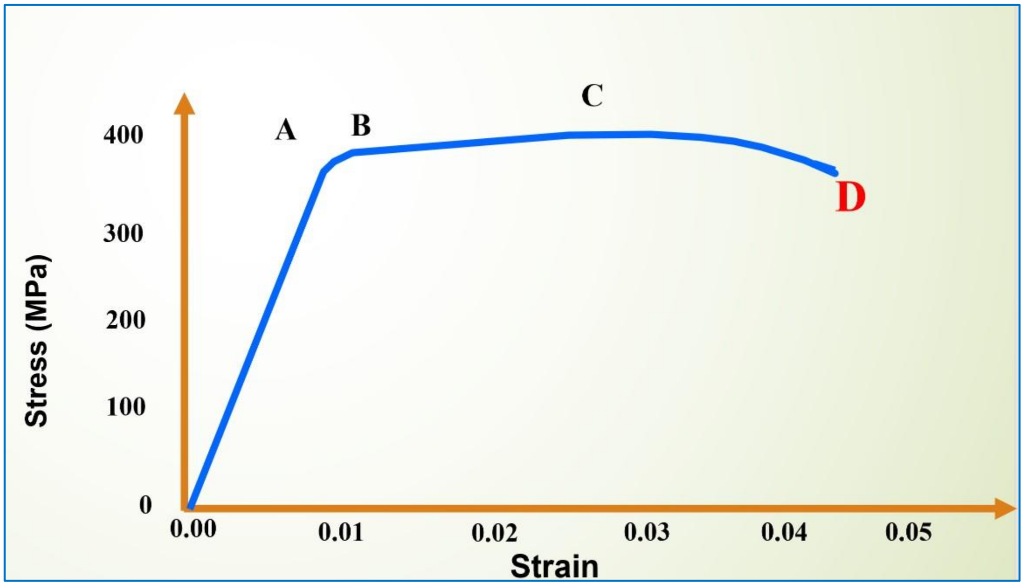
This is called **plastic deformation**. If the stress is increased more and more, the material will break.

Ultimate Strength (point **C**)**:** is the maximum stress that a material can withstand before failure. Examples: acrylic: 8000 PSI, Co/Cr:100000 PSI, stainless steel: 15000 PSI.



- **Fracture Strength** (point **D**): The stress at which a material fracture.

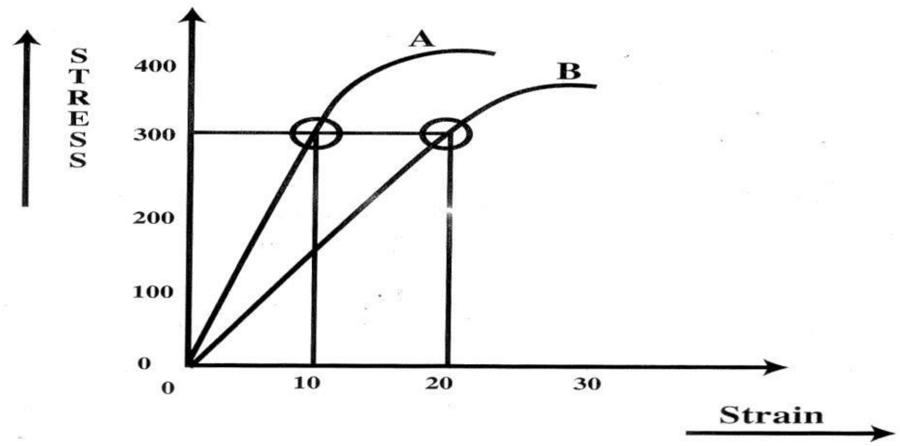
The fracture strength is not necessarily the ultimate stress at which the material will fracture.


Stress (MPa)
400
300
200
100
0
A
B
C
D
0.00
0.01
0.02
0.03
0.04
0.05
Strain

- **Modulus Of Elasticity (Elastic Modulus):** represents the stiffness or rigidity of a material within the elastic range. It is the constant of proportionality. If any stress value equal to or less than the proportional limit is divided by its corresponding strain value, a constant of proportionality will result that called the elastic modulus. It can be determined from a stress-strain curve by calculating the ratio between the stress and strain on the slope of the linear region from the following equation: **Modulus of elasticity = Stress / Strain**

Unit of the elastic modulus was same unit of stress.

Examples: enamel: 84Gpa, dentin: 17Gpa.

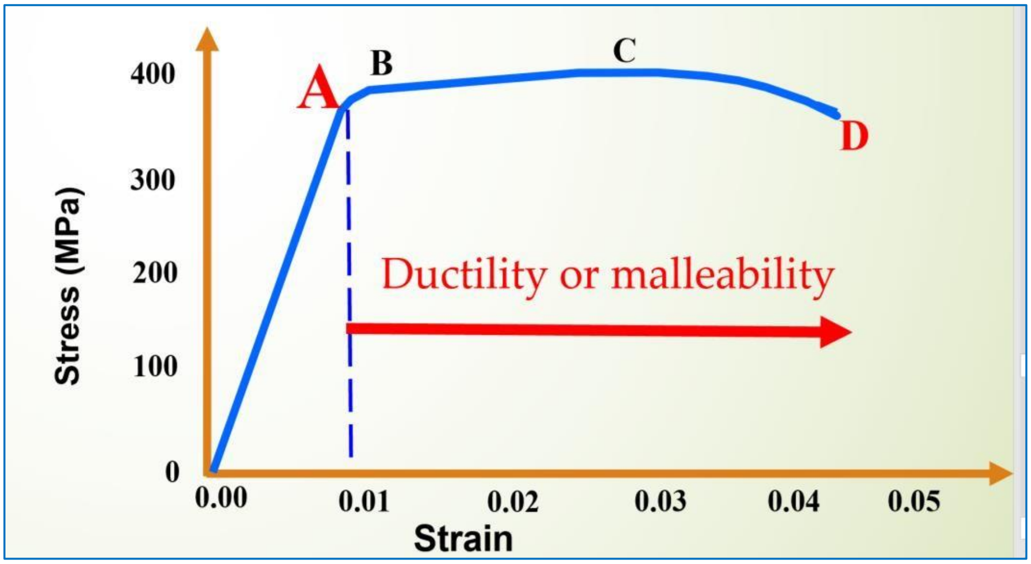


- **Flexibility:** The higher strain which occurs when the material is stressed to its proportional limit (the amount of strain up to the elastic limit), So that flexibility is the total amount of elastic strain in a material.

- **Ductility:** It is the ability of the material to withstand permanent deformation under **tensile stress** without fracture; it depends on plasticity and tensile strength. It's the ability of the material to be drawn into a fine wire. Examples: gold:

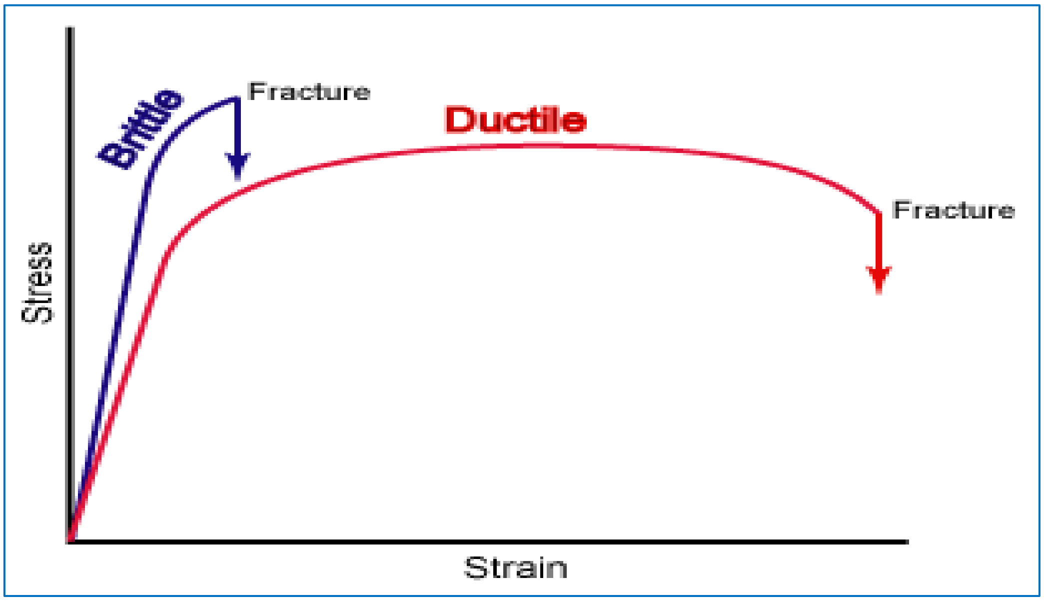
most ductile.

- **Malleability:** It is the ability of the material to withstand permanent deformation under **compressive stress** without fracture. It's the ability of the material to be drawn into a sheet. Examples: gold: most malleable.

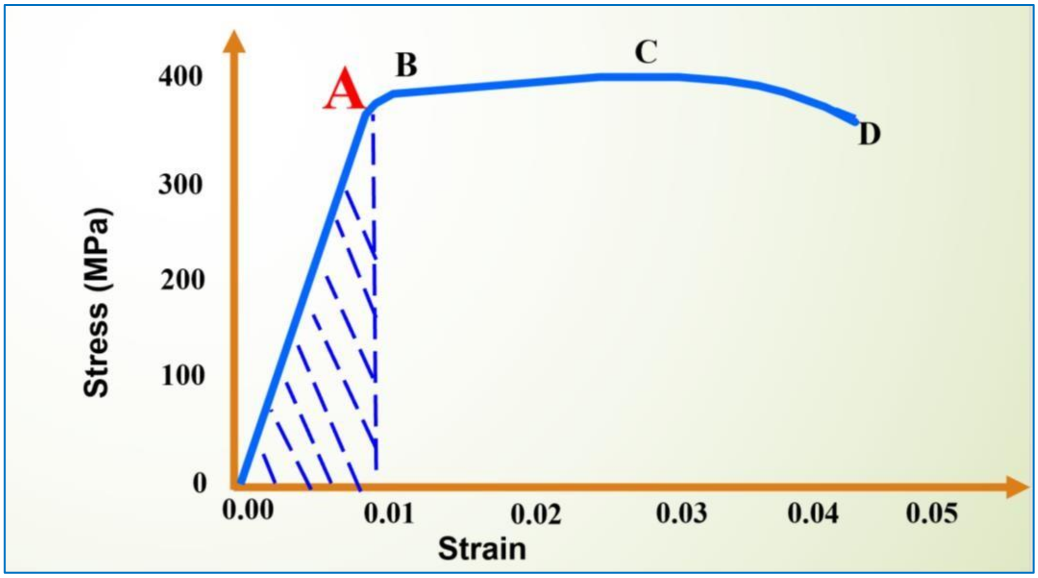


○ Elastic strain = flexibility. ○ Plastic strain = ductility or malleability.

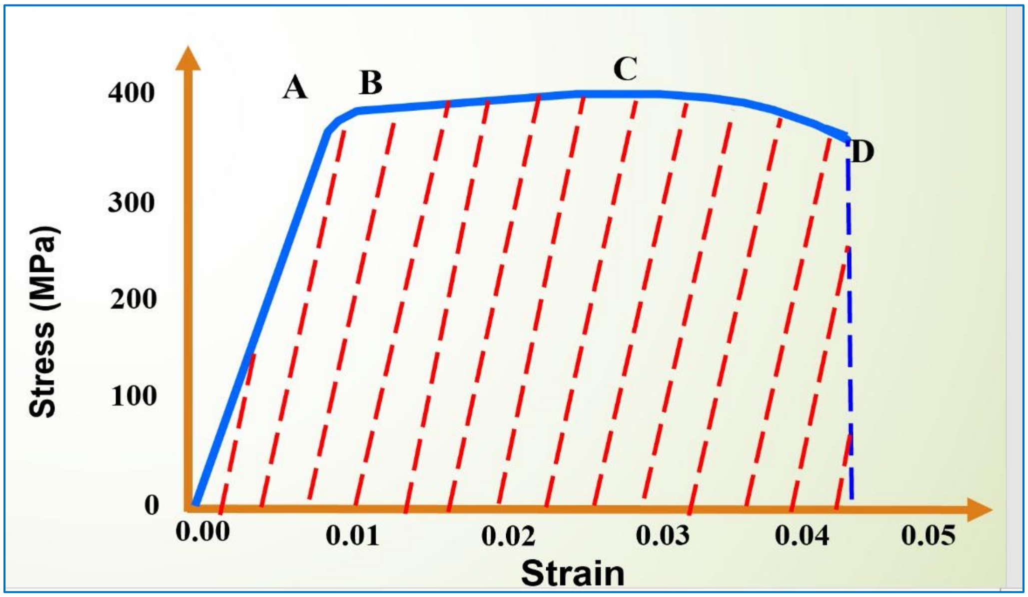
- **Brittleness:** It is the opposite of ductility; it requires lack of plasticity.



- **Resilience:** The amount of energy absorbed by a structure when it is stressed within the proportional limit . Or it is the energy needed to deform the material to its proportional limit.

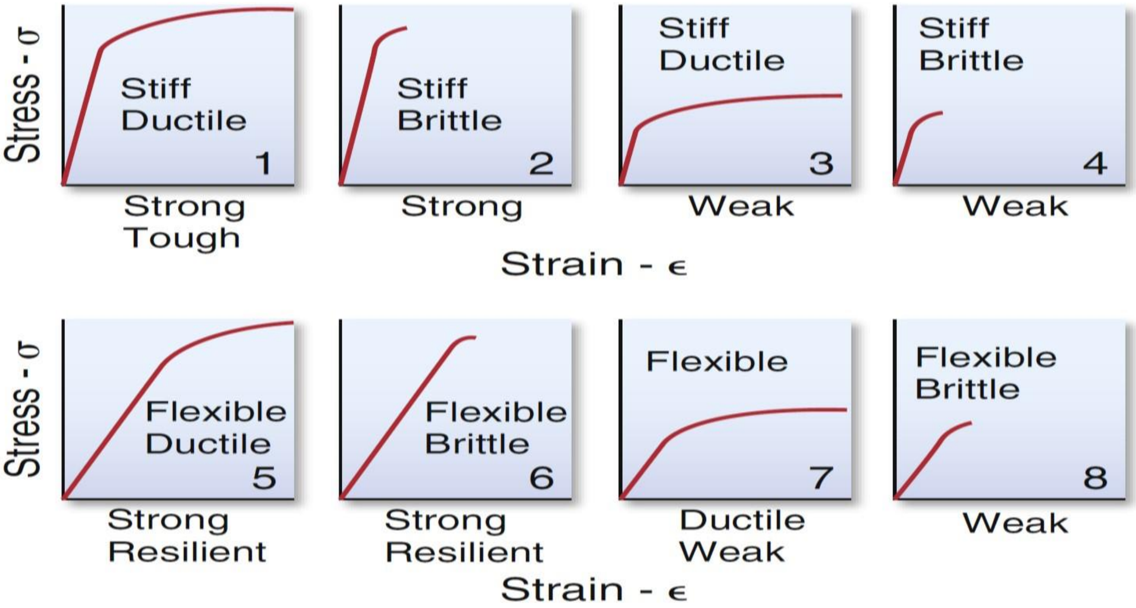


- **Toughness:** It is the total work or energy required to break the material. It's the total area under the stress-strain curve. It requires strength and plasticity .



Properties of Stress-Strain Curves

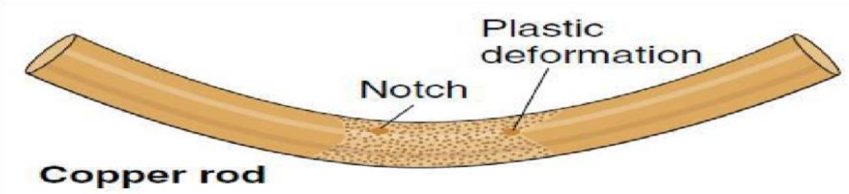
The shape of a stress-strain curve and the magnitude of stress and strain allow the classification of materials as regard to their properties e.g. weak, strong, flexible, stiff, ductile, brittle, resilient and tough.



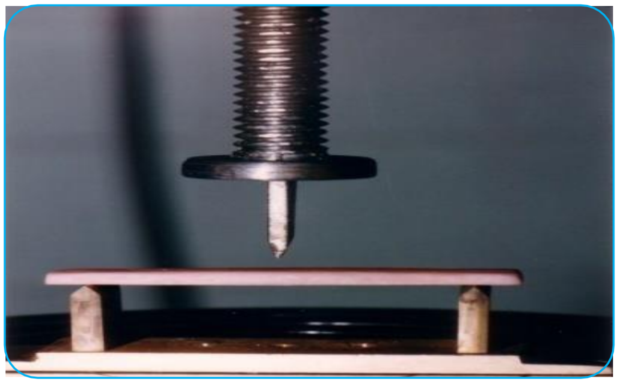
- **Strength:** is the measure of the resistance of the material to the externally applied force.

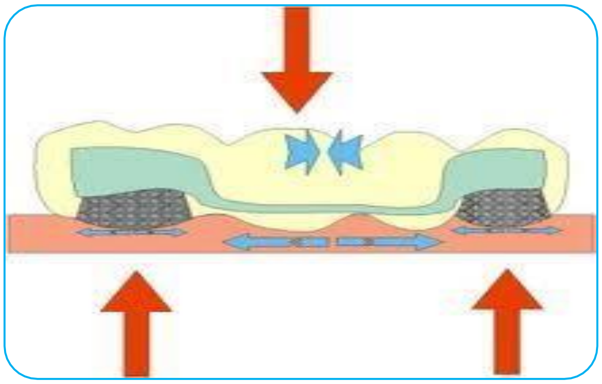
- **Fatigue:** is the fracture of a material when subjected to repeated (cyclic) small stresses below the Proportion limit.

It is when the material is constantly subjected to change in shape due to frequent application of force. The repeated application of small stress (below the Proportion limit) to an object causes tiny (very small) cracks to be generated within its structure. These tiny cracks do not cause failure immediately, with each application of stress, the cracks grow until the material breaks. Metal, ceramics can all fail by fatigue.

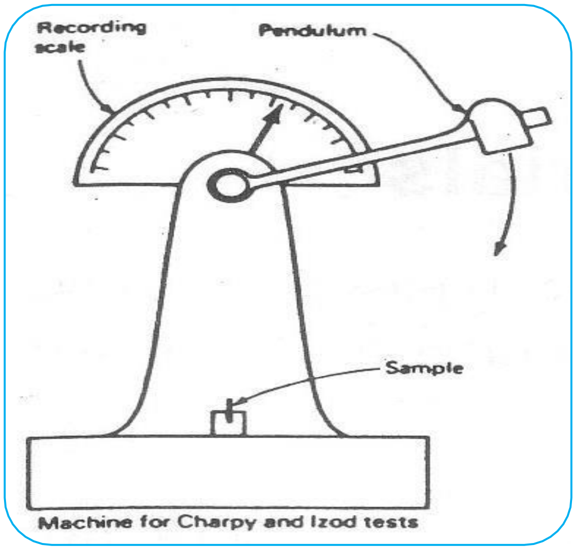


- **Transverse strength:** It is the strength of the middle of a beam, which is supported only at its ends. It is important in dental bridges. Examples: composite: 139Mpa, amalgam: 124Mpa.

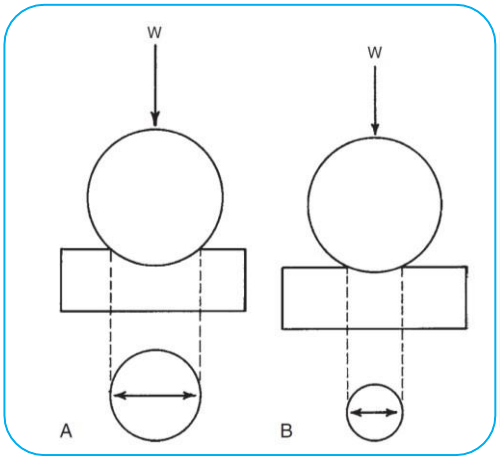


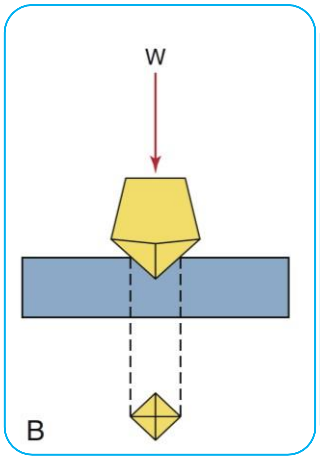


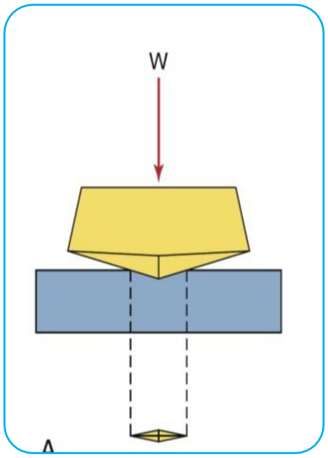
- **Impact strength:** It is the ability of the material to break on sudden impact. Low impact strength means brittle material, like dropping of the denture.



- **Hardness:** It is the resistance of the material to deformation caused by penetrating or scratching the surface. It is done either by using steal ball (Brinell or Rocwell test) or using diamond (Vickers and Knoop test). The higher the number, the harder the material. Examples: **Brienell hardness number**: acrylic: 22, dentin:65, gold: 250. **Knoop hardness number**: enamel: 343, dentin:68, Co/Cr: 391.Kg/mm^2.







Brinell's hardness test

Vickers hardness test

knoop hardness test

Lecture :3

Gypsum products

Products of gypsum are used extensively in dentistry. Gypsum is a mineral mind in various parts of the world .It is an industrial byproduct and it is used, for many centuries for construction purposes.

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Application in dentistry:

1. Impression plaster was used for impressions of the mouth.
2. Casts and dies over which dental prostheses and restorations are made.
3. Mounting to the articulater.
4. Molds for processing dental polymers.
5. Dental investments: when plaster is mixed with silica it is known as dental investment .They are used to form molds into which molten metal is cast.

Properties of ideal model material

1. Dimensional stability (no expansion or contraction during or after setting).
2. High compressive strength to withstand the force applied on it.
3. Hardness (soft material can easily scratch).
4. Reproduce the fine details.
5. Produce smooth surface.
6. Resenable setting time.
7. Compatible with impression materials.
8. Can be disinfected without damaging the surface.

Lecture :3

Types of gypsum products

Type I: impression plaster

Type II: plaster

Type III: stone

Type IV: die stone

Type V: High strength, high expansion dental stone

Manufacture of gypsum products

The process of heating gypsum to produce plaster is known as calcinations. Calcium sulfate dihydrate ($CaSO_4.2H_2O$),when heated loses part of its water of crystallization and changes to calcium sulphate hemihydrates. They are supplied as powder when mixed with water they form slurry or plaster, which set to form a rigid mass.

Plaster: when the gypsum is heated in open container to 110-120C, it gives part of its water to form plaster which is $CaSO_4.1/2\ H_2O$. The crystals of plaster are irregular in shape and porous and called Beta.

$CaSO_4.2H_2O \xrightarrow{110-120C} CaSO_4.1/2\ H_2O + \uparrow$ evaporation of water

Stone: chemically stone is the same as plaster that is $CaSO_4.1/2\ H_2O$ but it is made by heating gypsum in wet condition under super heat steam to 125 C. the crystals are dense regular and have prismatic shape they are called alpha particles.

Die stone: it is produced by boiling gypsum with 30% CaCl (calcium chloride). The crystals are also dense regular and have prismatic shape they are called alpha.

Lecture :3

Three types of powder particles in gypsum producing products (×400). **A,** Plaster of Paris (β-hemihydrate particles); crystals are spongy and irregular in shape. **B,** Dental stone (α-hemihydrate); crystals are prismatic and more regular in shape than those of plaster. **C,** Improved stone (modified α-hemihydrate); the cube-shaped particles have a reduced surface area that improves the flow of the mixture.

Setting reaction

When plaster is mixed with water it takes one and a half molecules of water, i.e it regains its water of crystallization and becomes calcium sulphate dihydrate. They are converted back to gypsum and set to hard mass. The reaction is exothermic and is the same for all gypsum products. Plaster or stone or die stone ($CaSO_4 \cdot 1/2\ H_2O$) dissolve in water.

Theories of setting: there two theories

1-Crystalline theory.

2-Gel theory.

Crystalline theory is more widely accepted. The setting reaction is explained on the basis of difference in solubility of hemihydrates and dihydydrate . Hemihydrate is four times more soluble than dihydrate.

Lecture :3

Steps of reaction:

1. It reacts with water to form gypsum ($CaSO_4 . 2 H_2O$).
2. Gypsum is less soluble in water and the solution becomes super saturated (unstable condition).
3. Gypsum crystallizes allowing more particles to dissolve and to form gypsum. This will continue until all the particles have been converted to gypsum ($CaSO_4 . 2 H_2O$). Each crystal as it forms becomes nucleus for crystallization. During this process part of gypsum form a gel which acts as a cementing medium between the crystals. Then the rigid mass is formed by the interlocking network formed by the long needle- like gypsum crystals.

$CaSO_4 . 1/2 H_2O + H_2O \longrightarrow CaSO_4 . 2H_2O$ +Heat (exothermic reaction)

The microstructure of the set gypsum:

The set material consists of an entagled aggregate of crystals, having lengths of 5-10 um. Two types of microscopic porosity can be seen the mass:

1- Microporosity caused by residual unreacted water. These voids are spherical and occur between clumps of gypsum crystals.

2- Microporosity resulting from growth of gypsum crystals .These voids are associated with setting expantion and are smaller than the first type.They appear as angular spaces between individual crystals in the aggregate**.**

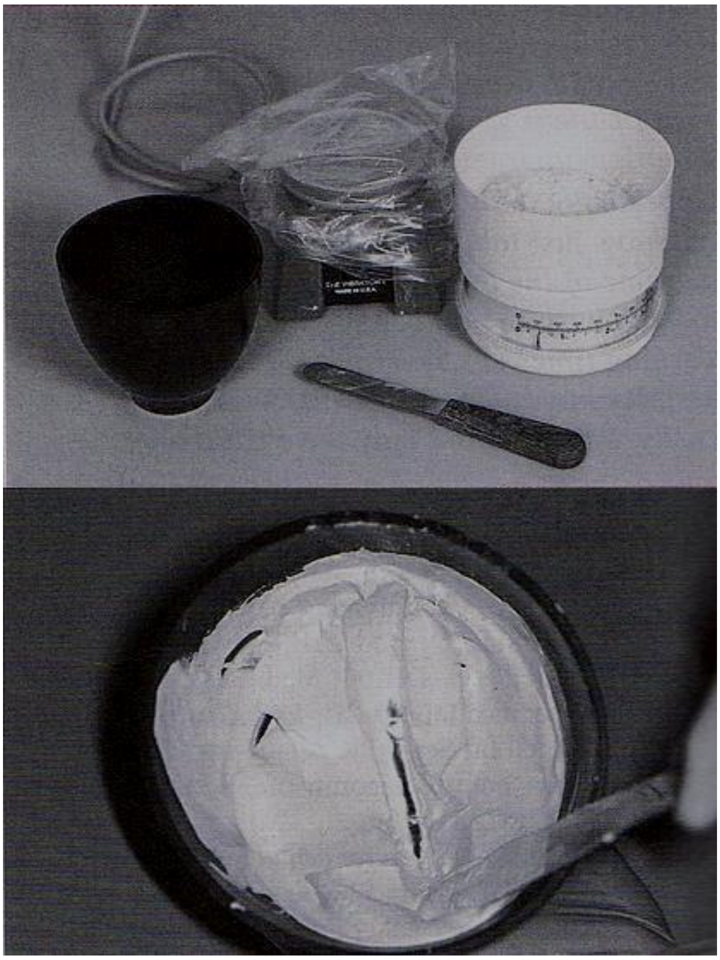
Water –powder Ratio: The W/P ratio is a very important factor in deciding physical and chemical properties of the final product. Example: The higher the w/p ratio, the longer the setting time and weaker gypsum products, there for w/p ratio should be kept as low as possible ,but at the same time sufficient to produce a workable mix.

The powder is mixed with water at certain ratio according to the type of gypsum product.W/P ratio for plaster is 0.5 that is 50ml of water for 100gm of plaster powder.

W/P ratio for stone is 0.3

W/P ratio for die stone 0.2

The difference in W/P ratio due to the difference in the bulk volume of the powders. the water is measured and put in a clean rubber bowel then the powder is stiffed on it gradually allow the powder to settle then the mix with clean spatula for 1 min. until creamy mix is obtained.



Setting time

Setting time is the time from the beginning of mixing the powder with water until the material hardens.

Mixing time: is the time from the addition the powder to the water until mixing is complete.

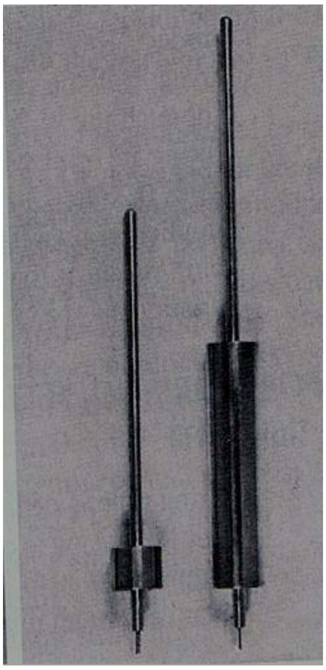
Working time: is the time available to make a workable mix.

Initial setting time: As the reaction proceeds, however, more hemihydrates crystals react to form dihydrate crystals . the viscosity of the mass is increased, and it can no longer be poured .The material becomes rigid (but not hard).It can carved but not moulded.

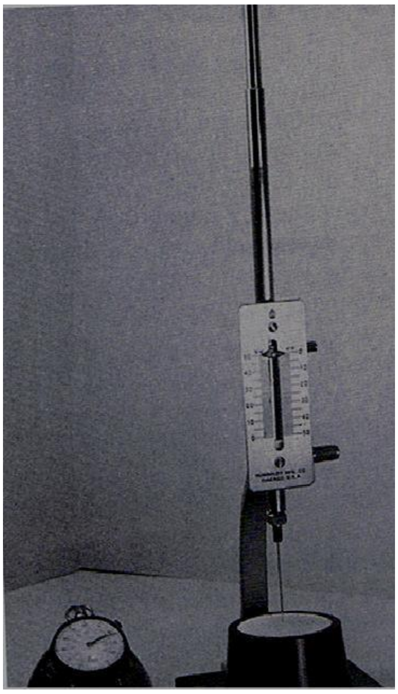
Final setting time :the time at which the material can be separated from the impression with out distortion or fracture.

Measurement of setting time:

1- **Loss of gloss method** :As reaction proceeds, the gloss disappears from the surface of the plaster mix (sometimes used to indicate initial set).
2- **Exothermic reaction**: The temperature rise of the mass may also be used for measurement of setting time,as the setting reaction is exo thermic.
3- **Penetration tests**: By using penetrometers .(Vicat needle(A), Gillmore needles(B)



(B)



(A)

Factors effecting the setting time

1. **W/P ratio:** the more water is used for mixing the fewer nuclei they will be per unit volume consequently the setting will be prolonged.
2. **Fineness:** the finer the particle size of the hemihydrate the faster the mix will harden. The rate of solution of the hemihydrate will be increased, also the gypsum nuclei will be more numerous and therefore a more rapid rate of crystallization will accur.
3. **Mixing:** the longer the plaster is mixed, the shorter is the setting time. When the powder is brought into contact with water some gypsum crystals will be formed as mixing begins more particles will be exposed to water and thus form more crystals at the same time the crystals are broken up by mixing and they are distributed through out the mixture and result in the formation more nuclei for crystallization thus the setting time is decreased.

Effect of Water/Powder Ratio (W/P) and Mixing Time on the Setting Time of Plaster of Paris

W/P Ratio	Mixing Time (min)	Setting Time (min)
0.45	0.5	5.25
0.45	1.0	3.25
0.60	1.0	7.25
0.60	2.0	4.50
0.80	1.0	10.50
0.80	2.0	7.75
0.80	3.0	5.75

4. **Temperature:** there is little change in the setting time between 0-50C but if the temp. exceeds 50C the setting time will be retarded. As the temp. approaches 100 C no setting will take place.
5. **Impurities:** if the manufactures add gypsum the setting time will be shortened because of the increase in the potential nuclei for crystallization.
6. **Retarders and acceleraters:** the addition of accelerators and retarders are the most effective and practical for control of the setting time.

Retarder: is the chemical material added to gypsum product to increase the setting time. ex. glue borax and gum Arabic. It will reduce the dissolution of hemihydrates and might deposit on the nuclei of crystallization and effectively reduce the rate of crystallization so retard the setting time.

Accelerator: is the chemical material added to gypsum product to decrease the setting time. ex. Sodium chloride and potassium sulfate in certain concentration. These salts increase the rate of dissolution of hemihydrates and thus the saturation of the solution occur more rapidly and the gypsum formation.

Dimensional changes on setting (setting expansion)

Setting expansion is of two types:

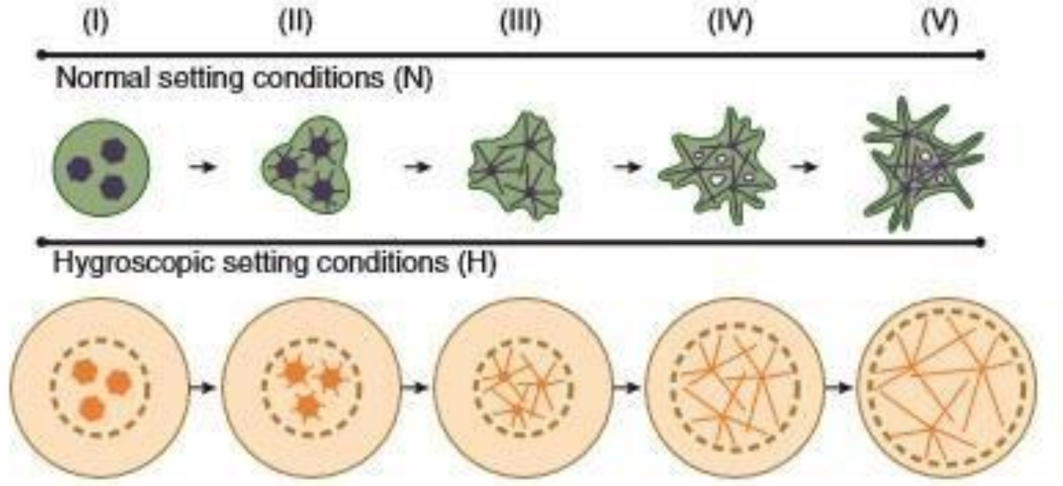
1-Normal setting expansion

2-Hygroscopic setting expansion

Regardless of the type of gypsum product an expansion of the mass can be detected during the change from the hemihydrate to the dihydrate after mixing with water. This expansion could be explained on the basis of the mechanism of crystallization. It is important in resulting of an accurate cast .

Normal setting expansion

There is an outward growth of crystals from nuclei of crystallization, as a result of the growth there is an entanglement and there is interception between the crystals. If one crystal intercepts another crystal there will be stress at the point of interception in the direction of the growth the impinging crystals. If the process is repeated by thousands of the crystals during growth, it is possible that the outward stress or thrust could produce an expansion of the mass. The final structure immediately after setting is composed of interlocking crystals between which are micro pores containing excess water. On drying the excess water is lost and the total empty space is greatly increased.



Factors affecting the setting expansion:

1. **W/P ratio:** the higher the W/P ratio the less the expansion because of fewer nuclei of crystallization per unit volume are present than the thicker mixes and since it can be assumed that the space between the nuclei will be greater in such case, it allows that there will be less growth interaction of the dehydrate crystals with less outward thrust resulting.
2. **Addition of chemicals (accelerators and retarders):** both will reduce the setting expansion. The reduction of the expansion is due to that the initial rate of crystallization is so rapid that subsequent growth is resisted with the accelerators. For the retarders the crystalline form may be changed and the crystals may become thick and short so the thrusting between the crystals is reduced so the expansion is reduced.

Effect of Water/Powder Ratio (W/P) and Mixing Time on Setting Expansion of Plaster of Paris W/P Ratio Mixing Time (min) Setting Expansion (%)

0.45 0.6 0.41
0.45 1.0 0.51 0.60
1.0 0.29 0.60 2.0
0.41 0.80 1.0 0.24

Hygroscopic expansion:

If the setting process is allowed to occur under water the setting expansion may be more than double in magnitude this is called hygroscopic expansion. This increased expansion is due to the additional growth of the crystals permitted and not to any difference in the chemical reaction.

Strength:

The strength of gypsum products is generally expressed in term of compressive strength although tensile strength is also considered.

Factors effecting the Strength:

1. W/P ratio
2. Mixing
3. Drying
4. Chemicals
5. Porosity

Effect of the Water/Powder (W/P) Ratio and Mixing Time on the Strength of Plaster of Paris W/P Ratio Mixing Time (min) Compressive Strength (MPa) 0.45
0.5 23.4 0.45 1.0
26.2 0.60 1.0 17.9
0.60 2.0 13.8 0.80
1.0 11.0

The strength of the gypsum increases rapidly as the material hardens after the initial setting time. The excess water presents in the set mass affect the strength. Therefore, there is wet strength and dry strength. The wet strength is when there is excess left in the mass. The dry strength is that when the excess water has been dried in air or in oven in warm temperature. The dry strength may be two times greater than the wet strength.

Drying period	compressive strength kg / cm2
2h	98
8h	110
24h	238

Effect of Drying on the Strength of Plaster of Paris

Drying Period (h)	Compressive Strength (MPa)	Weight Loss (%)
2	9.6	5.1
4	11.7	11.9
8	11.7	17.4
16	13.0	– –
24	23.3	18.0
48	23.3	18.0
72	23.3	– –

The effect of drying is to remove the excess water between the crystals. The excess water reduce the cohesion between the crystals themselves 40% of the strength is due to the cohesive forces between the crystals in addition to the strength which can be attributed to the interlocking of the crystals during growth.

The set plaster or stone is porous. The greater w/p ratio the greater the porosity and the fewer the crystals.

Mixing time also effect the strength. Increase mixing increase the strength but over mixing will reduce strength because it will break up the crystals which are formed and will result in less crystal interlocking.

The addition of accelerators and retarders lowers both the wet and dry strength. This is due to the reduction in the inter crystalline cohesion

.

Tensile strength

Gypsum is a brittle material ,thus weaker in tension than in compression .The one hour tensile strength of model plaster is approximately 2.3 MPs. When dry ,the tensile strength of dental stone is twice than that of plaster. It is significant in fracture of teeth in the cast while separating from the impression ,tensile strength is a better guide to fracture resistance.

Hardness and abrasion resistance

This is related to the compressive strength. The higher the compressive strength of the hardening mass, the higher the surface hardness .After the final setting occurs, the surface hardness remains constant until most of the excess water is dried, after which it increases.

Storage

Plaster and stone absorbs moisture which causes gradual deterioration. Hydration begins on the surface of the hemihydrates particles forming fine coat of gypsum and this will act as effective nuclei for crystallization and this shortens the setting time, to avoid deterioration plaster and stone powders should be stored in airtight waterproof containers in a dry region of the laboratory.

Material	compressive strength	Rockwell hardness	expansion	w/p
Plaster	98-140	15	0.3%	0.5

Stone	**210-280**	**66**	**0.2%**	**0.3**
		Die stone	**350 kg/cm2**	

Care of the cast

If the gypsum cast soaked in water it must be placed in a water bath in which plaster debris remains constantly on the bottom of the container to provide a saturated solution of calcium sulfate at all times. This is known as "slurry water ''.If the cast is washed in ordinary water, surface layer may dissolve ,so the slurry water is used to preserve surface details .All gypsum casts must be handled carefully, as any departure from the expected accuracy may result in a poorly fitting appliance.

Infection control

If the impression is not disinfected it is wise to disinfect the stone cast.

1-Immersion cast in a disinfection solution.

2-Addition of disinfectant into the stone.

TESTS FOR SETTING TIME: Vicat test

Needle with a weighted plunger rod is supported and held just in contact with the mix. soon after gloss is lost the plunger is released.

The time elapsed until the needle no longer penetrates to the bottom of the mix is known as the setting time.

Gillmore test

Measured by using the heavier Gillmore needle.

The elapsed time at with this needle leaves a barely perceptible mark on the surface is called the final setting time .

Differences between dental plaster and dental stone:

Manufacture	Dry calcination	Wet calcination
Particle size and shape	Larger,irregular,and porous	Smaller,regular and dense
W/P ratio	0.5	0.3
porosity	More porous	Less porous

Mechanical properties	Less strength and hardness	More strength and hardness
Application	Diagnostic casts	Master cast

Impression materials

Impression materials: The impression is a negative replica of the dental structure {used to make replicas (models or casts) of teeth and other oral tissues accurately}. In dentistry, we take impressions of teeth and their supporting structures (gingiva, alveolar bone or residual ridge, hard and soft palate, and frenum). The replicas are used to construct restorations and other appliances.

Sometimes impression materials are used to duplicate a cast or model that has been formed when more than one positive reproduction is required (Such impression materials are referred to as ***duplicating materials***).

The impression is a ***negative*** reproduction, whereas the replica (model or cast) is a ***positive*** reproduction.

Not all impression materials are compatible with all model materials. Because impression materials are used for many purposes, a wide variety of products are available to make impressions of oral tissues.

Some are use simply to produce a physical model of the oral tissues for study, called a ***study model*****.** Study models are used in diagnosis and treatment planning. Other uses require very exact replication of the size and shape of a preparation for the construction of a restoration or appliance, these replicas are called ***casts*****.** A replica of a single tooth is called a ***die*****.**

Impression materials are generally transferred to the patient's mouth in an ***impression tray*** (stock or special tray). The tray is required because these materials are initially quite fluid and require support. Once positioned in the patient's mouth, the material undergoes setting either by physical or chemical process. After setting, the impression is removed from the patient's mouth. This negative replica is converted into a positive replica by pouring it with cast or die materials.

Ideal Requirements of impression materials

Many materials have been used for taking impressions. But ***none*** of them is perfect. Each material is superior to other in some respects. So useful to enumerate the properties, which should be possessed by an ideal impression material.

1. Biological Requirements

- **Biocompatibility:** An ideal impression material should be non-toxic and nonirritant.

- **Disinfection:** It should be possible to decontaminate an impression to render it safe for further handling without affecting the accuracy or fine details.

2. Chemical Requirements

- **Inertness:** An ideal impression material should be: ○ Chemically inert in the mouth.
  - ○ Not dissolve or disintegrate in oral conditions.

- **Moisture compatibility:** An ideal impression material should be ***hydrophilic*** for better reproduction of details. Some are hydrophobic they require dry field of operation, otherwise they may be repelled by moisture in a critical area of the impression. This normally results in the formation of 'blow hole' in the impression. For hydrophilic materials no special precautions are necessary.

- **Compatible with cast or die materials:** Impression material should be compatible with model and die materials.

3. Rheological Requirements

Rheology is the science that explains the fluid or flow characteristics of materials.

• **Fluidity and viscosity:** Viscosity is the resistance offered by a fluid to flow. Impression material should have good flow property (***less viscosity***) before setting so that all finer details can be recorded and less flow property (***high viscosity***) after setting so that impression can be withdrawn from the mouth without any distortion. Based on viscosity, impression materials can be classified into mucostatic and mucocompressive materials.

- ○ **Mucostatic:** These are initially fluid and compress soft tissues to a lesser extent. They are more fluid so all the finer details can be recorded.
- ○ **Mucocompressive:** Initially more viscous, exert more pressure and displaces soft tissues to a greater extent. They are used to record primary or preliminary impression.

Mixing time, working time, and setting time

- Mixing time: Mixing time is the time from the start of mixing until a proper smooth creamy homogeneous mix is obtained.
- Working time: Working time is the time from the start of mixing until the material is no longer suitable for recording an impression. It is normally characterized by the time taken for the viscosity to increase by a given amount above that of freshly mixed material.

- Setting time: The setting time of an impression material may be defined in terms of the required time to complete the setting reaction or it is the time required to reach a certain degree of rigidity hardness or elasticity.

Ideally, an impression material should have longer working time and shorter setting time.

4. Mechanical Requirements

- **Accuracy:** Must be capable of reproducing all the finer details with greatest accuracy. Material that expands during setting, results in under sized die or cast and vice-versa.

- **Elasticity:** Impression materials should be sufficiently elastic (after setting) on removing from the mouth so that under cuts can be recorded without distortion or it should have large recovery and less permanent deformation.

- **Tear strength:** On removing the elastic impression material from undercut areas they are often put under a considerable tensile stress. So, the material should have sufficient tear strength to withstand such stresses without tearing.

- **Flexibility:** Should be sufficiently flexible to permit easy removal over undercuts.

- **Adhesion or retention:** Should be adhesive or remain attached to the tray during recording the impression. Partial detachment may cause distortion of the impression and will lead to ill-fitting of restorations. Retention can be achieved by using tray adhesive (for elastomers) or by using a perforated tray (for hydrocolloids).

- **Dimensional stability:** Should have no dimensional changes in or out of the mouth at all temperatures and humidity or should have perfect dimensional stability such that impression would retain its original accuracy indefinitely. Majority of material accuracy is best maintained by pouring gypsum cast soon after recording the impression.

5. Thermal Requirements

- **Coefficient of thermal expansion:** Must be zero or minimum to minimize dimensional change on cooling or heating. On being withdrawing from the mouth at 37°C to room temperature of 27°C, the impression undergoes approximately 10°C cooling. This results in thermal contraction.

- **Thermal conductivity:** Should be a **good conductor** of heat so that it can soften or harden uniformly which minimizes distortion. But practically, all impression materials are poor conductors of heat. Hence, they do not set simultaneously.

- **Softening temperature:** In case of thermoplastic material, the range of softening temperature should not be greater than 50–55°C. Otherwise on placing it in patient's mouth it may burn the oral tissues. It should set or harden at or near mouth temperature.

6. Esthetic Requirements

- **Color contrast:** Suitable colors are used to distinguish materials of different viscosities. Two paste materials must be supplied in contrasting colors so that it is easy to see when mixing has been completed satisfactorily, there are no streaks of individual color left in the mix.

7. Minor Requirements

- **Acceptable taste and odor:** Materials should have good taste and odor.

- **Shelf-life:** Materials should have longer shelf-life so that the unused material can be stored.

- **Economic:** Be relatively inexpensive, simple, and easy to use.

- **Availability:** Be easily available.

- **Ease of manipulation:** Should be easy to proportionate, mix and clean. Should not require any elaborate equipment for manipulation.

- **Sterilization:** Should be easy to sterilize if used for more than once.

- **Reusability:** To be used again and again without any loss of useful properties of material. Should permit multiple die pours. Be capable of having additions made and insertion in the mouth without distortion. This will allow minor corrections to be made without having to take an entirely new impression.

None of the available materials satisfies all the above requirements hence suitable material could be selected according.

Classification of Impression Materials

I. According to their mechanical properties–

1. Elastic
    - Hydrocolloids (Aqueous elastomeric impression materials)
        - a) Reversible – Agar-Agar
        - b) Irreversible – Alginate
    - Elastomers (Nonaqueous elastomeric impression materials)
        - a) Polysulfides
        - b) Polysilicones (Addition and condensation silicones)
        - c) Polyether (Chemically activated and light activated)
2. Inelastic or rigid
    - Impression compound
    - Impression waxes
    - Impression plaster
    - ZOE impression paste

II. According to their chemical name–

1. Impression compound
2. Impression waxes
3. Impression plaster
4. ZOE impression paste
5. Hydrocolloids
    - Reversible – Agar-Agar
    - Irreversible – Alginate

6. Elastomers
    - Polysulfides
    - Polysilicones (Addition and Condensation) silicones)
    - Polyether (Chemically activated and light activated)

III. According to the mouth condition–

1. Edentulous arches—All impression materials can be used.
2. Dentulous arches—Hydrocolloids and elastomers.

IV. According to the force exerted on the soft tissues–

1. Mucostatic
    - Impression plaster
    - Agar-Agar
    - Alginate
    - Light body elastomer
    - Impression waxes
    - ZOE impression paste.
2. Mucocompressive
    - Impression compound
    - Putty elastomer

V. According to the nature of hardening or setting–

1. By a physical change
    - Impression compound
    - Impression waxes
    - Agar-Agar
2. By a chemical change
    - ZOE impression paste
    - Alginate
    - Impression plaster
    - Elastomers

VI. According to their clinical applications–

1. Preliminary impression of edentulous arches—impression compound
2. Secondary or corrective wash impression
    - ZOE impression paste
    - Impression plaster
    - Alginate
    - Light body elastomer.
3. Cavity preparations of inlays and onlays
    - Elastomers.
4. Partial denture impressions – Hydrocolloids and elastomers.
5. Special uses
    - Syringe material, e.g. Light body elastomer.
    - Tray material, e.g. Tray compound, heavy body and putty body elastomers.

VII. According to their viscosity–

1. High viscosity—Impression compound and putty body elastomer
2. Medium viscosity—Regular body elastomers
3. Low viscosity—Impression plaster
   ZOE impression paste
   Hydrocolloids
   Light body elastomers

VIII. According to their dispensing system–

1. Cakes, cylinders, sticks, and cones – Impression compound and impression wax
2. Powder – Impression plaster and alginate
3. Two-paste system – ZOE impression paste, poly- sulfide, and polysilicone.
4. Three-paste system – Chemically activated polyether.
5. Single paste system – Light activated polyether.

					Used for the Construction of			
Type of Impression Material	Elasticity	Setting Process	reaction	Hydrophilicity	Full Denture	Partial Denture	Crown, or bridge	Study Models

impression Plaster	Rigid	Chemical	Irreversible	Hydrophilic	Final	No	No	No
impression Wax	Rigid	Physical	reversible	Hydrophobic	Primary	No	No	No
impression compound	Rigid	Physical	reversible	Hydrophobic	Primary	No	No	No
ZOE	Rigid	Chemical	Irreversible	Hydrophobic	Final	No	No	No
Reversible hydrocolloid (agar)	Elastic	Physical	reversible	Hydrophilic	Not used	Yes	Yes	No
Irreversible hydrocolloid (alginate)	Elastic	Chemical	Irreversible	Hydrophilic	Primary	Yes	No	Yes
Polysulfide	Elastic	Chemical	Irreversible	Hydrophobic	Final	Yes	Yes	No
Condensation silicone	Elastic	Chemical	Irreversible	Hydrophobic	Final	Yes	Yes	No
Addition silicone	Elastic	Chemical	Irreversible	Hydrophobic Hydrophilic	Final	Yes	Yes	No
Polyether	Elastic	Chemical	Irreversible	Hydrophilic	Final	Yes	Yes	No

Rigid impression material (inelastic)

1. Impression plaster.
2. Impression waxes.
3. Impression compound.
4. Zinc oxide eugenol impression material.

1. Impression Plaster

is described as a rigid, muco-static, Hydrophilic, irreversible impression material which set by chemical reaction.

The impression plaster has the same setting reaction and properties as the gypsum products that used for models and casts. The major difference is that impression plaster has flavors added and it sets more quickly to minimize the time that the material is in the mouth. When impression plaster sets, it is hard and brittle.

Presentation: present as powder mixed with water (w/p =0.6).

Composition:

1. ***Calcium sulphate β- hemihydrates ([CaSO4]1/2 H2O):*** Main reactive ingredient.
2. ***Accelerator Potassium sulphate (K2SO4):*** 4% to reduce expansion and to accelerate the setting reaction.
3. ***Borax:*** 0.04% retarder to reduce the rate of setting (counteract the accelerator).
4. ***Alizarin:*** 0.04% color pigment (to distinguish impression plaster and model plaster).
5. ***Starch:*** To render them soluble in water and permits rapid separation of the cast from the impression material (to help disintegration of impression on separation from the plaster/stone model). After cast hardens, the impression and the cast are put in hot water, the starch softens and swells in hot water and the impression disintegrate, making it easy to separate the cast from the impression.
6. **Flavoring agent:** To offset the bad taste of plaster.

Accelerator, borax, and alizarin dissolved in water and form a solution, called as ***antiexpansion*** solution.

Due to the addition of starch in plaster it is also called as ***soluble plaster***.

Uses:

1. Making final impression of the edentulous arches (constructing complete dentures).
2. It is primarily used when excess saliva produced by the patient (accessory palatine gland).

Manipulation:

The impression plaster should be mixed with water or an anti-expansion solution in the ratio of 100 g to 60 ml. The water is placed into rubber bowel and the powder is added, mixing them till the creamy mixture is formed then thin layer of mix impression plaster is placed in the special tray (thickness of 1-1.5 mm) that filled and seated into the patient mouth where it is allowed to set.

After the material has set it is removed from the mouth, washed free of saliva and then the surface of the impression is painted with a separating medium **(e.g. alcoholic solutions of varnish),** Failure to do so results in bonding the cast to the surface of the impression material.

Properties:

1. Setting time 4 ± 1 minutes.
2. The mixed impression plaster has very low viscosity which makes it possible to take impressions with a minimum force on the soft tissues (mucostatic technique).
3. It is hydrophilic (patient complain very dry sensation after having impression because of water absorption nature of this material) and thus adapts readily to soft tissue recording their surface details with great accuracy.
4. The material is best used in a special try made of acrylic (1-1.5 mm spacer).
5. Very good dimensional stability (dimensional change during setting about 0.06%).
6. A separating medium must be used between the cast and the impression plaster (rinse the impression plaster with solution of **sodium alginate or soap with water** before pouring the cast or using **alcoholic solutions of varnish)**.
7. unpleasant taste
8. Rarely used these days as they are brittle and fractures very easily.
9. Setting expansion: Maximum 0.15%

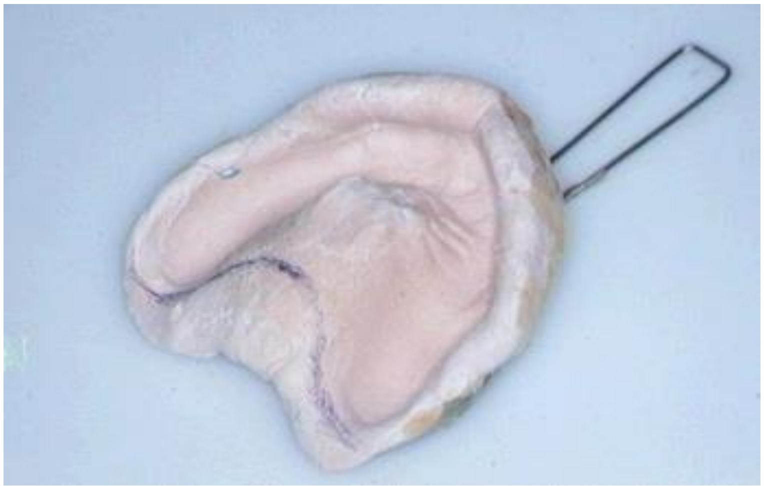
Advantages:

1. It reproduces good surface detail.
2. Rate of set is under the control of operator (4 ± 1 minutes).
3. Good Dimensional stability and accuracy if used with antiexpansion solution.
4. Compatible with all materials commonly used for making casts.
5. Stable on storage over long time if it is kept in a sealed condition.
6. Relatively inexpensive and easy to manipulate.
7. Easy to manipulated.

• Drawbacks

1. Set impression is brittle and may fracture when removed from undercut areas.
2. Bad taste and rough feel.

3. Water absorbing nature of these materials often causes patients to complain about a very dry sensation after impression has been recorded.
4. Exothermic heat is disliked by many patients.
5. Requires a separator before pouring the cast in the lab, this may cause surface inaccuracy.
6. Able to flow to pharynges.
7. Cannot be used in undercut ridge (rigid impression material).



Impression materials

2. Impression waxes:

It is described as a rigid, muco-static, Hydrophobic, reversible impression material which set by physical change on applying heat, it softens when heated and on cooling it hardens (thermoplastic material).

These materials consist from a mixture of low melting paraffin and bees waxes in ratio about 3:1. Waxes have high and larger coefficient of thermal expansion. So, it will distort when removed from undercut area. Impression waxes are rarely used to record complete impression.

The impression wax was probably the first impression material used in dentistry. It is cheap, clean, and easy to use. A multitude of waxes are used in dentistry. Some are hard, much like paraffin wax. Others are soft and moldable at room temperature, similar to Play-Doh. It's used in ranging consistencies of soft, medium, hard and extra hard.

Wax used for taking impressions is solid at mouth temperature but is moldable at a temperature that is tolerated by oral tissues. Wax comes in many forms (sticks, strips, tubes, etc.). Wax can be thought of as a low-molecular-weight polymer. It is a thermoplastic material. It is also very weak, and the procedure technique must compensate for wax's poor mechanical properties. Wax is often used to extend tray borders or adapt a stock tray when taking impressions.

Types of impression wax

1. **Corrective Impression Wax:** Corrective impression wax is used as a wax over an original impression to register the detail of soft tissues in a functional state.

2. **Bite-Registration Wax:** Bite-registration wax is used for accurate articulation of certain models of opposing arches. the addition silicone and polyether materials have replaced waxes for bite registration.

3. Impression compound

Impression compound is one of the oldest impression materials. It is classified as inelastic (rigid), hydrophobic, mucocompressive and reversible thermoplastic (it softens when heated and on cooling it hardens) impression material, which sets by physical change. It is mainly used for making impression of edentulous mouth (primary impression).

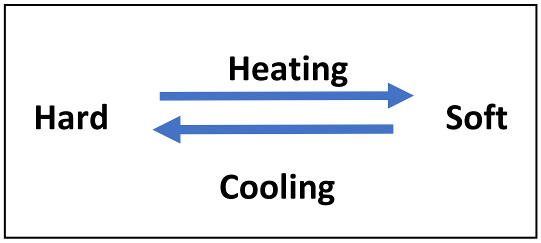
Alternative Names

- Dental compound
- Model compound
- Model plastic

Dispensing: present as cakes, sticks and cones.

Setting Reaction

Impression compound is a thermoplastic material, i.e. they soften when heated and harden when cooled, without occurrence of a chemical reaction.



Composition: in general impression compound is a mixture of:

Component	Wt%	Functions
Natural or synthetic resin - **Copal resin** - **rosin**	40	• Provides thermoplasticity. • Gives the qualities of flow and cohesion.
Waxes (Bee's wax, carnauba wax, paraffin wax)	7	• Provides thermoplasticity. • Characterizes the softening temperature and produces smooth surface.
Stearic acid, shellac, and gutta-percha	3	Acts as a plasticizer, which improves plasticity and workability (added to overcome brittleness).
Diatomaceous earth, French chalk, or talc	50	Acts as filler. • Increases strength. • Reduces flow at mouth temperature. • Reduces COTE (minimize shrinkage due to thermal contraction) • Overcome tackiness.
Coloring agent	Trace	Gives characteristic color

Types of impression compound: it classified into ***two*** types:

1. **Type I – Low fusing material,** e.g.
   - ***Impression compound:*** It is supplied in the form of sheets or cakes about 4 – 5 mm thick. It is used to take primary impression for edentulous ridges using stock tray, softened using water bath (55-60) C (found to be ideal for kneaded with fingers in order to obtain plasticity throughout the impression compound). Storage in water should not be so long to prevent leaching of

important constituents such as stearic acid over heating make the compound sticky and difficult to handle.

- ***Stick compound:*** Supplied in stick form and available in different colors such as green, black, gray, brown and white. The composition of stick compound is almost similar to that of impression compound with more plasticizers. Used for border molding of special trays during fitting of the special tray, It is softened by waving over a gas flame and kneaded (dry kneading). The compound should not allow boiling, otherwise the plasticizer is volatilized.

2. **Type II – High fusing material, e.g.**
   - ***Tray compound:*** They are usually supplied in the shape of tray, which may be black or white in color. it is stiffer and has less flow than regular impression compound and require higher temperature at which they soften (70° C). They are used to prepare custom made preliminary impression (special tray) that will later hold a second impression material, which will record final impression (secondary impression). Tray compounds lack strength and dimensional stability; hence they have been replaced to a large extent by trays made from self-cure acrylic resins.

The different in fusing temperature between type I and type II reflects a difference in the % of thermoplastic compound of each (waxes and resins).

Uses:

1. For making a primary impression for edentulous ridges**.**
2. Border molding of special tray**.**
3. constructing impression tray.

Manipulation

Softening: Impression compound can be softened by using a *thermostatically controlled water bath or open flame.* The compound is softened by immersing in the water bath at 55°C–60°C. Since the material has low thermal conductivity it must be immersed in the water bath for sufficient time to ensure complete softening.

Kneading: The compound is removed from the water bath and kneaded with the fingers in order to obtain uniform plasticity throughout the mass.

Loading: The compound is kneaded to suitable shape and placed in an impression tray (nonperforated stock tray).

Tempering: The outer surface (tissue side) of the compound can be waved over the flame or spray cold water on metal tray just before it is inserted into the mouth.

Making impression: The compound along with tray is then inserted into the mouth. The impression is retained until it cools to mouth temperature at that might take several minutes due to its lack of conductivity.

Removal: After it has completely hardened the impression is removed from the mouth and washed, dried and trimmed.

Casting: A mix of stone/plaster and water poured into the impression and allow it to set. The safest method for removal of the impression is to immerse it in warm water until the compound softens sufficiently to allow it to be separated easily from the cast.

Properties:

1. It is ***muco-compressive*** and it is the most viscous impression materials used (high viscous), therefore the reproduction of surface details is not very good. However, the reproduction can be improved by reheating the surface of the impression material after tacking the first impression and then reseated it in the patient's mouth even this is not good as the other impression materials.
2. ***Rigid*** once cooled not used to record undercuts (used for primary impression only).
3. ***Poor dimensional stability***, the material has high value of coefficient of thermal expansion (COTE) and undergoes considerable shrinkage on removal from mouth. also, because pressure is applied during formation of an impression (muco-compressive) residual stress exists in cool impression the gradual relief of internal stresses may cause distortion of impression (the impression should be poured as soon as possible within 1 hour).
4. ***Low thermal conductivity*** so it needs thorough heating and a water bath is preferred to soften the impression compound. We should wait for certain time in order that all the material is softened and when we introduce it into the patient mouth, we should wait enough time till the outer and the inner portion of the compound is hard before we can remove it from patient mouth.
5. It is a ***physical reaction*** not chemical reaction so the impression compound can be reused a number of times (for the same patient) in case of error;

inaccurate portions can be remade without having to remake the entire impression.

Advantages:

1. Compatible with model material and not need separating medium before pouring the plaster.
2. Can be reused a number of times, added and readopted.
3. Not need special tray.
4. Can be used for compressing soft tissues.
5. Can be used for any technique requiring a close peripheral seal.
6. Can be used in combination with other materials .
7. Relatively cheap.

Disadvantages:

1. Rigid once set and distorts easily so cannot be used in undercut area.
2. muco-compressive material (cause displacement to the soft tissue).
3. Does not reproduce fine surface detail (High viscous, low flow).
4. Can only give an accurate impression with a long and difficult technique. The handling of dental impression material is very technique sensitive. (if it is not prepared properly not softening enough, volatiles can be lost on heating or low molecular weight ingredient can be lost during long immersion in a water bath)
5. High coefficient of thermal expansion leading to dimensional changes.
6. Must be poured within one hour.
7. As it can be resoftened and reused it tends to become unhygienic since it cannot be sterilized without affecting its properties.
8. Its thermal properties are not ideal – large COTE and low thermal conductivity.

4. Zinc oxide eugenol (ZOE) impression paste:

It's described as a rigid, mucostatic impression material, irreversible impression material which set by chemical reaction. The combination of zinc oxide and eugenol is widely used in dentistry.

General uses of zinc oxide –eugenol

1. Final impression for edentulous arches.
2. Occlusal bite registration.
3. Temporary filling.
4. Surgical pack in periodontal surgical procedure.
5. Root canal filling.
6. Cementation and insulating medium.
7. Temporary relining material for dentures.

Types of Zinc oxide eugenol impression material

1. Type I hard.
2. Type II soft.

The difference between two types related to their hardness after setting.

Dispensing

Usually supplied as two pastes in collapsible metal tubes.

- Base paste (white color).
- Reactor or accelerator or catalyst paste (red in color).

Composition

Base paste		
Component	**Wt%**	**Functions**
Zinc oxide	87	• Reactive ingredient, which takes part in setting reaction.
Fixed vegetable oil or mineral oil	13	• Paste former. • Plasticizer – provides smoother and more fluid mix. • Retarder—retards the rate of reaction and increases the setting time. • Aids in masking the action of eugenol as an irritant
Water	Trace	• (Initiator)

Reactor paste		
Component	**Wt%**	**Functions**

Oil of cloves or eugenol	**12**	• Reactive ingredient, which takes part in setting reaction. • Oil of cloves contain 70–80% of eugenol it reduces the burning sensation in the soft tissues of the mouth when the mixed paste is first placed in contact with them
Gum or polymerized rosin	**50**	• Facilitates the speed of reaction and produces a smoother homogeneous mix. • Gives body and coherence to the mixed material.
Filler (silica type)	**20**	• Used to form a paste with eugenol. • Increases strength of the mixed paste.
Lanolin	**3**	• Plasticizer
Resinous balsam (Canada balsam)	**10**	• To increase flow and improve mixing qualities.
Accelerator solution ($CaCl_2$)	**5**	• Accelerates the setting reaction.
Color pigments	**Trace**	• To distinguish from other paste. • Enables thorough mixing to be achieved as indicated by a homogeneous color, free of streaks in the mixed material.

Chemical reaction

Zinc oxide +eugenol $\xrightarrow{H_2O}$ Zinc eugenolate +zinc oxide (unreacted)

The set material consists of a mixture of amorphous zinc eugenolate matrix which holds unreacted zinc oxide particles together.

Manipulation

The proper proportion of two pastes is generally obtained by squeezing two ropes of pastes of the same length onto the mixing slab (glass slab or oil impervious paper pad mixed). A flexible stainless steel spatula is used for mixing. The reactor paste is first collected and applied over the base paste. It is now mixed with broad strokes in a sweeping motion until a uniform homogeneous color mix is obtained. Mixing time is approximately 1 minute.

the mix is collected and spread over the special tray and is placed in the mouth. The surface of the special tray should be dry since the material will not adhere to wet surfaces. The mix will stick to the dried skin and instruments. So it is advisable to coat the patient's lips with petroleum jelly. This enables excess impression paste to be wiped away.

It is held firmly in position (in the patient mouth) until the material has uniformly hardened. Once the material has set, the impression is removed from the mouth. If the impression is not properly recorded another increment of a fresh mix can be placed over that and better impression can be obtained.

The impression is well-rinsed under running tap water for removal of any saliva or debris; disinfected and dried.

Cast is made by pouring a mix of dental stone and water into the impression and allowing it to harden. No separating medium is required when making the cast.

The impression can be separated from the cast by immersing in hot water at 60°C for 5–6 min.

Properties

1. These materials are nontoxic but those containing eugenol can be irritant giving stinging or burning sensation to the patient and leaving a persistent taste, which some patients may regard as unpleasant. So non eugenol paste was developed where the zinc oxide is reacted with a carboxylic acid.
2. Relatively low viscosity (mucostatic) allows all the finer details to be recorded in the impression.
3. Rigid inelastic once set and should not be used for partially edentulous arches, or undercut areas it's fractured when removed from undercut area.
4. It requires a fit special tray (without space) for impression making.
5. It has adequate adhesion to acrylic tray (no need adhesive material).
6. It has advantages of being dimensionally stable, a negligible shrinkage (less than
   0. 1 %) may occur during hardening.

7. It does not stick to the cast material (No separating medium is needed before the stone model is poured).
8. The paste tends to adhere to skin, so the skin around the lips and the cheek should be protected with petroleum jelly (Vaseline) to make the cleaning process much easier.
9. It can be checked in mouth repeatedly without deformation.
10. Setting time should not be too long as it causes inconvenience to the patient and should not be too short so that the material cannot be manipulated.
    - Type I: Initial setting time = (3-6) Min., final setting time = 10 Min.
    - Type II: Initial setting time = (3-6) Min., final setting time = 15 Min.

Factors affecting setting time		
Factors	*To decrease setting time*	*To increase setting time*
Temperature	Increase (Glass slab and spatula can be heated)	Decrease (Glass slab and spatula can be cooled)
Humidity	*Increase*	*Decrease*
Altering the ZnO paste to eugenol (not recommended)	More eugenol paste (reactor)	More ZnO paste (Base)
Mixing time (within limits)	Faster and longer	Slower and shorter
Chemical Modifiers	Add accelerators (CaCl2, MgCl2, and water)	Add retarders (inert oils and waxes

Advantage

1. Good adapted to the soft tissues without causing displacement of the soft tissue (mucostatic), so it has good reproduction of surface detail.
2. Good dimensional stability.
3. Well Adhere to the dried surfaces of special tray (no need for adhesive).
4. Inexpensive.
5. Not need separating medium before the stone model is poured. 6. It can be checked in the mouth repeatedly without deformation.
7. Minor defects can be corrected locally.
8. It has enough working time to complete border molding.
9. Easy to manipulate .

Disadvantage

1. Messiness
2. Inelastic and may fracture if undercuts present (It cannot be used when undercut exists).
3. Variable setting time due to temperature and humidity.
4. Some patients find the eugenol content unpleasant (may cause burning sensation or irritation to the oral tissues).
5. Requires special tray for making impression.
6. The skin around the lips and the cheek should be protected with petroleum jelly (Vaseline).
7. Instruments are difficult to clean

Elastic impression material

It is the ideal impression materials for reproduction of tooth form and relationship, which can be with-drawn from the undercut area & return to its original form without distortion.

Types of Elastic impression material

1. Hydrocolloids Impression Materials.
2. Elastomeric Impression Materials.

1. Hydrocolloid Impression Materials (Aqueous Impression Material)

Hydrocolloid impression materials used in dentistry are based on colloidal suspensions of polysaccharides in water.

The colloid exists in two forms:

- In Sol form: (fluid, low viscosity & random arrangement of polysaccharide chain.)
- In Gel form: (high viscosity may develop elastic property when the long polysaccharide chains become aligned.).

Gelation: Is the conversion of sol to gel & development of elastic properties through alignment of polysaccharide chains.

Hydrocolloids are classified into two types based on mode of gelation:

1. **Reversible:** called reversible because their physical state can be reversed; this make them reusable (by lowering the temperature). e.g. Agar impression material.
2. **Irreversible:** once these set is usually permanents, so known as irreversible Set by chemical reaction e.g. alginate impression material.

1. Agar (reversible hydrocolloid):

It is an organic hydrophilic colloid (strong affinity to water) polysaccharide extracted from certain type of seaweed. Presently, it has been largely replaced by alginate & rubber impression material (The preparation of agar to clinical use requires careful control & expensive apparatus).When agar heated they go into sol (liquefy) & on cooling they return to gel state.

$$\text{Gel} \xrightarrow{\text{heating}} \text{sol} \xrightarrow{\text{cooling}} \text{gel}$$

- **Uses:**

1. Widely used at present time for cast duplication (during fabrication of cast removable partial denture).
2. Full mouth impression without deep undercut.
3. Crown & bridge impression.
4. As tissue conditioner.

- **Presentation:**

1. Tray impression material: Gel form in collapsible tube for loading the tray. Each tube has enough material to fill a full arch, water-cooled tray is needed.
2. Syringe material: Packaged in plastic or glass cartridges that fit a syringe or in preloaded syringe. The syringe material has different color & it is more fluid than tray material and easy ejected from the syringe and inject around the teeth.
3. In bulk container (for duplication)

- **Composition:**

1. Agar (12% for tray material; 6-8 % for the syringe type). (Colloid).

The agar content is reduced in the syringe type, so it is more fluid at the time of injection than the tray material at the time of insertion.

2. Borax (to improve strength of the gel).
3. Potassium sulphate (accelerator for model material, to ensure proper setting of gypsum cast against agar).
4. Alkyl benzoate (preservative; antifungal agent).
5. Wax, hard (as a filler, effects strength, viscosity & rigidity).
6. Dyes & flavoring (trace), (to improve appearance and taste).
7. Water (85%), (as dispersion medium).

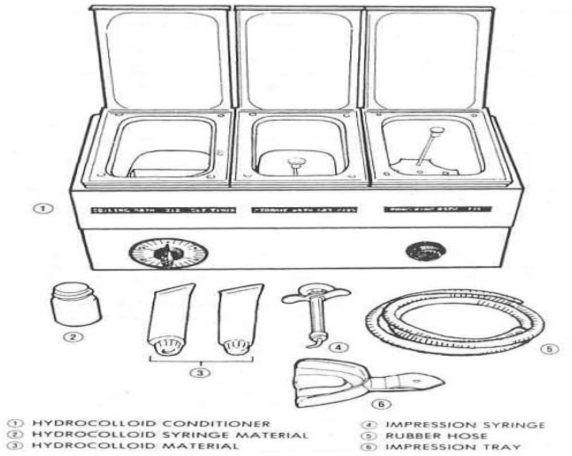
- **Gelation of Agar:**

The physical change from the sol to gel, & vice versa is induced by a temperature change. The gel must be heated to a higher temperature (liquefaction temperature 100C) to return it to the sol condition. It transverses to gel at 37C to 50C (gelation temperature). If the gelation temperature is too high the heat from sol may injure the oral tissue.

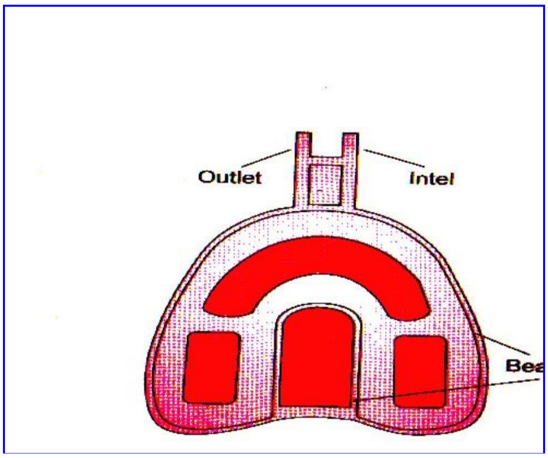
- **Manipulation**

Agar hydrocolloid requires special equipments:

A. Hydrocolloid conditioner.
B. Water cooled rim lock tray.



A



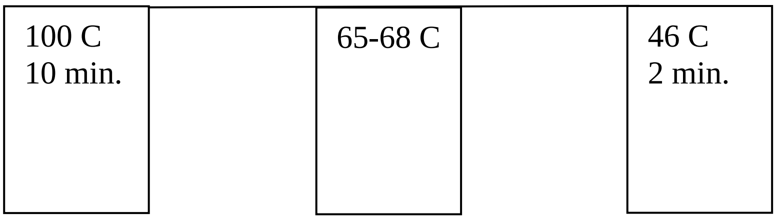
B

A. Hydrocolloid conditioner.

Agar is normally conditioned prior to use, using specially designed conditioning bath (temperature controlled water bath), the conditioning bath consists of 3 compartments each containing water hold at different temperature which are:

1. **Boiling section or liquefaction section:** The tube of gel is first placed in the 100C bath for 10 minutes; this rapidly converts the gel to sol & the content of the tube become viscous. The sol should be homogenous and free of lumps. Every time the material is reliquefied three minutes should be added. The tube is then transferred to
2. **Storage section:** 65-68C temperature is ideal for storing the agar in the sol condition till needed.
3. **Tempering section:** 46 C for about 2 minutes with the material loaded to the tray. This is done to reduce the temperature so that it can be tolerated by the

sensitive oral tissue and also make the material viscous. If the material is maintained at this stage for long time it slowly begins to revert to the gel form.



Liquefaction section storage section tempering section

B. Water cooled rim lock tray:

Metal tray with a narrow- bore metal tube attached to outer surface. The tube is connected to a cold water supply (18 to 21) C & the circulating water reduces the temperature of the tray.

The tray containing tempered material is removed from the bath, the outer surface of the agar is scraped off, then the water supply is connected to the tray and the tray is positioned in the mouth, water is circulated at until gelation occur. Rapid cooling is not recommended (e.g. ice cold water) as it can induce distortion.

Properties of agar:

1. It is hydrocolloid mucostatic impression.
2. It is cheap and is used in some laboratories for making duplicate models (reused up to 4 times).
3. Very accurate reproduction of surface details because in sol form the agar is sufficiently fluid.
4. In gel form it is sufficiently flexible to be easily removed.
5. Agar is highly accurate at the time of removal from the mouth. Storage of agar impression is to be avoided; the cast should be poured immediately.

Storage in air results in dehydration (shrinkage) and storage in water results in swelling of impression; it absorbs water in process known as **imbibitions.** The gel may also loose water by exuding of fluid in process known as **syneresis** (during syneresis small droplet are formed on the surface of hydrocolloid and the process occur irrespected of the humidity of the surrounding atmosphere), If storage is unavoidable, it should be limited to one hour in 100% relative humidity by wrapping it in wet towel (which result in least dimensional changes)

6. Poor mechanical properties & low tear resistance but it is better than alginate.
7. It is important to remove the tray by rapid snap action that enhanced elastic recovery & decrease permanent deformation.
8. It is necessary to have reasonable thickness of impression material to limit the extent of deformation arising on removal from the undercut.
9. Working time range between 7-15 minutes & setting time about 5 minutes. Both can be controlled by regulating the flow of water through the cooling tube.

- **Advantages:**

1. Accurate impression material if the material is properly handled.
2. It has good elastic properties and reproduces most undercut areas correctly.
3. It well tolerated by the patient, and hydrophilic.
4. Cheap, no mixing required.
5. Can be reused when used as duplicating material (not commended when used as impression material).

- **Disadvantages:**

1. Need special equipment.
2. Water cooled tray is very bulky.
3. Low tear resistance.
4. Difficult to disinfect.
5. If it is not pour as soon as possible led to low dimensional stability due to imbibitions and syneresis.

2. Alginate (irreversible hydrocolloid)

One of the most widely used dental impression material. It is more popular than agar for dental impression because it is simpler to use. It changes from sol to gel by chemical reaction.

- **Uses:**

1. An elastic impression material for partial & complete dental prosthesis.
2. To prepare study cast, not recommended for making impression of cavity preparation or crown and bridge (It doesn't give a high degree of accuracy).
3. For surgical splint.
4. For duplicating models.

- **Presentation:**

It's supplied as power mixed with water, A powder is packed in:

1. Bulk containers.
2. Preweighed packets for single impression.

A plastic scoop is supplied for dispensing the bulk powder & plastic cylinder for measuring the water.

- **Types:**

Depending on the setting alginate can be classified into:
*Regular set.
*Fast set.

- **Composition:**

1. Potassium alginate (hydrogel former, dissolve in water & react with calcium ions.)
2. Calcium sulphate dehydrate (provide calcium ions to react with potassium alginate to form an insoluble gel.)
3. Fillers (to control the consistency of the mixed alginate)
4. Potassium sulphate, (counteract the inhibiting effect of the alginate on the setting gypsum, giving high quality surface of the die.)

5. Sodium sulphate (control working time, serve as retarder react with calcium sulphate)
6. Quaternary ammonium (to provide self disinfection).
7. Organic glycol small amounts (coat the powder particles to minimize dust during dispending, to make the powder dustless).
8. Pigments (to produce color).
9. Reactive indicator, in some product (give color change when setting is complete).

- **Setting reaction**

When alginate powder is mixed with water a chemical reaction occurs , The calcium alginate precipitated into fibrous network with water .

$$\text{Sol (powder +water)} \xrightarrow{\text{chemical reaction}} \text{gel}$$

$$\text{Sodium alginate + calcium sulphate dihydrate} \xrightarrow{\text{+water}} \text{sodium sulphate + calcium alginate(gel)}$$

- **manipulation:**

Powder should be mixed thoroughly before use (to eliminate the segregation of component that may occur during storage).

The proper w/p (Usually one measure water with two level scoops of powder), with use of clean rubber bowel and clean spatula. The mixing is started with a stirring motion to wet the powder with water once the powder moistened rapid spatulation by swiping against the side of the bowel (when mixed powder with water a vigorous figure 8 motion is best with the mix swiped against the side of the rubber bowel with intermitted rotations of spatula to press out air bubbles). The mix should be smooth, creamy with minimum of voids and doesn’t drip off the spatula when it is raised from the bowel.

After the impression set it must be removed suddenly with a snap removal. Then the impression is rinsed thoroughly with cold water to remove saliva & excess water is removed by shaking the impression and disinfected. The cast should be poured as soon as possible to prevent dimensional changes (within 15 minutes after making the impression).

- **Properties:**

1. Alginate has well controlled working time but vary from product to product. There are regular setting & fast setting. Setting time for regular set 2-4.5 minutes, setting time for fast set 1-2 minutes. Lengthening the setting time is better accomplished by reducing the temperature of the water used with mix (18-24C).
2. The clinical setting time can be detected by the loss of tackiness of the surface.
3. The material should be left in place inside the patient mouth for 2-3 minutes after the tackiness has gone from the surface. Since the tear strength and resistance to permanent deformation increase significantly during this period).
4. It is mucostatic & hydrophilic.
5. Detail reproduction is lower when compared with agar or elastomers (they are not recommended for crown and bridge; they are popular for partial denture work.
6. Set alginate is susceptible to evaporation, syneresis & imbibitions (like agar). So the cast should be poured immediately, if storage is unavoidable keeping in humid atmosphere of 100% relative humidity result in least dimensional changes (not more 1 hour).
7. Like agar snap removal technique need to be employed in order to get an elastic response. The permanent deformation is somewhat higher than agar.
8. Has lower tear strength than agar & have poor mechanical properties.
9. Set gypsum model should not remain in contact with alginate impression for a periods of hours because contact of slightly soluble calcium sulphate dehydrate with alginate gel containing a great deal of water is detrimental to surface quality of model
10. Thin layer of alginate is weak; the thickness of alginate between the tray & tissue should be at least 3mm.
11. Alginate doesn’t adhere well to the tray therefore perforated one or rim lock should be used.
12. Mixing time for fast set 45 seconds while for regular set 60 seconds. Over mixing result in reduction in final strength as the gel fibril is destroyed also reduction in working time. While under mixing lead to inadequate wetting & reduced strength also the mix being grainy & poor recording of detail.

13. The dentist can control the setting time by altering the temperature of the water used for mixing (colder the water the longer the setting time, warmer the water the shorter the setting time.)
14. It has pleasant taste, smell and low cost.
15. It is highly elastic but less when compare to agar

- **Advantages:**
  1. It is easy to mixed and manipulation with minimal requirement of equipment.
  2. It has suitable setting time.
  3. Flexibility of the set impression.
  4. Accuracy if properly handled, low cost.
  5. Hydrophilic, comfortable to patient.

- **Disadvantages:**

1. It can't be corrected.
2. Poor dimensional stability (due to syneresis and imbibition's). Poor tear strength.
3. Lower detail reproduction.
4. High permanent deformation.
5. Difficult to disinfect.

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Types of Elastic impression material

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$$\text{Gel} \xrightarrow{\text{heating}} \text{sol} \xrightarrow{\text{cooling}} \text{gel}$$

- **Uses:**

1. Widely used at present time for cast duplication (during fabrication of cast removable partial denture).
2. Full mouth impression without deep undercut.
3. Crown & bridge impression.
4. As tissue conditioner.

- **Presentation:**

1. Tray impression material: Gel form in collapsible tube for loading the tray. Each tube has enough material to fill a full arch, water-cooled tray is needed.
2. Syringe material: Packaged in plastic or glass cartridges that fit a syringe or in preloaded syringe. The syringe material has different color & it is more fluid than tray material and easy ejected from the syringe and inject around the teeth.
3. In bulk container (for duplication)

- **Composition:**

1. Agar (12% for tray material; 6-8 % for the syringe type). (Colloid).

The agar content is reduced in the syringe type, so it is more fluid at the time of injection than the tray material at the time of insertion.

2. Borax (to improve strength of the gel).
3. Potassium sulphate (accelerator for model material, to ensure proper setting of gypsum cast against agar).
4. Alkyl benzoate (preservative; antifungal agent).
5. Wax, hard (as a filler, effects strength, viscosity & rigidity).
6. Dyes & flavoring (trace), (to improve appearance and taste).
7. Water (85%), (as dispersion medium).

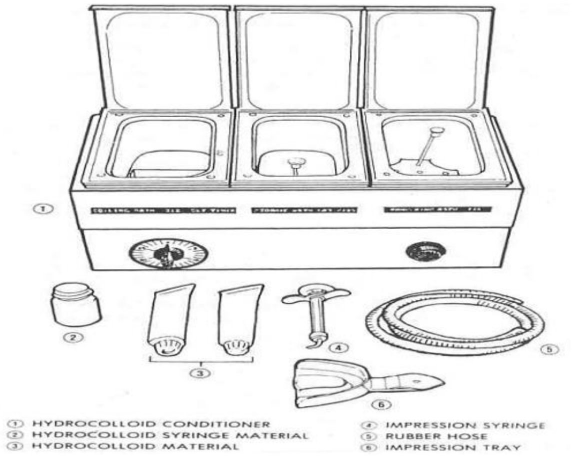
- **Gelation of Agar:**

The physical change from the sol to gel, & vice versa is induced by a temperature change. The gel must be heated to a higher temperature (liquefaction temperature 100C) to return it to the sol condition. It transverses to gel at 37C to 50C (gelation temperature). If the gelation temperature is too high the heat from sol may injure the oral tissue.

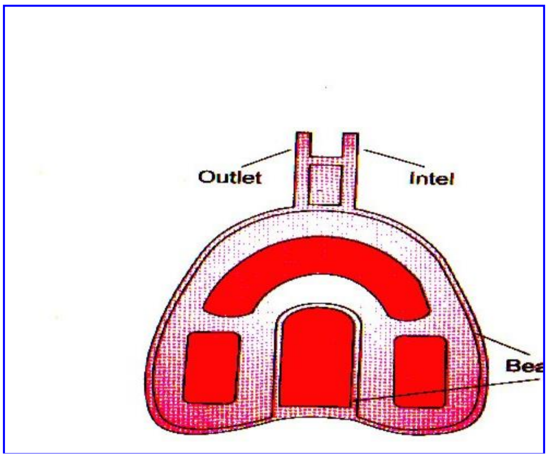
- ## Manipulation

Agar hydrocolloid requires special equipments:

A. Hydrocolloid conditioner.
B. Water cooled rim lock tray.



A



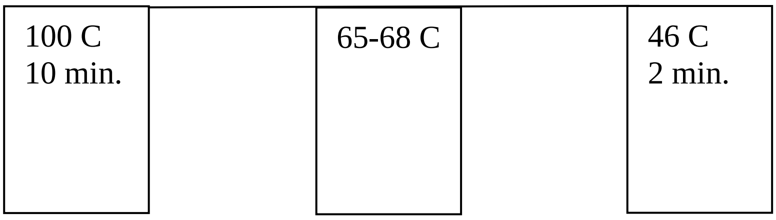
B

A. Hydrocolloid conditioner.

Agar is normally conditioned prior to use, using specially designed conditioning bath (temperature controlled water bath), the conditioning bath consists of 3 compartments each containing water hold at different temperature which are:

1. **Boiling section or liquefaction section:** The tube of gel is first placed in the 100C bath for 10 minutes; this rapidly converts the gel to sol & the content of the tube become viscous. The sol should be homogenous and free of lumps. Every time the material is reliquefied three minutes should be added. The tube is then transferred to
2. **Storage section:** 65-68C temperature is ideal for storing the agar in the sol condition till needed.
3. **Tempering section:** 46 C for about 2 minutes with the material loaded to the tray. This is done to reduce the temperature so that it can be tolerated by the

sensitive oral tissue and also make the material viscous. If the material is maintained at this stage for long time it slowly begins to revert to the gel form.



Liquefaction section storage section tempering section

B. Water cooled rim lock tray:

Metal tray with a narrow- bore metal tube attached to outer surface. The tube is connected to a cold water supply (18 to 21) C & the circulating water reduces the temperature of the tray.

The tray containing tempered material is removed from the bath, the outer surface of the agar is scraped off, then the water supply is connected to the tray and the tray is positioned in the mouth, water is circulated at until gelation occur. Rapid cooling is not recommended (e.g. ice cold water) as it can induce distortion.

Properties of agar:

1. It is hydrocolloid mucostatic impression.
2. It is cheap and is used in some laboratories for making duplicate models (reused up to 4 times).
3. Very accurate reproduction of surface details because in sol form the agar is sufficiently fluid.
4. In gel form it is sufficiently flexible to be easily removed.
5. Agar is highly accurate at the time of removal from the mouth. Storage of agar impression is to be avoided; the cast should be poured immediately.

Storage in air results in dehydration (shrinkage) and storage in water results in swelling of impression; it absorbs water in process known as **imbibitions.** The gel may also loose water by exuding of fluid in process known as **syneresis** (during syneresis small droplet are formed on the surface of hydrocolloid and the process occur irrespected of the humidity of the surrounding atmosphere), If storage is unavoidable, it should be limited to one hour in 100% relative humidity by wrapping it in wet towel (which result in least dimensional changes)

6. Poor mechanical properties & low tear resistance but it is better than alginate.
7. It is important to remove the tray by rapid snap action that enhanced elastic recovery & decrease permanent deformation.
8. It is necessary to have reasonable thickness of impression material to limit the extent of deformation arising on removal from the undercut.
9. Working time range between 7-15 minutes & setting time about 5 minutes. Both can be controlled by regulating the flow of water through the cooling tube.

- **Advantages:**

1. Accurate impression material if the material is properly handled.
2. It has good elastic properties and reproduces most undercut areas correctly.
3. It well tolerated by the patient, and hydrophilic.
4. Cheap, no mixing required.
5. Can be reused when used as duplicating material (not commended when used as impression material).

- **Disadvantages:**

1. Need special equipment.
2. Water cooled tray is very bulky.
3. Low tear resistance.
4. Difficult to disinfect.
5. If it is not pour as soon as possible led to low dimensional stability due to imbibitions and syneresis.

2. Alginate (irreversible hydrocolloid)

One of the most widely used dental impression material. It is more popular than agar for dental impression because it is simpler to use. It changes from sol to gel by chemical reaction.

- **Uses:**

1. An elastic impression material for partial & complete dental prosthesis.
2. To prepare study cast, not recommended for making impression of cavity preparation or crown and bridge (It doesn't give a high degree of accuracy).
3. For surgical splint.
4. For duplicating models.

- **Presentation:**

It's supplied as power mixed with water, A powder is packed in:

1. Bulk containers.
2. Preweighed packets for single impression.

A plastic scoop is supplied for dispensing the bulk powder & plastic cylinder for measuring the water.

- **Types:**

Depending on the setting alginate can be classified into:
*Regular set.
*Fast set.

- **Composition:**

1. Potassium alginate (hydrogel former, dissolve in water & react with calcium ions.)
2. Calcium sulphate dehydrate (provide calcium ions to react with potassium alginate to form an insoluble gel.)
3. Fillers (to control the consistency of the mixed alginate)
4. Potassium sulphate, (counteract the inhibiting effect of the alginate on the setting gypsum, giving high quality surface of the die.)

5. Sodium sulphate (control working time, serve as retarder react with calcium sulphate)
6. Quaternary ammonium (to provide self disinfection).
7. Organic glycol small amounts (coat the powder particles to minimize dust during dispending, to make the powder dustless).
8. Pigments (to produce color).
9. Reactive indicator, in some product (give color change when setting is complete).

- **Setting reaction**

When alginate powder is mixed with water a chemical reaction occurs , The calcium alginate precipitated into fibrous network with water .

$$\text{Sol (powder +water)} \xrightarrow{\text{chemical reaction}} \text{gel}$$

$$\text{Sodium alginate + calcium sulphate dihydrate} \xrightarrow{\text{+water}} \text{sodium sulphate + calcium alginate(gel)}$$

- **manipulation:**

Powder should be mixed thoroughly before use (to eliminate the segregation of component that may occur during storage).

The proper w/p (Usually one measure water with two level scoops of powder), with use of clean rubber bowel and clean spatula. The mixing is started with a stirring motion to wet the powder with water once the powder moistened rapid spatulation by swiping against the side of the bowel (when mixed powder with water a vigorous figure 8 motion is best with the mix swiped against the side of the rubber bowel with intermitted rotations of spatula to press out air bubbles). The mix should be smooth, creamy with minimum of voids and doesn’t drip off the spatula when it is raised from the bowel.

After the impression set it must be removed suddenly with a snap removal. Then the impression is rinsed thoroughly with cold water to remove saliva & excess water is removed by shaking the impression and disinfected. The cast should be poured as soon as possible to prevent dimensional changes (within 15 minutes after making the impression).

- **Properties:**

1. Alginate has well controlled working time but vary from product to product. There are regular setting & fast setting. Setting time for regular set 2-4.5 minutes, setting time for fast set 1-2 minutes. Lengthening the setting time is better accomplished by reducing the temperature of the water used with mix (18-24C).
2. The clinical setting time can be detected by the loss of tackiness of the surface.
3. The material should be left in place inside the patient mouth for 2-3 minutes after the tackiness has gone from the surface. Since the tear strength and resistance to permanent deformation increase significantly during this period).
4. It is mucostatic & hydrophilic.
5. Detail reproduction is lower when compared with agar or elastomers (they are not recommended for crown and bridge; they are popular for partial denture work.
6. Set alginate is susceptible to evaporation, syneresis & imbibitions (like agar). So the cast should be poured immediately, if storage is unavoidable keeping in humid atmosphere of 100% relative humidity result in least dimensional changes (not more 1 hour).
7. Like agar snap removal technique need to be employed in order to get an elastic response. The permanent deformation is somewhat higher than agar.
8. Has lower tear strength than agar & have poor mechanical properties.
9. Set gypsum model should not remain in contact with alginate impression for a periods of hours because contact of slightly soluble calcium sulphate dehydrate with alginate gel containing a great deal of water is detrimental to surface quality of model
10. Thin layer of alginate is weak; the thickness of alginate between the tray & tissue should be at least 3mm.
11. Alginate doesn’t adhere well to the tray therefore perforated one or rim lock should be used.
12. Mixing time for fast set 45 seconds while for regular set 60 seconds. Over mixing result in reduction in final strength as the gel fibril is destroyed also reduction in working time. While under mixing lead to inadequate wetting & reduced strength also the mix being grainy & poor recording of detail.

13. The dentist can control the setting time by altering the temperature of the water used for mixing (colder the water the longer the setting time, warmer the water the shorter the setting time.)
14. It has pleasant taste, smell and low cost.
15. It is highly elastic but less when compare to agar

- **<u>Advantages:</u>**
  1. It is easy to mixed and manipulation with minimal requirement of equipment.
  2. It has suitable setting time.
  3. Flexibility of the set impression.
  4. Accuracy if properly handled, low cost.
  5. Hydrophilic, comfortable to patient.

- **<u>Disadvantages:</u>**

1. It can't be corrected.
2. Poor dimensional stability (due to syneresis and imbibition's). Poor tear strength.
3. Lower detail reproduction.
4. High permanent deformation.
5. Difficult to disinfect.

Elastic impression material

2. Elastomeric impression material

They are soft and rubber like and are known as elastomers or non-aqueous impression material. Elastomers are flexible cross-linked polymers when set. They are synthetic polymers which can be converted to solid rubber at room temperature by mixing with a suitable catalyst they undergo polymerization and /or cross linking (by condensation or addition) reaction to produce firm elastic solid.

Types of elastomers (According to the chemistry):

1. Polysulphides.
2. Condensation polymerizing silicones.
3. Addition polymerizing silicones.
4. Polyether.
5. Hybrid impression (combination of silicon and polyether).

- **Presentation:**

Regardless of type all elastomeric impression materials are supplied as two paste systems (base and catalyst) in collapsible tubes. While the Putty consistency is supply in jars.

Each type may be further divided into five viscosity: In increasing order of filler content

- Extra low or very low bodied.
- Low or light bodied (Also referred to as *syringe type*, or *wash type*. A special syringe is used to place the light-bodied material immediately around the prepared teeth.
- Medium or regular bodied (used with special tray).

- Heavy bodied or tray consistency (Often referred to as *tray-type* materials they are much thicker.
- Very heavy or putty consistency.

Extra-low and very heavy (putty) forms are available only for condensation and addition silicones. There is no heavy-body product for condensation silicone.

- **Uses**: generally used in all cases
  1. Crown and bridge impressions.
  2. Partial and complete denture impressions.
  3. Implant.

Polysulphide impression material:

This was the first elastomeric impression material to be introduced. It is also known as Mercaptan or Thiokol.

- **Presentation:** paste in collapsed tubes as base and accelerator or catalyst.

Base is white colored; accelerator is brown or gray.
Available in three viscosities (by controlling the filler in its composition). **Light bodied, medium bodied, heavy bodied**.

- **Composition:**

Base:

1. Liquid Polysulphide polymer with terminal and pendant thiol (-SH) groups (this is further polymerized and cross linked to form rubber).
2. Inert filler (silica or titanium dioxide); (to give body, control viscosity and modify physical properties.

Catalyst:

1. Lead dioxide (react with thiol groups causing setting).
2. Dibutyl phthalate (plasticizer).
3. Sulfer (to enhance reaction).
4. Magnizium stearate (retarded and deodorants).

- **Setting reaction**

Equal length of base paste and acceleration paste are mixed, it undergoes a chemical reaction. The liquid polymer sets to form solid but highly elastic and flexible rubber like material.

The reaction is exothermic 3-4 c rise in temperature. The reaction is sensitive to heat and moisture increase in either one will accelerate the setting reaction.

Mercaptan + lead dioxide ⟶ polysulphide +water (by product)

- **Properties**:

1. Unpleasant odor and color. It stains the clothes and it is messy to work with it. Has long setting time (12.5 min) cause discomfort for patient.
2. Accurate reproduction of detail, dimensional stability; the curing shrinkage is highest permanent deformation among the elastomers. this improve with time so pouring of the model should be delay by half an hour, further delay is avoided to minimize curing shrinkage, loss of the by product (**water**) is also causing shrinkage(dimensional changes).
3. Has good flexibility, it has high tear strength and Low hardness.
4. It is hydrophobic, so the mouth should be dried before making an impression. Care should also be taken while pouring the stone to avoid air pockets.
5. The half-life is good 2 years .Inexpensive to use.
6. Need special tray (2mm spacer), the tray is painted with adhesive before putting the impression.

7. These materials are extremely viscous and sticky, mixing is difficult, however they exhibit pseudo plasticity (if sufficient speed and force is used for mixing the material will seem easier to handle).

- **Manipulation:**

Equal length of base paste and acceleration paste are mixed on the paper pad by using stiff bladed spatula, the mixing is continued until the mix is free from steaks and uniform in color.

Silicone impression materials

Two types of silicon impression materials based on the type of polymerization reaction occurring during its setting.

1. Condensation silicon impression materials.
2. Addition silicone impression materials.

Condensation silicon impression materials

It was the earlier of the two silicone impression materials, available in four viscosities. (**Very low, light bodied, medium bodied and putty**).

- **Presentation:** The materials are supplied as

- Base paste and a low-viscosity liquid catalyst.
- Base putty and a low-viscosity liquid catalyst.
- Base putty and paste catalyst.
- Two-paste system. (Not equal in size)
- Two-putty system.

- **Composition:**

Base:

1. polydimethyl siloxane (hydroxyl-terminated).
2. Inert filler colloidal silica or metal oxide filler.
3. Color pigments.

Accelerator:

1. Orthoethyl silicate (cross linking agent)
2. Stannous octoate as a catalyst.

- **Setting reaction:**

It is condensation reaction, polymerization occurs as a result of cross linkable between the orthoeyl silicate and the terminal hydroxyl group of dimethyl siloxane to form a three-dimensional network. The reaction is exothermic (1 C) rise. **Ethyl alcohol** formed as by product evaporates gradually form the set rubber leading to shrinkage.

Dimethyl siloxane + orthoethyl silicate $\xrightarrow{\text{stannous octoate}}$ silicone rubber + ethyl alcohol

- **Properties:**

1. Pleasant color and odor, avoid skin contact to prevent allergic reaction.
2. Setting time is (6-9) min. (shorter than polysulphide), Excellent reproduction of surface details.

3. Dimensional stability is comparatively less because of high curing shrinkage (0.4-0.6) % and shrinkage due to evaporation of **ethyl alcohol** by product. To avoid this cast should be poured immediately.
4. Tear strength is lower than the polysulphide.
5. Elasticity develops earlier than polysulphide.
6. It is stiffer and harder than the polysulphides. The hardness increase with time. The spacing in the tray is increased to 3mm to compensate for the stiffness.
7. It is hydrophobic. Shelf life is slightly less than polysulphide due to the unstable nature of the orthoethyl silicates, expensive, Need to paint the tray with adhesive.
8. The putty consistency mostly widely used with stock offering an advantage over the polysulphide which are used with special tray only.
9. The viscosity is less than the polysulphide (they are easier to mix)

Addition silicone impression materials.

They have better properties than condensation silicone and the polysulphide. This material is often called a polyvinyl siloxane (PVS) or vinyl polysiloxane (VPS) impression material. Addition silicone is available in **extra low, low, medium, heavy, and very heavy (putty)** consistencies.

- **Presentation:** The materials are supplied as

- Two-paste system: The base and catalyst pastes come in equal size tube (unlike condensation silicones).
- two- putty system (jars): Two equal size jars, one containing the base and the other the catalyst.

- **Composition:**

Base:

1. Poly methyl hydrogen siloxane.
2. Other siloxane prepolymers.
3. Fillers.

Accelerator:

1. Divinyl polysiloxane.
2. Other siloxane prepolymers.
3. Platinum salt (chloroplatinic acid), catalyst.
4. Palladium or hydrogen absorber.
5. Retarders.
6. Fillers.

- **Setting reaction:**

It is addition reaction. Base polymer is terminated with vinyl group and is cross linked with silane (hydride group). The reaction is activated by the platinum salt (chloroplatinic acid). There are no by products.

Sulfur compounds retard the setting of silicones. One source of sulfur contamination is from latex gloves worn by the operator when mixing the impression (the vinyl gloves should be used).

Vinyl siloxane + silane siloxane $\xrightarrow{\textbf{chloroplatinic acid}}$ silicon rubber

- **Properties:**

1. Pleasant odor and color, avoid skin contact to prevent allergic reaction.
2. Excellent reproduction of surface details, setting time is (5-9) min.
3. It has the best dimensional stability among the elastomers even after 1 week (dimensional stability), it has good tear strength, hydrophobic.
4. It has low flexible and harder than polysulphides. Extra spacing 3mm. should be provided in the impression tray. Care should be taken while removing the stone cast from the impression to avoid any breakage.
5. Shelf life range from 1 to 2 years, more expensive.
6. Need to paint the tray with adhesive.

Polyether impression material

It has good mechanical properties and dimensional stability. Its disadvantages were that the working time was short and the material was very stiff. It is also expensive and bitter in taste. Polyether remain popular among a large number of clinicians mainly because of their hydrophilic nature.

- ## Presentation:

Available as base and accelerator in collapsible tubes (the accelerator tube is usually smaller). A third tube containing a thinner was provided. It is available in three viscosities (**light bodied, medium bodied and heavy bodied**).

- ## Composition:

Base:

1. Polyether polymer.
2. Colloidal silica (filler).
3. Glycolether or phthalate (plasticizer).

Accelerator:

1. Aromatic suffonate (cross linking agent).
2. Colloidal silica (filler).
3. Phthalate or glycolether (plasticizer).

- ## Setting reaction:

Polyether+ sulphonic ester ⟶ cross linked rubber

The reaction is exothermic (4 to 5 C) rise.

- ## Properties:

1. Pleasant color and odor, bitter in taste, excellent reproduction of detail.
2. Direct skin contact should be avoided (the sulphonic ester may cause skin reaction),(3-5) setting time decreased by heat.

3. Dimensional stability is very good. Curing shrinkage (0.24) % and permanent deformation is low. Polyether absorbed water and can change dimension (should not be stored in water or in humid climates), good tear strength.
4. It is extremely stiff and its hardness is higher than the polysulphides and increase with time. Removing it from undercuts is difficult. So extra spacing (4 mm) should be given. Care should be also taken while removing the cast from the impression to avoid any breakage.
5. It is hydrophilic. So moisture in the impression field is not critical. It has the best compatibility with stone.
6. Shelf life is excellent (more than 2 years), expensive.
7. Tray adhesive used before putting the impression in the tray.

Hybrid impression (combination of addition silicon and polyether):

The vinyl polyether silicon impression material (VPES) represents the next generation of impression material. It combined the benefits of polyether and the vinyl poly siloxane impression materials. It is available in two setting time (fast and regular) and in 4 viscosities (**light body, medium body, heavy body and putty).**

- **properties**
  1. Pleasant tasting (mint taste), excellent tear strength, fast setting time.
  2. Adequate Bond of impression material to tray, hydrophilic.
  3. Superior elasticity – elasticity without distortion allows for easy removal, multiple pours due to elasticity.
  4. Excellent dimensional accuracy and flow, Exceptional reproduction of detail.
  5. Resistance to deformation, can be disinfected.

- **Methods of making impression:**

1. **Single mix technique:** Tray used (resin special tray with 2 to 4 mm spacing). Viscosity used (regular only).
2. **Multiple mix technique:** Tray used (resin special tray with 2 to 4 mm spacing). Viscosity used (heavy bodied and light bodied).
3. **Two stage putty wash technique:** Tray used (perforated stock tray). Viscosity used (putty and light bodied).

Properties	poly sulphide	condensation silicon	addition silicon	polyether
Setting time	moderate- long	short-moderate	short-moderate	short
Shrinkage on setting	high	moderate-high	very low	low
Elastic recovery after removal	moderate	high	very high	high
Flexibility during removal	high	moderate	low-moderate	low-moderate
Tear strength	moderate-high	low- moderate	low- moderate	moderate
Wettability by gypsum mixed	moderate	poor	good-very good	very good
Detail reproduction	excellent	excellent	excellent	excellent

- **DIGITAL IMPRESSIONS**

Several digital impression systems are currently on the market that allows the dentist to make a digital impression in place of a traditional impression. Digital impressions offer a precise fit with fewer incidents of remakes and shorter adjustment time.

CAD/CAM, the abbreviation for computer-aided design/computer-aided manufacturing, describes a process in which digital images or models of objects are created and used for the design and fabrication of final products.

Dental CAD/CAM systems consist of three components:

1. A scanner or digitizing instrument.

2. Software that processes the scanned data and creates images of the digitized object.

3. Fabrication technology that transforms the digital data of the restoration into a physical product.

Scanners use either a series of static images or a stream of video images to capture the geometry of the tooth preparation and oral tissue.

Dental waxes

Waxes are one of the many essential materials used in dentistry. Fabrication of artificial restoration of soft and hard tissues of the oral cavity requires use of wax in one form or the other. Waxes are, essentially, soft substances with poor mechanical properties.

Composition of waxes

Waxes are organic polymers consisting of hydrocarbons and their derivatives. These are composed of mixtures of thermoplastic materials (softened by heating then hardened by cooling) which are normally solid at room temperature but melt without decomposition to form mobile liquids. The waxes that used in dentistry normally consist of two or more components which may be natural or synthetic waxes, resins, oils, fats and pigments.

Requirements of dental waxes:

1. Must conform to the exact size and shape and contour of the appliance which is to be made.
2. Should have enough flow when melted to reproduce the fine details.
3. No dimensional change should takes place once it's formed.
4. Boiling out of the wax without any residue.
5. Easily carved and smooth surface can be produce.
6. Definite contrast in color to facilitate proper finishing of the margins.

Applications

1. Used in the formation of wax pattern.
2. Used in the dental laboratory to box impressions prior to cast pouring with gypsum.
3. Used as a base plate for the registration of jaw relationships.
4. Used as a casting wax to establish minimum thickness to certain areas.
5. Used as a utility wax to prevent distortion of impression materials.
6. Used as a sticky wax to join fractured parts together.
7. Used as a corrective impression wax to contact and register the detail of soft tissues.

Classification of waxes

- Classification of waxes according to their origin
- Classification of waxes according to the Application in Dentistry

Classification of waxes according to their origin

According to their origin waxes are classified as:

1. Synthetic Waxes

Synthetic wax is a man-made wax synthesized from appropriate monomers. The synthetic waxes differ chemically from the natural waxes. The synthetic waxes have specific melting points and are blended with natural waxes. These are more often refined when compared to the natural waxes. For example, polyethylene waxes.

2. Natural waxes

Type	Example	Source	Properties
1. mineral	Paraffin wax	Obtained during the distillation of crude petroleum	•Brittle at room temperature. • Softening temperature: 37–55°C • has relatively low melting point range: 40–71°C
	Ceresin wax	From natural and mineral petroleum	Added to increase the melting range of paraffin wax.
	Microcrystalline wax	Obtained from petroleum	• Less brittle than paraffin wax due to their oil content. • Melting range: 60–80°C • Added to modify the softening and melting ranges of wax blends. • Less volumetric change during solidification
2. Plants waxes	Carnauba wax	from trees and plants	• Melting temperature: 84–91°C. • Added to increase the melting range and hardness of paraffin wax.
	Candelilla wax	from trees and plants	• Melting temperature: 68–75°C • Added to harden paraffin waxes.
3. Animal waxes	stearin wax	obtained from animal fat	• has low melting point 50 °C
	Spermaceti Wax	Obtained from the whale.	• Used as a coating in the manufacture of dental floss.

	Bees wax	obtained from honycomb	• Less brittle. • Melting temperature: 63–70°C. often blended with paraffin wax in order to modify the properties of the paraffin. The effect of adding beeswax to paraffin wax is to render the material less brittle and to reduce the extent to which it will flow under stress at temperatures just below the melting point.

Classification of waxes according to the their Application in Dentistry

1. Pattern wax: the primary uses of the wax in dentistry are to form ***patterns*** of appliances prior to casting.

Following the production of a stone model or die, the next stage in the formation of many dental appliances, dentures or restorations is the production of a wax pattern of the appliance on the model. The wax pattern defines the shape and size of the resulting appliance and is eventually replaced by either a polymer or an alloy using the ***lost-wax technique***. Methods which involve the production of a model followed by the laying down of a wax pattern are known as ***indirect techniques***. Some dental restorations, may be produced by a ***direct wax pattern technique*** in which the inlay wax is adapted and shaped in the prepared cavity in the mouth.

Waxes used in the production of patterns by either the direct or indirect technique must have very precisely controlled properties in order that well fitting restorations or appliances may be constructed**.** The Pattern wax divided to the following types which are:

A. **Inlay wax:** Should be hard and brittle in order to fracture rather than to distort when removed from undercut areas. The wax is mostly blue in color. They are used to make inlays crowns and pointic replicas. They are mostly paraffin with carnauba wax. There are 2 types.
   - Type 1: for direct technique
   - Type 2: for indirect technique

B. **Denture casting wax:** used to produce the metal components of cobalt – chromium partial denture. It is based on paraffin wax with bees wax to give softness necessary for molding and stickiness necessary to ensure adhering to an investment material. It is mostly green sheet.

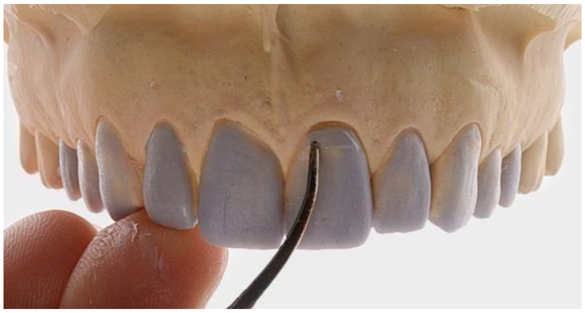
C. **Modelling waxes (Denture base plate wax, sheet wax):** It is used to form the base of the denture and in setting of teeth. Modelling waxes consist mainly of mixtures of paraffin wax and bees wax and have melting points in the range 49–58ºC. They are generally supplied in pink sheet form. Modelling waxes are tough enough to resist fracture when withdrawn from shallow undercuts.

Three types of material are available, designated as follows:

- Type 1 soft wax
- Type 2 hard wax
- Type 3 extra hard

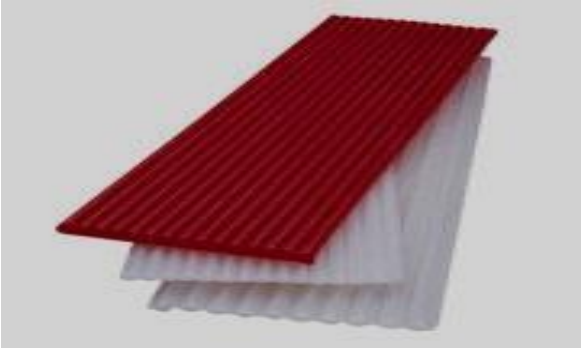
These products differ primarily in regard to their softening temperature.

D. **White wax:** to make pattern simulate veneer facing in crowns.

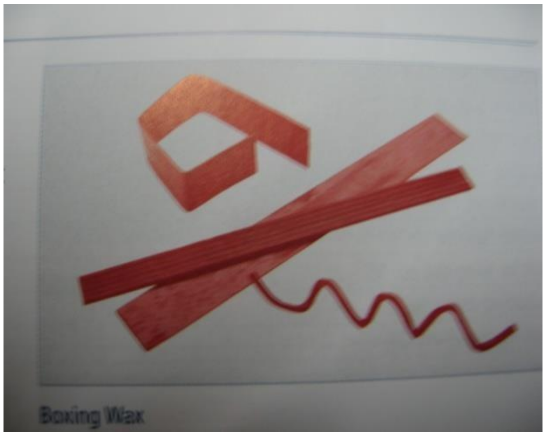


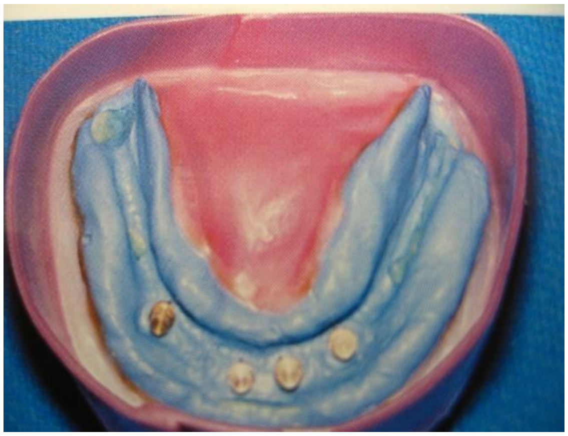
2. Processing wax: used during processing of the appliance like:

A. **Beading wax:** used to make beading around the impression before pouring gypsum to protect the margins



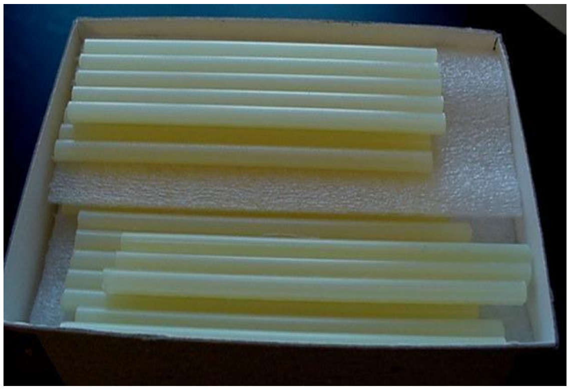
B. **Boxing – in wax:** used to make box around the impression to make pouring gypsum into the impression easier and more perfect.



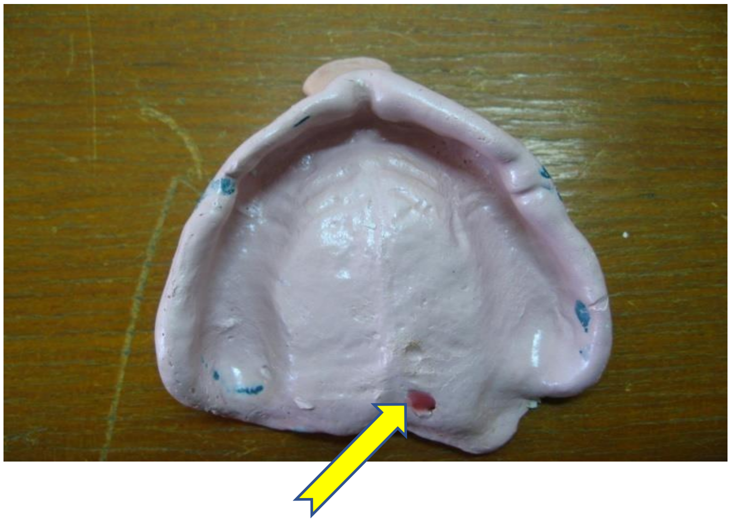


C. **Block – out wax:** to block – out undercut areas on cast during processing of Co/Cr metal frame work.

D. **Sticky wax:** used for temporarily joining two components of an appliance and join the broken pieces of the denture before repair.



3. **Impression wax:** They are previously used to make impression but distort when removed from undercut, they have high flow.



Wax Properties:

1. They are **thermoplastic materials** that are soft when heated and are solid at room temperature.
2. **High coefficient of thermal expansion and contraction** it is the ***highest*** of dental materials. 300×10^{-6}/°C – 1000×10^{-6}/°C. shrinkage of wax from liquid to solid at room temperature is 0.4% thermal contraction of wax is compensated by expansion of investment.
3. **Poor thermal conductivity** after softening of the wax it is allowed to cool, which is accompanied by contraction. because of poor thermal conductivity only the outer layer solidify and the inner solidify later which will produce internal stress. Relief of the stresses accrues later especially when temp. increases, greater stresses may be incorporated if the wax is not properly softened.
4. Methods for softening wax prior to using include a ***water bath, an infra-red lamp and a bunsen burner***. The best way to soften the wax is to be held in the warm raising air above the flame and <u>not in the flame itself</u>. While The ideal method for softening wax is to use a ***wax annealer*** (This is a thermostatically controlled oven which keeps the wax at a constant temperature, just above the softening point, ready for use).

5. **Flow:** should have high flow when softened but should have little or no flow at room temp. or mouth temp. in order not to distort.
6. **Brittleness:** inlay wax should be brittle in order to fracture rather than distort when removed from undercut of the cavity.

Wax Distortion

Distortion is one of the most serious problems faced when forming the pattern and removing it from the mouth or die specially in the direct technique.

Reasons for wax Distortion

The wax distorted by:

1. Thermal changes, using of the wax at not uniform temperature. Some parts of the wax pattern may thermally contract more than others when stresses are introduced.
2. Releasing of internal stresses. The stresses are induced from the natural tendency of the wax to contract on cooling, from occluded gas bubbles, change of shape during moulding and due to carving, etc.
3. Distortion may also take place due to flow of wax under its own weight particularly at a higher temperature.
4. During carving operation, some molecules of wax will be disturbed and the stresses will be introduced.
5. Time and temperature of storage before investment may result in stress release.
6. If the wax has to be melted and added to the pattern in order to repair some parts that were not accurately obtained, the added wax will introduce stress during cooling.
7. If the wax is not held under uniform pressure during cooling.

Avoidance of wax distortion:

1. Minimal carving
2. Minimal change in temperature.
3. Minimal storage of the pattern (Invest immediately).
4. Use warm instruments for carving.
5. Store in fridge if necessary.

Polymers

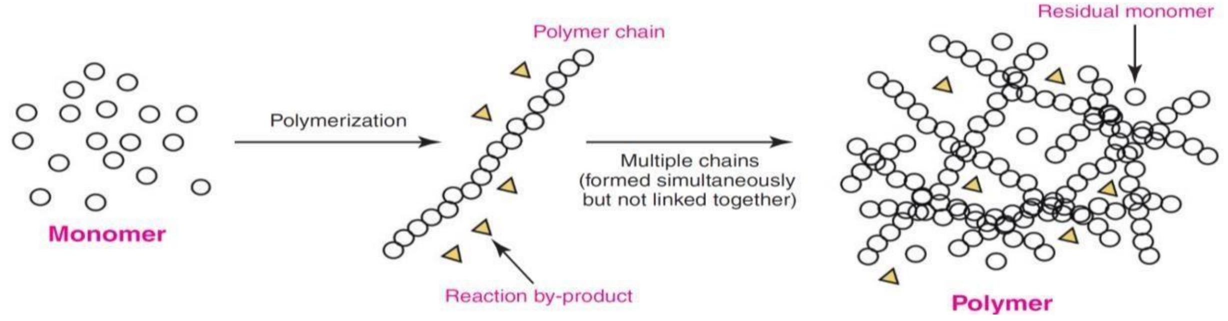
Polymer: a chemical compound consisting of a large organic molecule (macromolecule) formed by the union of many smaller repeating units (**mers**).

Monomer: it is a single molecule from which the polymer is constructed. It is a chemical compound that is capable of reacting to form a polymer.

Mer: The term used to designate the repeating unit or units in a polymer chain; thus mers are the “links” in the chain.

Polymerization: Chemical reaction in which monomers of a low molecular weight are converted into chains of polymers with a high molecular weight. The polymerization is *exothermic reaction*.

Monomer+ Monomer+ Monomer+ Monomer polymerization Mer Mer Mer Mer



Copolymers: Polymer made of two or more monomer species and identical monomer units (mers) occurring in relatively long sequences along the main polymer chain. Copolymerization is used to improve the physical properties of the resulting resin.

Crosslinked: A difunctional or multifunctional monomer that forms a link between two polymer chains. Crosslinked polymers have many such crosslinks between neighboring chains such that a three-dimensional interconnected polymer network result.

Degree of polymerization (D.P): is specified by the total number of repeated units in the chain of the polymer. The higher the degree of polymerization the better will be the physical properties.

Glass transition temperature (Tg): The temperature at which macromolecule molecular motion begins to force the polymer chains apart. Thus, polymeric materials soften when heated above this temperature (It is the temperature was the polymers leave the rigid state and transfer into rubber like phase).

Factor control polymer properties:

1. Chemical composition of the polymer: This depends on types of monomers and its structure. e.g.

CH_2—CH---R **vinyl polymer** when R=H polyethylene, the repeating unit is CH_2 group. Polyethylene is hydrophobic semicrystalline polymer.

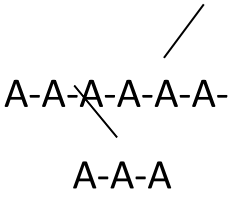
But when R=OH the (polyvinyl alcohol) hydrophilic, water soluble polymer with gelling properties.

2. Topology of polymer chain:

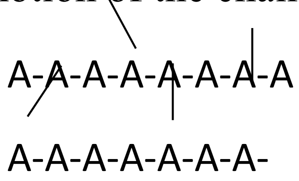
- **Linear polymer**. A-A-A-A

A-A-A

- **Nonlinear (branched) polymer**.

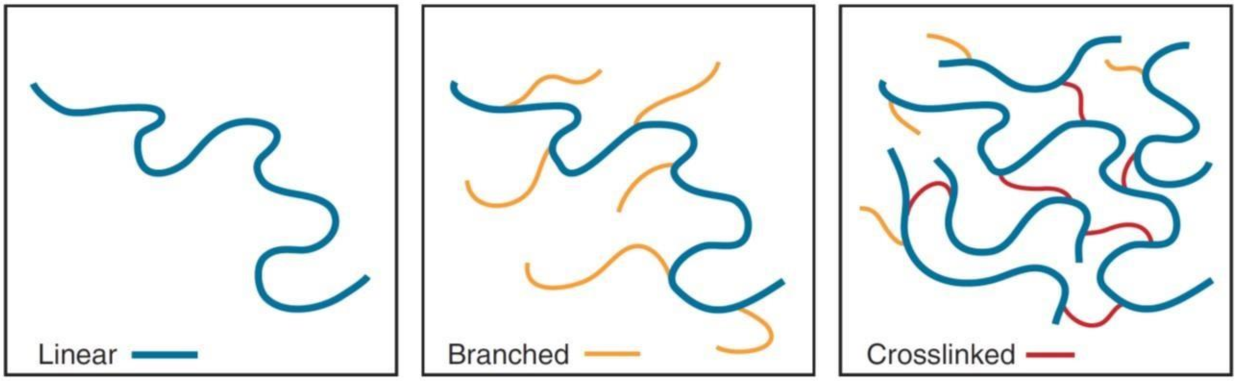


- **Cross linked polymer (polymer network).** The cross linking (permanent connection between the polymer chains) restricting the motion of the chains and improve rigidity of polymer. A-A-A-A-A-A-A



The advantages of cross-linking agents:

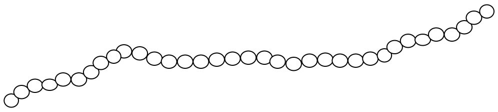
1. Improve hardness and stiffness.
2. Increase wear and solvent resistance.
3. Increase crazing resistance.
4. Increase brittleness.
5. Increase thermal resistance.
6. Decrease water sorption and solubility.

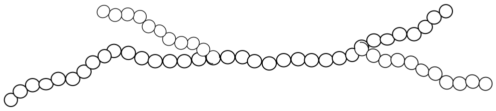


3. Monomer distribution in the polymer chain:

A. **Homo polymers** (one type of monomer) (linear or branched).

A-A-A-A-A-A

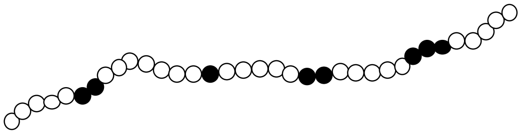




B. **Co polymers** (2 or 3 types of monomers) it is ether:

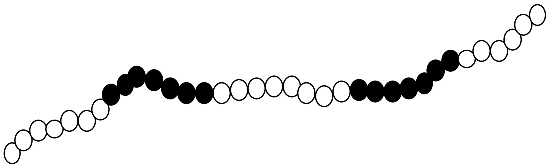
- *Random copolymer:* No sequential order exists among the two or more mer units along the polymer chain.

…ABBABABAAABAAAABABBBABAAAABABABB…

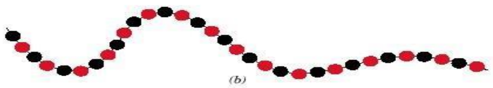


- *Block copolymer*: Identical monomer units occur in relatively long sequences (blocks) along the main polymer chain.

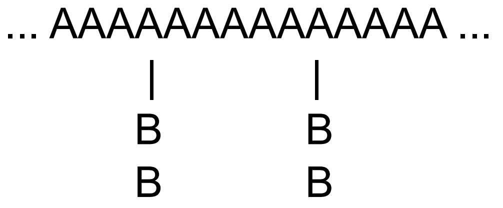
…AAAAABBBBBBAAAABBBBBBAAABBBAAAA…



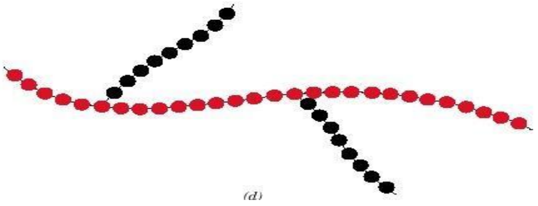
- *Alternating copolymer:* **…..ABABABABAB…..**



- *Graft or branched copolymer*: Sequences of one type of mer unit (B) are “grafted” onto a backbone chain of a second (A) type of mer unit to form a branched configuration.



$$\ldots\ \mathrm{AAA}\underset{\substack{|\\ \mathrm{B}\\ \mathrm{B}}}{\mathrm{A}}\mathrm{AAAAA}\underset{\substack{|\\ \mathrm{B}\\ \mathrm{B}}}{\mathrm{A}}\mathrm{AAAA}\ \ldots$$



4. Polymer molecular weight (Mw).

Mw of polymer molecules= the Mw of the mers x number of mers

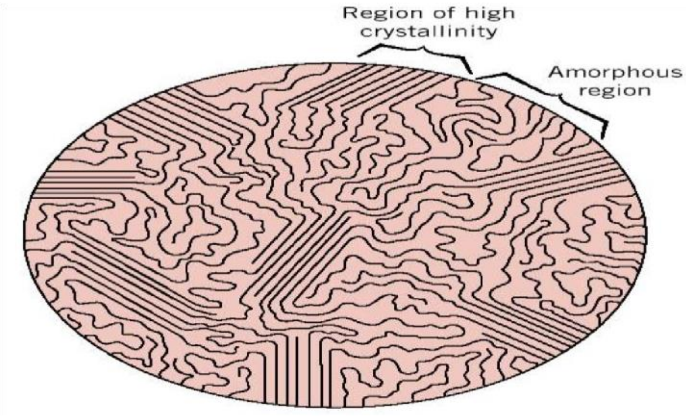
Mw may range from thousand to millions of molecular weight units depending on preparation conditions.

Mw of polymers plays an important role in determining its *physical properties*. Most polymers have a wide range of Mw and so vary widely in their properties. The higher the Mw the higher the softening and melting point and the stiffer the plastic. The higher the Mw of polymer made from a single monomer, the higher the degree of polymerization. The strength of the resin increases with the increasing of the degree of polymerization until a certain Mw is reached. Above this there is no change.

5. Supra molecular structure (molecular organization).

A. **Amorphous polymers** (coiled irregular) random Shape of polymer chains.

B. **Semi crystalline polymer:** domains with regular (crystalline) structure acting as special type of cross - links.



Polymers used in dentistry:

- **Natural polymers**. e.g. gutta percha.
- **Synthetic polymers** (prepared by polymerization reaction).

Application of polymers in dentistry:

1. **Prosthodontics:** denture bases, denture teeth, soft liners, custom trays, impression materials, cementing materials, maxillofacial prostheses …….
2. **Operative Dentistry:** dentin bonding agents, cavity fillings, resin and glass-ionomer cements, veneers…..
3. **Orthodontics:** brackets, bracket bonding resins and cements, and spacers.
4. **Endodontics:** gutta-percha points, root canal sealants, and rubber dams.
5. **Equipment:** mixing bowls, mouth guards , protective eyewear….

The types of polymerization reaction:

1. **Condensation polymerization.**
2. **Addition polymerization.**

1. **Condensation polymerization:** usually more than one type of monomer is used; The condensation reaction progress by the same mechanism as chemical reaction between two or more simple molecules. The reaction produces *by products* such as water, halogen acids and ammonia or alcohol.

2. **Addition polymerization:** *most dental resins* are polymerized by additional polymerization which simple involves the joining together of monomer molecules to form polymers chain. In this type of reaction, no by product is obtained. There is no change in composition during addition polymerization. It's formed from smaller units or monomers without change in composition, the monomer must have an *unsaturated group* in its structural formula for covalent bond with another molecule. **The additional reaction take place in 3 stages as follow:**

    1. Induction stage
    2. Propagation stage
    3. Termination stage

1. Induction stage: Two processes control the induction stage *(activation and initiation)*. For an addition polymerization process to begin, a source of *free radicals* (R•) is required. Free radicals can be generated by the activation of radical-producing molecules like **heat**, **visible light** and **chemical agents**.

Free radicals: are very reactive chemical species that have unpaired electron; the free radicals are produced by reactive agents called initiators. The free radical reacts with a monomer and initiates the polymerization process.

Initiators: are molecules which contain one relatively weak bond which is able to undergo decomposition to form two reactive species (free radicals). The decomposition of bond of initiator needs source of energy (activator) such as heat, light and chemical activator. Initiator which is used extensively in dental polymers is **Benzoyl peroxide**. Decomposed and free radicals are formed.

R ——⁄——**R** **+ external energy** **2 R•** (R= represent any organic molecular)
Initiator free radicals

R• + **M** ———————— **R-M•**
Free radicals monomer reactive free radical species

The initiation reaction is an addition reaction producing another active radical species which is capable of further reaction (addition of free radical on the double bond of monomer).

The initiation period depends on the purity of the monomer and the temperature of the reaction. Any impurities present that are able to react with activated groups can increase the length of this period (induction period). The higher the temperature, the more rapid the formation of free radicals and consequently the shorter the induction period.

2. Propagation stage: The initiation stage is followed by the rapid addition of other monomer molecules to the free radical and shifting of free electron to the end of growing chain, this called propagation stage.

R—M• + M ———————— R—M—M•
R—M—M• + M ———————— R—M—M—M• R—M—
M—M• + M ———————— R—M—M—M—M•

3. Termination stage: The growing chain is stopped. Termination occurs when monomer units are used up or free radical is finished by reaction. Chain reaction can be terminated either by reaction of two growing chains to form one dead chain or by reaction of growing chains with molecules of initiation, dead polymer, impurity or solvent if present.

R—M—M—M• + R—M—M—M• ___________R—M—M—M—M —M—M—R

Inhibitor: it is chemical materials added to prevent or delay polymerization during storage and in order to provide enough working time and decrease sensitivity to ambient light like **hydroquinone**.

The following factors inhibit the polymerization:

1. Any **impurity** in the monomer that can react with free radicals or with any activated growing chain to prevent further growing.
2. The addition of small amounts of **hydroquinone** to the monomer.
3. The presence of **oxygen** also causes retardation of polymerization reaction because the oxygen reacts with free radicals and so the degree of polymerization is decreased.

Plasticizer: these are substance added to the resins to:

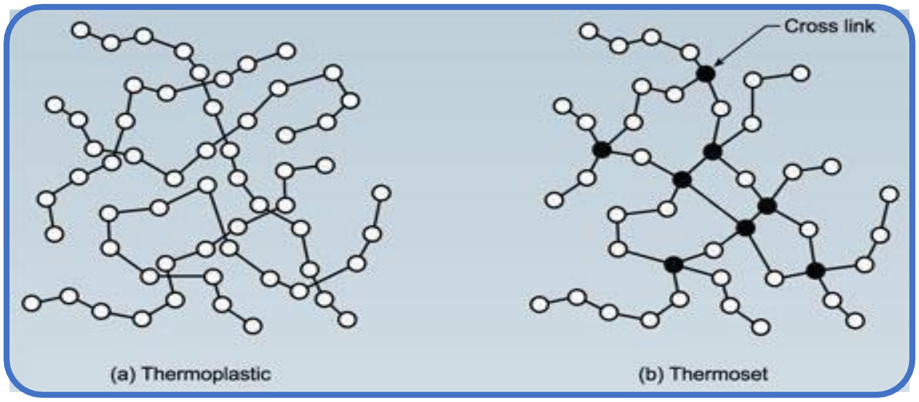
1. Decrease the brittleness of the polymer.
2. Increase the solubility of the polymer in the monomer.
3. It decreases strength, hardness and softening point it is used to prepare flexible polymer.

Classification of polymer according to thermal response:

1. Thermoset polymer.
2. Thermoplastic polymer.

Thermosetting polymer or resins: Thermosetting polymers undergo a chemical change during the setting reaction and become permanently hard when heated above the temperature at which they begin to polymerize; they do not soften again on reheating to the same temperature. They are usually cross linked in this state, and thus, they are insoluble and will not melt. Instead, they decompose if heated to a high enough temperature. Thermosetting polymers generally have superior abrasion resistance and dimensional stability compared with thermoplastic polymers.

Thermoplastic polymer or resins: They soften when heated above the glass transition (The resin can be shaped and molded) and upon cooling it will harden; this cycle can be repeated almost indefinitely. The setting reaction is reversible because of the relatively weak bonds among the molecular chains. Thus, in contrast to thermosetting resins, thermoplastic resins can be melting and are usually soluble in organic solvents and have better flexural and impact properties. e.g. flexible denture.



Denture base resin material

Various materials have been used to construct dentures like cellulose products, phenol- formaldehyde, vinyl resins and vulcanite, however they have suffering from a variety of problems. Acrylic resin (polymethyl methacrylate) (PMMA) is now the material of choice to use as denture base material because it is easy to process and use, cheep and good esthetic. Even so it is not ideal in all respects.

The ideal requirements of denture base material represents by the followings:

1. Natural appearance.

2. High strength, stiffness, hardness and toughness.
3. Dimensionally stability.
4. Tasteless, odorless, non toxic and none irritating the oral tissue.
5. Insoluble in saliva or other fluids taken in to the mouth.
6. Good retention to polymer, porcelain and metals.
7. Easy to fabricate and Easy to repair.
8. Good shelf life.
9. Low density.
10. Accurate reproduction of surface details.
11. Resistance to bacterial growth.
12. Good thermal conductivity.
13. radiopacity
14. Easy to clean
15. Inexpensive to use
16. The softening temperature should be higher than mouth temperature.

The Types Of Denture Base Resin:

- **Heat cure** denture base resin, set by heat
    a. water bath
    b. microwave
- **Light cure** denture base resin
- **cold cure, self-cure** denture base resin

Classification of denture base materials According to the Type of Materials

- metallic e.g. Cr/Co denture base
- nonmetallic materials e.g. poly (methyl methacrylate)

According to the Method of Polymerization

- Addition polymers, e.g. poly (methyl methacrylate)
- Condensation polymers, e.g. nylon.

According to their Thermal Response

- **Thermoplastic**, e.g. polyvinyl acrylics and polystyrene.
- **Thermosetting**, e.g. poly (methyl methacrylate).

According to the Method of Activation

- ***Thermal***; e.g. poly (methyl methacrylate).
- ***Microwave***; e.g. poly (methyl methacrylate).
- ***Catalyst***; e.g. poly (methyl methacrylate).
- ***Visible light activated***; e.g. poly (methyl methacrylate).

According to the Dispensing System

- **Power and liquid system**, e.g. heat-cure and self-cure acrylic resins.
- **Sheets and ropes**: (Single component system), e.g. light activated denture base resins.
- **Gel type**, e.g. vinyl acrylics.

Denture base resin material
Heat cure denture base resin

Compositions: The heat cure acrylic resin supplied as powder and liquid.

Powder:

1. Poly methyl methacrylate beads or granules so they are already polymerized not monomer (Main ingredient which will polymerize). 2. Benzoyl peroxide (initiator to produce free radicals).
3. Dibutyl phthalate (Plasticizer to make it softer and added flexibility).
4. Zinc or titanium oxide (opacifier to make it radio-opaque).
5. Pigments.
6. Synthetic fibers (nylon acrylic to look like blood vessels and to give the gingival tissues natural appearance).

Liquid:

1. Methyl methacrylate monomer.
2. Cross linking agent that improves the mechanical properties (add strength)

3. Hydroquinone Inhibitor prevent setting while storage.

Properties of Methyl methacrylate monomer

- It is a clear transparent liquid (colorless), liquid at room temperature. It has typical smell of its own.
- Can get evaporated (Volatile).
- Inflammable.
- Should store in dark colored bottle.
- It is a known allergen.
- Boiling point 100.8 ^{0}C, Melting point 48 ^{0}C.
- Light weight.
- Volumetric shrinkage during polymerization of 21%.

Manipulation of heat cure acrylic resin (Polymer-monomer interaction):

The liquid is placed in clean and dry mixing jar then powder is added slowly and mixed in proper proportion (Powder /liquid ratio is **3:1** by volume or **2.5:1** by weight) and allow each powder particles to become wetted by monomer and workable mass is formed and left until it reaches a consistency suitable for packing. During this period, a cover should be placed above the mixing jar to avoid monomer evaporation. The type of the reaction is addition polymerization reaction (it is extremely exothermic reaction).

The resultant mixture will pass into **5 stages:**

1- **Sandy stage:** the monomer wets the outside of the polymer's particles.
2- **Sticky stage:** the monomer attaches the surface of the polymer beads, some polymer chains are dispersed in the liquid monomer, the viscosity of the mixture was increased, this stage is characterized by stickiness when the materials is touched.
3- **Dough like stage:** when the monomer diffuses further into the polymer particles and the mass become saturated. The mass does not adhere to

the walls of the mixing jar; clinically the mass behaves like as pliable dough.

4- **Rubber or elastic stage:** in this stage monomer is dissipated by evaporation and by further penetration into the remaining polymer beads. The mass is no longer plastic, its rubber like.

5- **Stiff stage:** on standing for period, the mixture becomes stiff, this may be attributed to the evaporation of free monomer. Clinically the mixture appears very dry.

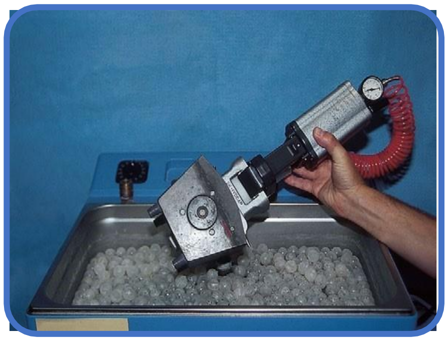
Dough forming time: the time from beginning of mixing of polymer with monomer until reaching the dough like consistency less than 10 min.

Working time: The time that the mixture remains in dough like stage. The dough remains moldable for at least 5mins. the working time is affected by temperature. In warm weather when the working time is insufficient can be extended by refrigeration (the resin store in refrigerator in air tight container to avoid moisture contamination).

The complete Polymerization not occurs until the denture flask is heated to **above 70^0C**. (In heat activated acrylic resin), The chemically activated materials start to polymerization soon after the powder and liquid are mixed and proceed more rapidly through the various consistency stages than the heat accelerated types.

Technical consideration: Heat activated denture resin are shaped by:

1. ***Injection molding technique:*** This technique required a special thermoplastic resin and special equipment. The fluid resin is contained in the injector and is forced into the mold space as needed. It is kept under pressure until it has hardened.



2. ***Compression mold technique:*** This is the most commonly used technique in the fabrication of acrylic resin denture. The steps of this technique are:
    - Preparation of the waxed denture pattern.
    - Preparation of the mold. (Flasking, De waxing).
    - Application of separating medium.
    - Mixing of powder and liquid (Placing acrylic dough in the mold).
    - Packing, closing the flask together and removing the excess.
    - Curing (Heat curing under pressure, the denture flask under pressure is placed in heated water bath or microwave oven).
    - Cooling. Deflasking, finishing and polishing.

Packing: The placement and adaptation of denture base resin within the mold cavity are termed packing. This process represents one of the most critical steps in denture base fabrication.

Cooling: The flask should be cooled slowly i.e. bench cooled. Fast cooling can result in warpage of the denture due to different in thermal contraction of the resin and the gypsum product mold. Cooling overnight is ideal.

Deflasking: the cured acrylic denture is removed from the flask. Deflasking should be done with care to avoid breaking of the acrylic denture.

Polymerization cycle or curing cycle: The curing cycle or polymerization cycle is the technical name for the heating process used to control the initial propagation of polymerization in the denture mold. This process should be well controlled to avoid the effect of uncontrolled temperature rise such as boiling of monomer and denture base porosity. Curing may be done either:

1. In **water bath** to raise the temperature.
2. In **microwave** oven (where the flask used should be non-metallic type).

There are two recommended curing cycles:

1. **Long curing cycle**: Curing in a constant temperature water bath (8hr10hr at 74 ^{0}C). (The satisfactory processing).
2. **Short curing cycles**: curing for 2hr at 74 ^{0}C then 1hr at 100 ^{0}C.

Properties of heat cured acrylic resin:

1. **Taste and odor:** completely polymerized acrylic resin is tasteless and odorless.
2. **Esthetic:** it is clear transparent resin which can be pigmented (colored) easily to duplicate the oral tissue. It is compatible with dyed synthetic fillers so esthetic is accepted.
3. **Density:** the polymer has a density about 1.2 gm/Cm^3.
4. **Strength:** these materials are typically low in strength. Compression strength=**75 Mpa**, while the tensile strength= **52 Mpa**. The cold cured resin has lower strength value than the heat cure acrylic.

5. **Impact strength:** it has lower impact strength, the ideal denture resin should have high impact strength to prevent breakage when it is accidently dropped, Addition of plasticizers increases the impact strength. Self-cured acrylic has lower impact strength.
6. **Hardness:** acrylic has lower hardness, can be easily scratches. Selfcured acrylic has lower hardness value than Heat cured acrylic. Brienell hardness number heat cure acrylic: **22** while for cold cure resin= **16-18.**
7. **Modulus of elasticity:** they are sufficient stiff for use in complete and partial dentures. When compared with metal denture bases it has very low stiffness (more flexible than metal). The cold cured resin has slightly low modulus of elasticity than the heat cure acrylic.
8. **Dimensional stability:** well processed acrylic resin denture base has **good** dimensional stability. The processing shrinkage is balanced by expansion due to water sorption.
9. **Shrinkage:** acrylic resin shrinkage during processing due to: 1. Thermal shrinkage on cooling and 2. Polymerization shrinkage.
10. Polymerization shrinkage of heat cure acrylic (volume shrinkage **8%**, linear shrinkage **0.53 %**) while the linear shrinkage of cold cure resin about **0.25%**
11. **Water sorption:** acrylic resins absorb water and expand (**0.6mg/cm^2**). This partially compensates for its processing shrinkage. This shrinkage is reversible. Thus, on drying they lose water and shrink. However repeated wetting and drying should be avoided as it may cause warpage of the denture.
12. **Solubility:** acrylic resin is insoluble in water and oral fluids. They are soluble in Ketons and esters.
13. **Thermal conductivity:** they are **poor** conductors of heat. This is undesirable because the patient wearing acrylic dentures often complain that they cannot fell the temperature of food or liquids they ingest.

14. **Coefficient of Thermal Expansion:** Acrylic has **High** Coefficient of Thermal Expansion about **76 *10^{-6} Cm/Cm. C°**. Addition of fillers reduces the coefficient of expansion.
15. **Color stability:** Heat cured acrylic have **good** color stability. Cold cured is slightly lower (yellows very slightly).
16. **Biocompatibility:** Completely polymerized acrylics are biocompatible due to low percentage of residual monomer, so allergic reactions to acrylic resin may be seen in the oral cavity.
17. **Adhesion:** Adhesion of acrylic to metal and porcelain is poor and mechanical retention is required. Adhesion to plastic denture teeth is good (chemical adhesion).
18. **Residual monomer:** Instances of toxicity or allergic reaction have been related to excessive residual monomer that results from improper processing. The highest Residual monomer level is observed with cold cure acrylic. During the polymerization process of the hot cured acrylic the amount of Residual monomer decrease firstly rapidly and then later more slowly. It should be processed for a long time to reduce the Residual monomer.

Microwave polymerized polymer

Resins are the same as used with conventional heat cured material or using specially microwave acrylic resin and are processed in a microwave by using **non-metallic flask**. The properties and the accuracy of these materials have been shown to be as good as or better than those of the conventional heat cured material. The advantages of microwave curing are cleaner and faster than the water bath polymerization. Processing time is much shorter (4-5 min).

Light activated denture base resins

This material is a composite having a matrix of urethane dimethacrylate with an acrylic copolymer, microfine silica fillers, inhibitors and light initiator for polymerization (comphorquinone amine).

It is supplied in premixed sheets (Single component) and rope form in light proof pouches having clay like consistency. It is polymerized in a light chamber (curing unit) with visible blue light (400-500nm) is the activator in curing unit.

Chemically activated resin (auto polymerized or cold cure or self-cure polymethyl methacrylate):

Composition same as the heat cure version with following differences

1) The powder contains small particles size beads of polymer of poly methyl methacrylate that have a lower molecular wt. and contain **benzyl peroxide (initiator).**
2) The liquid contains a chemical **activator ((1-2%) tertiary aromatic amine)** which activated the benzyl peroxide (initiator) to produce free radicals so that polymerization is initiated in manner similar to that describe for heat cure acrylic. (Upon mixing tertiary amine causes activation of benzyl peroxide).

Compared to heat cure acrylic:

1. Low molecular weight (degree of polymerization not completed compared to that achieved using heat activated). Dentures processed have more residual monomer **(3-5%)**. While heat cured resin is reach up to **1%.**
2. Color stability inferior (tertiary aromatic amine susceptible to oxidation), stabilizing agents should be added.
3. Working time is shorter than heat cure acrylic. The chemically accelerated materials start to polymerize soon after the powder and liquid are mixed and proceed more rapidly through the various consistency stage than the heat accelerated type.
4. Less shrinkage than heat cures resin (Lower dimensional change).
5. Decreased transverse strength (residual monomer act as plasticizer).
6. Lower hardness.

Thermoplastic polymer (flexible dentures)

Thermoplastic resins are used for the fabrication of flexible denture. A thermoplastic is a plastic which becomes pliable or moldable above a specific temperature and returns to a solid state upon cooling. There are different kinds of thermoplastic resin like:

1. Thermoplastic acetal.
2. Thermoplastic acrylic.

3. Thermoplastic polycarbonate.
4. Thermoplastic nylon.

The Thermoplastic nylon is used as a denture base in every case specially used in partial and complete denture when we have undercut (because of the flexibility of the material) also used in tilted teeth, patient allergy to acrylic monomer, (there is no free monomer in this material), patient allergic to nickel, if there is reduced mouth opening and when we need high esthetic demand.

Chemically nylons are **condensation copolymers** formed by reacting equal parts of **diamide** and **dicarboxylic** acid. **Water** result as reaction by product. Usually, the Thermoplastic nylon is supply as beads and prepared by injection molding technique, the injection temperature ranges from (274-293) ^{0}C.

Properties of the Thermoplastic nylon (Flexible dentures):

1. High strength.
2. Excellent flexibility and ductility.
3. It is semi translucent and provides excellent esthetic. No metal clasp appearance on the tooth surface
4. Bio compatible (frees of monomer and metal which are the principle cause of allergic reaction).
5. High fracture resistance and impact properties, unbreakable martial (not fracture even if thrown from height).
6. Difficult to adjust, polish and repair.
7. Lower water sorption than PMMA resin.
8. Good resistance to most chemical but they can affect by strong acids and alcohols.
9. Light weight.
10. Nylon is aprone to creep.

11. Minimal bonding strength to artificial teeth and to relining material.
12. After short period of time the flexible dentures deteriorate, stain and develop a rough surface.

Processing Errors:

1. *Porosity:* Presence of voids or bubbles within structure of resin. When the porosity present in the surface it:

- Makes the appearance of the denture base unsightly.
- Proper cleaning of the denture is not possible, so denture hygiene and oral hygiene is suffered.
- It weakens the denture base.

Porosity can be of two types: **internal porosity and external porosity**.

Internal denture porosity: it is in form of voids and bubbles within the mass of polymerized acrylic. Not present on the surface of the denture. It is developed in thick portion of the denture base. **Causes:**

1. Vaporization of the monomer when the temperature of the resin increases above the boiling point of the monomer (100.8 ^{0}C).
2. Very low molecular weight polymer exothermic heat of the surface resin dissipates easily into the investing plaster.
3. The center of the thick portion, the heat cannot be conducted away therefore the temperature in the thick portion may rise above the boiling point of monomer causing porosity.

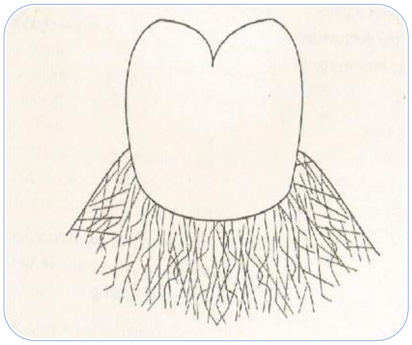
Minimized by: Denture with excessive thickness should be cured using long and low temperature curing cycle.

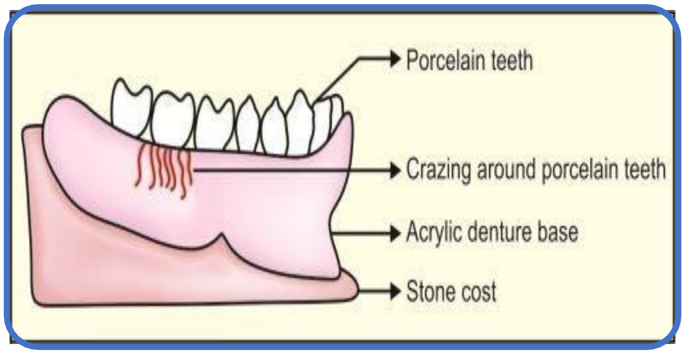
External denture porosity: it can occur due to two reasons

1- Lack of homogeneity: **<u>Causes</u>:** if the dough is not homogenous at the time of polymerization the portions containing more monomer will shrink more than the adjacent area. This localized shrinkage results in voids, the resin appears white. **<u>Minimized to by</u>** Using proper powder liquid ratio and mix it well. The mixture is more homogenous in the dough stage (so packing should be done in dough stage).
2- Lack of adequate pressure: **<u>Causes</u>:** lack of pressure during polymerization or inadequate amount of dough in the mould during final closure cause bubbled which are not spherical and the resin color is lighter. **<u>Minimized by</u>** using the required amount of dough in flask and check for excess of flash during closure (flash indicated adequate material).

2. ***<u>Crazing:</u>*** Crazing is formation of surface cracks on denture base resin and has a weakling effect on the resin and reduces the esthetic qualities. The cracks formed can cause fracture. **Causes:**

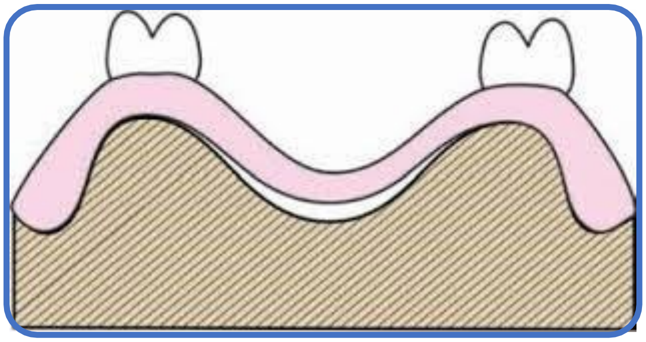
- Mechanical stresses (tensile stress).
- Attack by solvent (alcohol)
- Incorporation of water during processing.





3. ***Denture warpage:*** it is change in shape or deformation of denture which can affect the fit of the denture. Warpage can occur during processing as well as at other times. **Cause** by

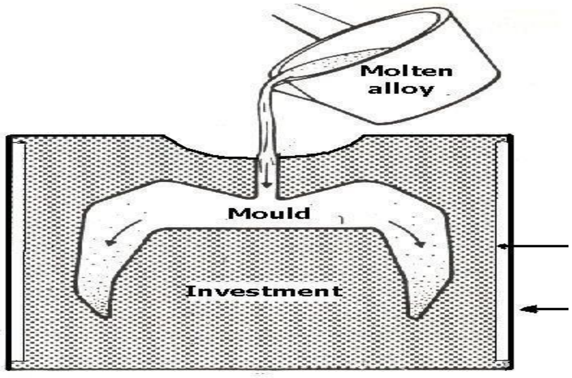
- Release of stresses incorporation in denture during processing. Causes of stress are (curing shrinkage or rapid cooling or packing of the acrylic in rubber stage or improper deflasking).
- Rise in temperature while polishing.
- Immersion of processed denture in hot water.
- Re curing of the denture after addition of relining material.
- Repeated wetting and drying cause warpage of the denture.



Investment Materials

An investment material can be described as a **ceramic material** that is suitable for forming a mold into which a metal or alloy is cast.

When a restoration or appliance is being made by a "**lost wax**" process, the wax pattern is embedded in an **investment material**. After the investment material has set, the wax is removed by **burn out process**, that creates a space in the investment called as **mold space**, which is filled by the material of which the restoration or appliance is to be made.



Ideal properties required for an investment

1. Should not react with wax and alloys.
2. Should be easily manipulated.
3. The inner surface of the mold should not breakdown at higher temperature.
4. At higher temperature, the investment must not decompose to give off gases that could corrode the surface of the alloy.
5. The investment should have enough expansion to compensate for shrinkage of the wax pattern and the metal that takes place during the casting procedure.

6. A dental casting investment should be porous enough to allow the air or other gases in the mold cavity to escape easily during the casting procedure.
7. The investment should produce a smooth surface and fine detail and margins on the casting.
8. Should have long shelf life.
9. Should be inexpensive.
10. Should have high compressive strength to withstand impact forces of molten alloy.

No single material is known that completely fulfills all of these requirements.

General composition of investment materials

Generally, an investment is a mixture of the following materials: **1. Refractory Material:** Refractory material is usually a form of ***silicon dioxide*** such as quartz, tridymite or cristobalite or mixture of these.

Contraction of gypsum during casting can be eliminated by using the proper form of silica in the investment.

On heating silicon dioxide change their crystalline structures, this change in crystalline structure results in ***decrease in density*** *and* ***increase in volume that causes rapid increase in linear expansion***, which helps in compensating the casting shrinkage.

Combinations of different types of silica can also be used in dental investments (quartz or cristobalite). As per the type of silica is present in an investment it can be classified as “quartz or cristobalite investment”.

2. Binder Material: Binder materials are used to form a coherent solid mass with refractory material. Most commonly used binders in dental investments are ***α-calcium sulfate hemihydrate, phosphate, and ethyl silicate.***

3. Modifiers: These include sodium chloride, boric acid, potassium sulfate, graphite, copper powder or/ and MgO; are added in a small quantity to modify some physical and mechanical properties of the investment.

In general, there are three types of investments, the choice of investment material depended on melting range of alloy and preference of clinician.

- Gypsum bonded investment (for conventional gold alloys)
- Phosphate bonded investment (for metal ceramic restorations)
- Ethyl silicate bonded investment (for casting of RPD with base metal alloy).

Classification Of Investments

1. Based on type of binder present:

a) Gypsum bonded investment: CaSO4 α-hemihydrate
b) Phosphate bonded investment: Monoammonium phosphate
c) Silica bonded investment: Ethyl silicate.

2. Based on refractory material:

a) Quartz investments
b) Cristobalite investments

3. Based on temperature of casting:

a) Low temperature investments
    - Gypsum bonded investment: CaSO4 α-hemihydrate

b) High temperature investments.
    - Phosphate bonded investment
    - Silica bonded investment: Ethyl silicate.

Gypsum Bonded Investments ($CaSO_4$ α-hemihydrate)

Gypsum is a mineral that is extracted in various parts of the world. Chemically the gypsum that is produced for dental purposes is nearly pure calcium sulfate dihydrate.

Uses: it is used to form mold for casting gold alloys for crown and bridges.

Composition:

Ingredient	Wt %	Functions
Calcium sulfate α-hemihydrate	25–45	• Acts as a binder. • Improves strength.
Silica	55– 75	•Refractory material and can withstand high temperatures. • Regulates the thermal expansion.
Modifiers ex. Boric acid, NaCl,	Trace	•Regulates the setting expansion and setting time. •Also prevents most of the shrinkage of gypsum, when it is heated above 300°C.
Reducing Agents ex. Carbon, powdered graphite	Trace	•To provide a nonoxidizing atmosphere in the mold when the gold alloy is cast.
Coloring Agents	Trace	Provides characteristic color

Properties:

1. Three types of expansion may develop: setting, thermal and hygroscopic expansion (Thermal, setting and hygroscopic expansion is about 1.3% - 2%).

2. It will decompose to sulfur dioxide and sulfur trioxide when heated above 700 C tending to embrittle the alloy therefore it is not used for casting Co / Cr or palladium alloys but used for gold alloy.

Setting Reaction

The most recognized theory of the mechanism of setting is the crystalline theory.

Setting Time

It is the time from the beginning of mixing until material hardens, it ranges between 5−25 minutes.

Factors Influencing Setting Time

Theoretically, there are at least **three** methods by which such control can be achieved.

1. The solubility of hemihydrate can be increased or decreased by addition of potassium sulfate (accelerator) or Borax (Retarder).
2. The number of nuclei of crystallization can be increased or decreased, i.e. the greater the nuclei of crystallization, the faster the gypsum crystals form and the sooner the hardening of mass will occur.
3. The rate of crystal growth can be increased or decreased by addition of accelerator or retarder, the setting time can be accelerated or retarded.

Factors Controlled by Manufacturer

1. *Effect of Varying the Composition:* More amount of silica in the investment powder increases the manipulation time, initial setting time, because the particles of refractory filler interfere with the interlocking of

growing gypsum crystals and making this less effective in developing a solid structure.

2. *Fineness:* The finer the particle size of the hemihydrate, the faster the mix hardens. (More number of gypsum nuclei hence more rapid rate of crystals).

3. *Impurities:* if the manufacturer adds gypsum, the setting time will be shortened because of increase in potential nuclei of crystallization.

Factors Controlled by Operator

In practice, these methods have been incorporated into the commercial products available. The operator can vary the setting time by altering w/p ratio and mixing speed.

1. W/P Ratio: The more the water that is used for mixing, the fewer nuclei are there per unit volume, i.e. setting time is prolonged.

2. Mixing: Within the practical limits, the longer and the more rapidly the mixing is done, the shorter is the setting time, i.e. some gypsum crystals form immediately as it is brought into contact with water. As the mixing begins, the formation of these crystals increases and at the same time the crystals are broken up by the mixing spatula and are distributed throughout the mixture which results in formation of more nuclei of crystallization, thus setting time is decreased.

3. Effect of Temperature: The temperature of the water used for mixing as well as room temperature affects setting time.

- Increased water temperature acts as an accelerator. But temperature above 50°C has a reverse effect.
- A change in temperature results in variation in the solubility of $CaSO_4$ hemihydrate and dihydrate, which may change the rate of chemical reaction.

Normal Setting Expansion (NSE)

The volumetric or linear increase in physical dimensions of an investment caused by chemical reactions that occur during hardening to a rigid structure is called normal setting expansion.

Regardless of the type of gypsum product used, an expansion of the mass can be detected during the change from the hemihydrate to the dihydrate.

As the amount of gypsum increases during setting period, the mass thickens because of the formation of needle-like crystals. The crystallization procedure is an outgrowth of crystals from nuclei of crystallization. Crystals growing from the nuclei can intermesh with and obstruct the growth of adjacent crystals.

If this process is repeated by thousands of the crystals during growth, an outward thrust or stress develops that produces an expansion of the entire mass. Thus, a setting expansion takes place, this crystal impingement and movement results in the production of **micropores**. The structure immediately **after setting** is composed of interlocking crystals, between which are micropores and pores containing the excess water required for mixing. **On drying**, the excess water is lost and the void space is increased.

- A mixture of silica and hemihydrate results in setting expansion greater than that of the gypsum product when it is used alone. The silica particles interfere with the intermeshing and interlocking of the crystals as they form. Thus, the thrust of crystals is outward during growth and they increase expansion.
- The purpose of the setting expansion is to aid in enlarging of the mold to compensate partially for the casting shrinkage of the mold.

Hygroscopic Setting Expansion (HSE)

If the setting process is allowed to occur under water, the setting expansion may be more than double in magnitude. The reason for the increase expansion when the hemihydrate is allowed to react under water is related to the additional crystal growth permitted.

The hygroscopic setting expansion differs from the normal setting expansion in that it occurs when the gypsum product is allowed to set under or in contact with water and that it is greater in magnitude than normal setting expansion. The hygroscopic setting expansion may be **6 or more times** the NSE of a dental investment.

Factors Controlling the Hygroscopic Expansion

1. *Effect of composition:* The finer the particle size of silica the greater is the expansion.
2. *Effect of w/p ratio:* The higher the w/p ratio of the investment the lesser is the expansion.
3. *Effect of spatulation:* as the mixing time is reduced, the hygroscopic expansion is decreased.
4. *Shelf-life of investment:* The older the investment, the lower the hygroscopic expansion.

Thermal Expansion

Thermal expansion is the increase in dimension of a set investment due to temperature increase during burnout.

The expansion of a gypsum-bonded investment is directly related to the <u>amount</u> of silica present and to the <u>type</u> of silica employed.

Thermal Contraction

On cooling from 700°C an investment can undergo contraction, which is less than its original dimension. This contraction results in contraction of gypsum and not related to the amount and any property of silica. On reheating it may expand, thermally to the same dimensions when it was first heated. But reheating of investment is not advisable as it develops internal cracks.

Strength

The strength of an investment increased rapidly as the material hardens after initial setting time. However, the free water content of the set product definitely affects its strength.

Hence two strengths of a gypsum product are recognized.

1. ***Wet or green strength:*** Strength obtained when the water in excess of that required for the hydration of the hemihydrate is left in the test specimen.
2. ***Dry strength:*** When the specimen has been dried of the excess water, the strength obtained is dry strength. The dry strength is 2 or more times the wet strength.

The strength of an investment must be adequate to prevent chipping of the mold during heating and casting of the alloy.

Factors Affecting Strength

1. *W/P ratio*: The greater the w/p ratio, the greater will be porosity. The more the water is employed in mixing; the lower is the strength because the greater is the porosity, fewer crystals are available per unit volume for a given weight of hemihydrate.
2. *Temperature:* Heating the investment to 700°C may increase or decrease the strength as much as 65%, depending on the composition, i.e. greatest reduction with NaCl containing investment.

3. After the investment has cooled to room temperature its strength decreases considerably mainly because of fine cracks that form during cooling.
4. The addition of an accelerator or retarder lowers both the wet and dry strength.

Manipulation

Clean rubber bowl, plaster spatula, required amount of investment material and distilled water (The water and powder should be measured by using an accurate graduated cylinder and scoop) then **Mixing** either by **Hand mixing or Mechanical mixing,** then after mixing the investment material poured around wax pattern and allow for setting.

Phosphate bonded investments

The rapid growth of the use of metal ceramic restorations and the increased use of higher melting alloys has resulted in an increased used of phosphate bonded investments.

Uses: to form mold for casting high temp. dental alloys like Co / Cr. Also use as fixture for holding dental appliance to be soldered or welded.

Composition

It composed from *Powder* (Table) and *liquid.*

Liquid (Colloidal silica liquid suspensions): Colloidal silica suspensions are used with the phosphate investments in place of water as it requires greater expansion. Some phosphate investments are made to be used with water for the casting of many alloys.

Ingredient of the powder	Wt %	Functions
Refractory materials E.g. Quartz or cristobalite or mixture of both	80	•Withstand higher temperatures. • Give large setting expansions.

Binder E.g. Mixture of basic MgO and acidic ($NH_4H_2PO_4$)	20	Increases strength, setting and thermal expansions.
Carbon	Trace	Acts as reducing agent.

Working and Setting Time

- Phosphate investments are affected by temperature. The warmer the mix, the faster it sets. The setting reaction itself is exothermic, and this further accelerates the rate of setting.
- Increased mixing time and mixing efficiency, results in a faster set and a greater rise in temperature.

-

  In general, the more efficient the mixing, the better the casting in terms of smoothness and accuracy.
- Mechanical mixing under vacuum is preferred.

Setting and Thermal Expansion

In practice, setting reaction shows slight expansion, and this expansion can be increased by the use of a colloidal silica solution instead of water. When phosphate investments are mixed with water, they exhibit shrinkage between the temperatures of (200–400) °C. This contraction is practically eliminated by replacing the water with colloidal silica solution.

Manipulation

Required amount of powder and liquid are dispensed in vacuum mixer bowl and hand spatulated for 30 seconds until the powder is wetted by the liquid. Then the mixing bowl is attached to the vacuum mixer and mechanically spatulated according to manufacturer's recommended mixing time. Then the mix is poured in the casting ring (poured around wax pattern and allow for setting).

Advantages

- They have the ability to withstand high temperatures.
- They have sufficient strength.
- They can withstand the impact forces and pressure of centrifugally cast molten alloy.
- They provide setting and thermal expansion high enough to compensate for the thermal contraction of cast metal prosthesis during cooling.

-

Disadvantages

- Using the casting temperature greater than 1375°C, results in mold breakdown and rougher surfaces of the castings.
  The high strength of these investments makes removal of the casting from the investment a difficult task.

Ethyl Silicate Bonded Investments

The ethyl silicate bonded investments require more complicated and timeconsuming procedures. It is used in the construction of the high fusing base metal partial denture alloys.

It is supplied as a powder that requires mixing with a liquid to bind the mixed mass via setting reaction at room temperature.

- The powder consists of refractory particles of silica and glasses in various forms along with MgO and some other oxides in minor amount.
- The liquid that is used for the setting reaction may be supplied as a stabilized alcohol solution of silica gel or it may form from two liquids that are supplied. When the system uses two liquids then one is ethyl silicate and the other may be an acidified solution of denatured ethyl alcohol.

Advantages

- These investments offer the ability to cast high temperature Co / Cr and Ni /Cr alloys.
- Good surface finish (thin sections with fine detail can be reproduced).
- Low distortion and high thermal expansion.
- They are less dense (i.e. more permeable) than phosphate bonded investments.

-
- The low-fired strength makes removal of casting from investment easier than with phosphate bonded investment.

Disadvantages

- Added processing attention and extra precaution needed in handling the low strength fired molds.
  The low strength and high thermal expansion requires a more precise burn out process and firing schedule to avoid cracking.
- The silica-bonded investments undergo slight contraction during setting and the early stages of heating. This is due to the nature of the setting reaction and subsequent loss of water and alcohol from the material.
- Of the three main types of investment—the phosphate bonded products are becoming popular. Silica bonded materials are rarely used nowadays due to the fact that they are less convenient to use than the other products and that ethanol produced in the liquid can spontaneously burn at elevated temperature.

Soldering investment:

It is composed of quartz and calcium sulphate hemihydrates binder for low melting point alloys. For high melting point alloys phosphate bonded investment should be used. Soldering investment should have lower setting and thermal expansion than casting investment. They are made of ingredients that do not have as fine particles size as casting investment

All ceramic crown investment:

This investment must accurately reproduce the fine details; remain undamaged during firing of ceramic. And have thermal expansion

-

compatible with that of ceramic. They are also phosphate bonded and contained fine grained refractory fillers to allow accurate reproduction of details.


FASTFIRE 15
INVESTMENT
AND LIQUID
100
ENVELOPES
90
GRAMS EACH
FastFire 15
FastFire 15
FastFire
Liquid

Dental cement

Dental cements materials: are materials of low strength but they are used extensively in dentistry .They dissolve in oral fluids ,also called cement base or lining, used underneath the filling material to act as a barrier against thermal, electrical and chemical stimuli also against irritant filling.

Luting cements: cements base used for cementation of crown and bridge restorations.

Requirements for ideal cement materials:

1-Protect the pulp from chemical irritants of the filling like acrylic monomers in some of resin based filling material.

2-Form a protective barrier against thermal stimuli especially under metallic restoration and acrylic based filling.

3-protect the pulp from electrical current created when the amalgam restoration placed in contact with gold restoration.

4-It should have sufficient working and setting time.

5-It should be compatible with the filling material.

6-Should not irritant to the pulp.

7-Should not absorbed by oral fluid especially for the luting material.

8-Should has enough strength to withstand the force applied.

Special Applications

1- Root canal sealer.

2- Gingival tissue pack.

3- Surgical dressing.

4- Cementation of orthodontic bands.

5- Orthodontic bonding.

Classification

1-Cements based on phosphoric acid:

a-Zinc phosphate cement. b-Silico phosphate cement.

c-Copper cement

2-Cements based on organo metallic chelate compounds:

a-Zinc oxide\ eugenol cement. b-Ortho-ethoxybenzioc acid(EBA) c-Calcium hydroxide cement. 3-Cement based on polyalkenioc acid: a-Zinc polycarboxylate cement.

b-Glass ionomer cement.

4-polymeric cement.

Zinc phosphate cement

Powder and liquid, two paste

Powder :zinc oxide (reactive component) and other oxides like magnesium oxide.

Liquid :aqueous solution of phosphpric acid buffered by zinc oxide and aluminum oxide. Uses:

1-lining materials

2-Luting materials

3- Sometimes used as a temporary filling material.

Properties:

1-Have a sufficient working time.

2-proper film thickness when used as a luting aagent , depends on particle size and P\L ratio.

3- Ultimate compressive strength for luting agent reach about 80 MPa for lining material 140 MPa ,so it can with stand the forces applied during amalgam condensation,5 minuts should be left before placement of the amalgam filling.

4-Low solubility in water.

5-High initial acidity especially when freshly placed this depend on the P\L ratio, so in deep cavity a sub liner should be used.

6-Good thermal insulator.

7-The material is opaque due to high amount of un reacted zinc oxide, so it should not be used under porcelain teeth.

Manipulation:

The P\L ratio is according manufacturer instruction .Usually for cavity lining putty like consistency P\L ratio (3.5\1) for the luting more fluid mix more fluid mix required to have adequate flow.

Low P\L lead to high acidity and weak mix and irritation of the pulp.

High P\L lead to thick mix and decrease setting time and insufficient working time.

Mixing is done on cold slab, because the reactin is exothermic, the powder is best incorporated in to the liquid by small increments until the desired consistency is reached. a-delay the set

slightly and create more working. b-allow

sufficient powder to be incorporated into the

liquid lead to

higher strength achieved in the final set material.

Silicophosphate cement:

Liquid: phosphoric acid

Powder :mixture of zinc oxide and aluminosilicate glass.

- the set material is more soluble than zinc phosphate cement , but more translucent cement so can be used under porcelain restoration.

-it contains sufficient amount of fluoride ion has a significant anticariogenic influence on the surrounding tooth substance.

Uses : luting cement and temporary filling.

Copper cement:

Powder: is amixture of zinc oxide and copper oxide.

Liquid :phosphoric acid.

-has a bacteriocidal effect produced by the presence of copper has black appearance.

-used in deciduous teeth.

Zinc oxide eugenol cement.

Powder :zinc oxide and zinc acetate(accelerator)

Liquid :eugenol, olive oil (control viscosity)

Uses:

1-temporary filling.

2-Retention of temporary crowns.

3-cement base especially resin reinforced zinc oxide eugenol.

4-Root canal paste but has certain additives.

Properties:

1- compressive strength 20 MPa so not used under amalgam, the reinforced material has a higher strength 40MPa so can be used under amalgam.

2-can be used in deep cavity without subliner (not irritant to the pulp).

3-higher solubility so not used as a luting agent.

4- free eugenol has an effect on resin based filling material ,interfere with polymerization and setting time , cause discoloration so not used as a lining with these types of filling.

5- effective thermal barrier.

Calcium hydroxide Ca (OH)2

Either suspension of ca(OH)2 in water or mostly as 2 pastes.

One paste contains ca(OH)2 and accelerator(zinc stereate)

Other contains glycol salicylate with inert fillers ,pigments and radiopacifiers.

Indication: as a subliner material and pulp capping.

Properties:

1-set within few seconds ,setting time affected by moisture. the set of light activated material is more under control by operator

2-Relatively weak compressive strength 29 MPa.

3-High solubility , not used as luting agent.

4-Sufficient biocompatibility when placed adjacent to the pulp and can destroy any remaining bacteria, also it is able to initiate formation of secondary dentine layer at the base of cavity so used as pulp capping.

5-It can be used under resin based filling material : composite filling.

6-Not used as luting agent

Polycarboxylate cement:

Powder: Zinc oxides and aluminum oxide.

Liquid:Aqueous solution of polyacrylic acid 40%.

Properties:

1-Ultimate compressive strength 80MPa which is sufficient to with stand amalgam condensation.

2- acidic but less irritant than zinc phosphate cement. a-

polyacrylic acid is weaker acid than phosphoric acid.

b- polyacrylic acid has a large molecules and lack mobility to penetrate to dentinal tubules .but not used in deep cavities without subliner.

3-higher solubility than zinc phosphate and glass ionomer but used widely as luting agent.

4-Form an adhesive bond with enamel and dentine, weak bond with gold and strong bond with stainless steel, so used for bonding ortho bands.

5-Set material is opaque and this may detract from the appearance of porcelain crown especially if cement lute margin is visible.

Glass ionomer cement:

Available as:

-Powder\liquid in bottles.

-Pre-proportioned powder \liquid in capsules.

-Light cure system.

-Powder\distilled water(settable type).

Composition: powder: calcium flouroaluminosilicate glass

Liquid:47% solution of 2:1 polymeric acid \taconic acid in water.

For the powder and water product :polyacrylic acid is incorporated in powder.

Uses:

1-cement base.

2-luting agent for crown and bridge.

3-bonding of ortho bands.

4-restoration of deciduous teeth.

P\L ratio 1.3:1

P\W ratio3.3:1

Mixing on paper pad with stiff spatula, mixing time is 30-60 seconds, the cement should be used immediately because the working time is2 minutes .Working time can be increased when mixing is done on cold slab.

Properties:

1- compressive strength range from 60MPa cement material and 220 MPa for filling material.

2-Adhere well to tooth substance(the free carboxyl group bonds to the hydroxyapetite of enamel and dentine giving initial adhesion.

3- lower solubility than ZPC AND Zpolycarboxylate.

4- Translucent due to the presence of unreacted glass.

5-high acidity at freshly mix.

6-Has sustained fluoride relrease.

Temporary filling materials

Indications:

1-During treatment of root canal filling.

2- Inlay and only preparation. TF 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-In pedodontic treatment.

Requirements:

1-Should be easily removed from the cavity.

2- Should have sedative effect to the tooth.

3- Reasonable strength and abrasive resistance.

4- Radiopaque.

5-Reasonable setting time and has flow after setting.

Types of TF:

1-Zinc oxide eugenol ZOE

2-Zinc phosphate (ZP)

3-Zinc –silico phosphate(ZSP)

4-Gutta percha(G.P)

Zinc oxide eugenol

According to ADA specification. There are 4 types of ZOE:

Type 1:temporary cementation

Type 2:permanent cementation of the restoration.

Type 3:temporary filling.

Type 4:cavity liner (base).

It’s the material of choice as temporary filling. supplied as :
Powder :zinc oxide , zinc acetate.

Liquid: olive oil, eugenol.(mixing according to manipulation instructions).or as 2 pastes or 1 paste.

Properties:

1-It has sedative effect on the teeth , reasonable sealing of the cavity ,but it has low strength, low abrasive resistance, low flow after setting.placement of ZOE should not be more than few days, maximum few weeks.

2-The strength and abrasive resistance could be improved by adding 20-40 wt% of fine polymer particles and treating the surface of zinc oxide particles with carboxylic acid(reinforced ZOE type).

3-Sufficient powder should be added to the liquid to achieve putty consistency.

Zinc phosphate cement

Powder and liquid

Properties:

1-Has higher strength and abrasive resistance than ZOE, has a relatively low solubility in oral fluids .but still has low abrasive resistance in area subjected to high load of mastication.

2-Higher powder \liquid is required for low acidity and high strength.

3-Reinforced Z phosphate is more durable and could be used when longer time for TF is required.

Zinc silico phosphate

Powder: zinc oxide powder and silicate glass.

Liquid : phosphoric acid.

Used as TF because of fluoride presence in its composition.

Properties:

1-Has superior strength and it is more translucent than Z phosphate.

2-Not promote healing of the pulp.

3-Used when longer time for T filling is required.

Gutta percha

Composition:

Natural gutta percha, Zinc oxide,wax or resin and metal salts to give radiopacity.

It is supplied by softening the G.P. on the flame and put it inside the cavity.

Disadvantages:

1-Lack the ability to seal cavity.

2-Heat lead to pain to the patient.

3-Low strength

Metal and metal alloys

Alloys: an alloy is a metal containing two or more elements at least one of which is metal and all of which are mutually soluble in the molten state.

Requirements of casting alloys:

1-They must not tarnish or corrode in the mouth.

2-They must be sufficiently strong for intended purpose.

3-They must be biocompatible (non toxic, non allergic).

4-They must easy to melt, cast, cut, grind (easy to fabricate).

5-They must flow well and duplicate fine details during casting.

6-They must have minimum shrinkage on cooling after casting.

7-Easy to solder.

Applications:

1-Construction of metallic framework of removable partial denture.

2-Construction of metal core of crown and bridge. 3-Making

orthodontic wires, bands, brackets, etc…

4-Making endodontic instruments.

5-construction of dental implants.

Classification of metals:

Noble metals like (gold, Platinum, rhodium, ruthenium, osmium, silver, however in the oral cavity silver is not considered noble because of tarnish.

Non noble (base metal) like (chromium, cobalt, nickel, iron, copper etc…

Classification of dental alloys

A-according to number of elements

1-Binary: 2 elements

2-Tertiary: 3 elements

3-Quaternary: 4 elements

B-according to nobility

1-High noble alloys: contain 40% gold or more and 60% noble or more

2-Noble alloys: contain 25% or more noble metals

3-Base metal alloys: contain less than 25% noble.

C-according to major elements:

1-gold alloys

2-silver alloy

3-palladium alloys

4-nickel alloys

5-cobalt alloys

6-titanium

D-according to 3 major elements:

1-Gold- palladium-silver alloys

2- Palladium silver – tin alloys

3-Nickle- chromium-molybdenum alloys

4-Cobalt-chromium-molybdenum alloys

5-Iron-nickel-chromium alloys

6-Titanium-aluminum-vanadium alloys

Gold: gold foil filling (pure gold)

Pure gold is very malleable and ductile. Gold foil is in the form of very thin sheath or foil about 0.001 mm thickness .Its condensed into the cavity and each layer of foil become welded to material already condensed.

Advantages of gold foil filling:

1-perfect corrosion resistance

2-adequate mechanical properties

3-very durable

Disadvantages of gold foil filling:

1-Highly expensive

2-Not esthetic

The technique is time consuming and depend on the skill of operator.

Gold alloys

They are classified according to yield strength and percentage of elongation:

Type 1: soft it is indicated for small inlay restoration not subjected to mastication stress like cl V cavities and cl III cavities.

Type II: medium it is indicated for large inlay restoration

Type III: hard it is indicated for crown and bridge

Type IV: extra hard it is indicated for crown and bridge and removable partial dentures

Composition of gold alloys:

Gold, copper, silver, palladium and some platinum, Zinc, Tin and iron.

Copper: reduce melting point and density, increase hardness, gives red color to gold .If high % it reduce corrosion and tarnish resistance.

Silver: whiten the alloy, increase strength and hardness slightly .In large amount reduce tarnish resistance.

Platinum: increase strength and corrosion resistance and melting point, has white color.

Palladium: It hardens and whitens the alloy, raises fusion temp., increase tarnish resistance. It is less expensive than gold

Zinc: Act as scavenger for oxygen.

Properties:

1-color: yellow and white gold depending on the whitening elements present (silver, platinium, and palladium)

2-melting range: 920-960

3-density: pure gold is 19.3 gm\cm. good alloys have less density

4-yield strength: type III-270 Mpa, type IV -275Mpa,

5- Hardness: type III-121Mpa, type IV-149

6-elongation: type III30-40%, type IV30-40%

7-tarnish and corrosion resistance: they are resistance to tarnish and corrosion due to high content of noble metal.

8-casting shrinkage: it is less than 1.25 -1.65%

9-biocompatibilty: they are relatively biocompatibility

10-invesment: gypsum bonded investment

Alternative to gold alloys:

A-palladium alloys:

These are cheaper than gold alloys, whiter in color, their properties is similar to type III and VI gold alloys but:

1- Lower ductility and corrosion resistance.

2-lower density.

B-Titanium and titanium alloys.

Metal ceramic alloys:

They are alloys that are compatible with porcelain and capable of bonding to it .A layer of porcelain is fused to the alloys to give natural tooth appearance .Porcelain is brittle so these alloys reinforce porcelain (ceramic).

Requirements of metal ceramic alloys:

1-the melting temperature, should be higher than the porcelain firing temp.

2-It should resist creep

3-should be able to bond with porcelain.

4-should have high stiffness (high modulus of elasticity)

5-should not stain or discolor porcelain.

Types of metal ceramic alloys

1-High noble (gold alloys) like gold –palladium, gold palladium- platinum. Gold palladium silver

2-Noble (palladium) like palladium- silver, palladium- gold, palladium- copper

3-Base metal alloys like nickel –chromium, pure titanium, titanium- aluminum

Removable denture alloys

Requirements:

Beside all requirements of metal casting alloys partial denture alloys:

1- Should have low weight, because it is large in structure.

2-should have high stiffness which help in making casting more thinner which is important in the palate

3-should have good fatigue resistance. It is important for clasp

4-should not react with denture cleaners

5-should have low cost

Types:

Cobalt chromium, Nickel chromium, Aluminum alloys and type IV gold alloys

Cobalt chromium alloys:

They are also called satellite because of their shiny- star like appearance. Have a high strength, excellent corrosion resistance, hard.

Application:

1-Denture base

2-Cast removable partial denture framework

3-Crown and bridge

4-Bar connectors

Composition:

1-Cobalt-35-65%-decrease hardness-strength and rigidity

2-Chromium-23-30%- passivity effect, decrease melting point

3-Nickel-0-20%- decrease strength and hardness, increase ductility

4-Molybdenum-0-7% increase hardness

5-Iron-0-5%- increase hardness

Carbon-0.4%

Nickel cause sensitivity in some patients

Properties:

1-Density: It is half of gold alloys (8-9) gm.\cm

2 -Fusion temp. : Higher than gold alloy (1250-1480c)

3-Yield strength : Higher than gold alloys (710Mpa)

4-Elongation: less than gold (1-12%)

5-Modulus of elasticity: Twice than gold alloys (225*10 Mpa)

6-Hardness: harder than gold (432HN) thus cutting grinding, finishing is difficult, special hard. High speed finishing tools are needed

7-Tarnish and corrosion resistance, passivity effect: the formation of layer of chromium oxide on the surface of these alloys prevents tarnish and corrosion in the mouth .Hypochlorite and other chlorine in some denture cleaning solutions should not be used because it will cause corrosion of the alloy

8-Casting shrinkage: it is about 2.3%

Advantages of base metal alloys

1-Lighter in weight

2-better mechanical properties

3-As corrosion resistance as gold alloys (due to passivity effect)

4-Less expensive than gold

Disadvantages:

1-More technique sensitive

2-Complexity in production of dental appliance

3-High fusing temp

4-Extremely hard. So require special equipment for finishing

5-High harden cause wear of restoration and natural teeth contracting then.

Titanium and titanium alloys (Ti-6A1-4V)

Titanium and its alloys are new used in metal-ceramic and for removable partial denture and implants

It has excellent biocompatibility, light weight, good strength and ability to passivity.

Application in dentistry:

1-Metal ceramic restoration

2-Dental implant

3-Partial denture framework

4-Complete denture base

5-Bar connectors

Properties:

1-Color-white color metal

2-Density-light metal (1-4) gm.\cm)

3-Modulus elasticity-110 GPa, half rigid as base metals.

4-Melting temp.: high (1668c) special equipment is needed.

5-Cofficient of thermal expansion CTE-8.3*10cm\cm .It is low compared to porcelain 12.7-14.2*10. So special low fusing porcelain is used with it.

6-Biocompatibility- it is non toxic and excellent biocompatibility with soft and hard tissues

7-Tarnish and corrosion resistance- passivity effect and formation of oxide larger to protect the metal from further oxidation

8-Invesment-phosphate and ethyl silicate bonded investment is used.

Nickel chromium alloys:

They are used for metal ceramic crown and bridge.

Composition:

1-Nickel-61-81% minor elements Beryllium

2-Chromium-11-27%

3-Molybdenum-2-9%

4-Minor elements Beryllium

5-Aluminum

6-silicate

7-copper

Properties:

1-color-white

2-melting point-1155-1304c

3-density-7.8-8.4gm\cm

4-casting-sensetive technique

5-hardness-175-360VHN, the high hardness make them difficult to cut, grind and polished

6-Yield strength-310-828Mpa, stronger than gold

7-Modulus of elasticity-150-210 Mpa (*10). This mean we can make casting thinner and lighter.

8-Elongation-10-28%. They are ductile but not easily burnishable

9-Porcelain bonding- this alloy forms adequate oxide layer which bonds to porcelain.

10-Asthetic- dark oxide layer may be seen at porcelain metal junction.

Wrought stainless steel alloys

Wrought alloys are defined as alloys which are shaped without applying heat (room temperature) by hammering cold working.

Stainless steel is an alloy of iron and carbon that contains Chromium, Nickel and manganese.

Cold working: the alloy is hammered, drawn or bent into shape at room temperature .It is called wrought alloy and it is used for making instruments, burs, wires.

Filling materials

Filling material: can be defined as the material that is used to replace a missing part of the tooth which may result from dental caries, trauma or abrasion. It can be divided in to:

1. **Direct filling materials:** the filling that is placed directly into a cavity on a tooth, and shaped to fit it.
   1. **Indirect filling materials** the dental impression is taken after tooth preparation and sent to a dental technician who fabricates the restoration that place in the prepared tooth.

Requirement of an ideal Filling material:-

1-Working time should be sufficiently long, to enable manipulation and placement of material before setting.

2. Setting time should ideally be short for comfort and convince of both the patient and clinician.
3. The material must withstand large variation in PH and a variety of solvents which may be taken into mouth in drink food stuffs and medicaments.
4. Filling should be good thermal insulator, protecting the dental pulp from the harmful effect of the hot and cold stimuli (low thermal diffusivity).
5. Materials should have values of coefficient of thermal expansion similar to those of enamel and dentine.
6. Metallic material should not undergo excessive corrosion, or be involve in the development of electrical currents which may cause " Galvanic pain " .
7. Should have satisfactory mechanical properties to withstand the force applied, abrasion resistance, compression and tensile strength, modulus of elasticity.
8. It should adhere well to the tooth walls and seal the margins to prevent ingress of fluid and bacteria.

9. It should be harmless to the operator and to the patient and should not be irritant to dental pulp and soft tissue.
10. It should be radiopaque.
11. It should bacteriostatic and anticariogenic .radiopaque

Classification of filling materials:

1. **Metallic**
    a. Amalgam.
    b. Direct Gold filling.
    c. Indirect cast restorations.
2. **Non metallic which include**
    a. **Polymeric**
        - **Unfilled resin (acrylic)**
        - **Filled resin (composite, compomers)**
    b. **Non polymeric**
        - **Silicate cement**
        - **Glass**

ionomers cement Other classifications:

1. **Anterior filling material (tooth colored filling).**
2. **Posterior filling material.**

Composite materials : - The term composite may be defined as a compound of two or more distinctly different materials with properties that are superior or intermediate to those of the individual constituents. In dentistry, the term resin composite refers to a reinforced polymer matrix materials used as restorative materials.

Composition:

A resin composite is composed of four major components:

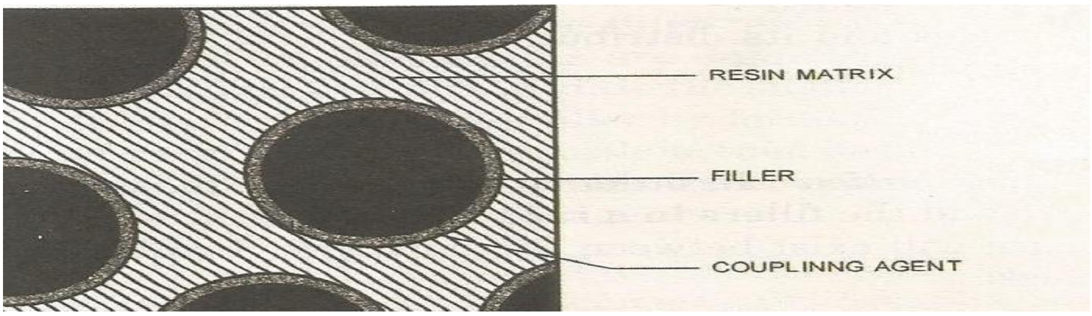
1. Organic resin matrix. (Bis- GMA or urethane dimethacrylate)

2. Inorganic filler particles (Quartz, colloidal silica glasses or ceramic containing heavy metals.
3. Coupling agent (organo silanes).
4. The initiator-accelerator system.

Also they contain

5. Hydroquinone - inhibitor to prevent premature polymerization
6. UV absorber - to improve color stability
7. Opacifiers - e.g. titanium dioxide and aluminum oxide. 8. Color pigments - to match tooth color

Organic resin matrix:- The nature of it may alter slightly from one product to another, essentially The monomers used for the resin matrix are **dimethacrylate** compounds. Its properties were superior to those of acrylic resins. The two monomers that have been commonly used are (**Bis- GMA**) and **urethane dimethacrylate (UDMA**).



Inorganic Filler particles: Fillers have been obtained by grinding minerals such as quartz, glasses, or sol-gel derived ceramics. Composite resins use 3 types of fillers:

1. **Ground quartz filler**
2. **Colloidal silica**

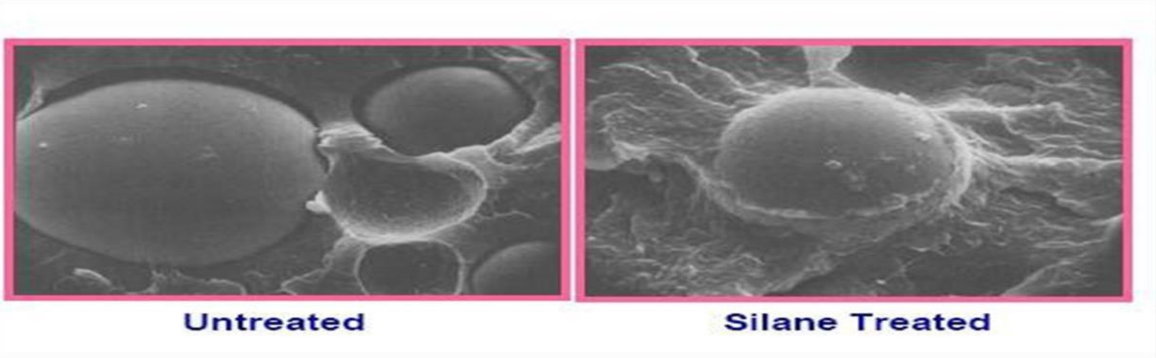
3. **glasses / ceramics containing heavy metal**

- **The function of the addition of filler particles into resin matrix are**

1. Reinforcement (Improves mechanical properties). Increased filler loading generally increases physical and mechanical properties such as compressive strength, tensile strength, modulus of elasticity.
2. Reduction of polymerization shrinkage/contraction.
3. Reduction in coefficient of thermal expansion and contraction.
4. Decreased water sorption. Absorbed water softens the resin and makes it more prone to abrasive wear and staining. 5. The radiopacity are improved

The Coupling agents: the composite to have successful properties, a good bond must form between the inorganic filler and the organic resin, The most commonly used coupling agents are organosilanes (often referred to as silane). Function of coupling agents:

1. They improve the physical and mechanical properties of resin.
2. They prevent water from penetrating the filler - resin interface.
3. Prevent the filler from being dislodged from the resin matrix.



✓**The initiator-accelerator system:** is to polymerize and cross-link the system into a hardened mass. The polymerization reaction can be activated by light-activation, self-curing (chemical activation), and dual curing (chemical and light-curing).

Properties of the composite

1. Low polymerization shrinkage
2. Low water sorption

3. Coefficient of thermal expansion similar to tooth structure
4. High fracture and wear resistance
5. High radiopacity
6. Good bond strength to enamel and dentin (by using bonding)
7. Good color match to tooth structure
8. Easy to manipulation

Types of composite

Based on **curing mechanism** can be divided to:

1. Chemically activated composite or self cured composite.
2. Light activated composite.
3. Dual cured composite

Based on **size of filler particles** can be divided to:

1. Conventional or traditional composite.
2. Small particles composite.
3. Micro filled composite.
4. Hybrid composite.

5. Nanocomposites.

Chemically activated composite resins (self cured composite):

This is two paste system (base and catalyst) two tubes.

The base paste Contains **benzyl peroxide initiator**

The Catalyst paste contains **tertiary amine activator**

The properties of self cures composite are:

1. Activated by peroxide-amine system.
2. Chemical activation is accomplished at room temperature
3. Working time is limited.
4. Air may get incorporated during mixing resulting in reduction of properties.

Light activated composite resins:

UV activated systems: The earliest system used Ultra Violet light. Not used now a day because of the Limited penetration of the light into the resin.

Visible Light activated resins: They are widely used than the chemically activated resins. These are single paste system containing Photo initiator (**camphoroquinone**) and Amine accelerator.

The properties of light cures composite are:

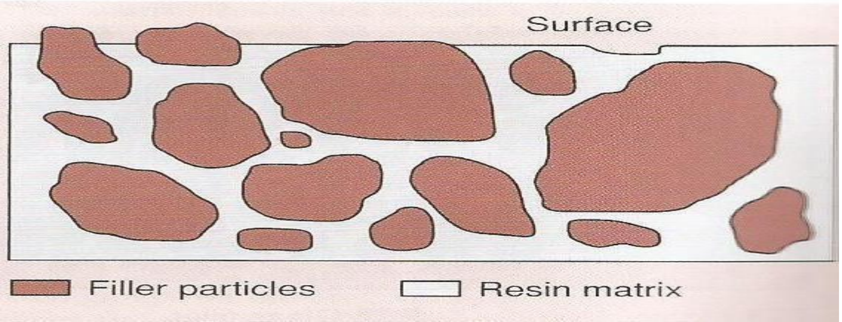
1. Supplied as single component (light tight syringes) or unit-dose capsules.
2. Working time under control of Operator.
3. More Homogenous mix
4. Cure only where sufficient Intensity of light is received. 5. Less chance of air entrapment during manipulation

Dual cured composite: This formulation contained an initiator accelerator that allow light activation follow by self curing. It consists of two light-curable pastes, one containing **benzoyl peroxide** and the other containing an **aromatic tertiary amine accelerator**. The major advantage of this system is assurance of completion of cure.

Classification based on size of filler particles

1. **Conventional composite (Traditional or macrofilled composite):** The early composites were macrofills, These composites contained large spherical or irregular shaped filler particles. they had certain disadvantages:

   1. Surface finish was very poor and dull appearance (Polishing was difficult and results in a rough surface) this is due to selective wear of the softer resin matrix leaving the hard filler particles elevated.
   2. Poor resistance to occlusal wear.
   3. Tendency to discolor, the rough surface tends to stain.



The conventional composite after polishing

2. **Micro filled composite:** They were developed to overcome the problems of surface roughness of conventional composite. The microfilled composite achieved the smoothness of unfilled acrylic direct filling resins the advantages of having filler. The microfilled composite is the resin of choice for esthetics restoration of anterior teeth, especially in non-stress bearing Area.

3. **Small particles composite:** Small particles composite were introduced in an attempt to have good surface smoothness (like microfilled composite) and yet retain or improve the physical and mechanical properties of conventional composite.

4. **Hybrid composite: -** These were developed so as to obtain better surface smoothness than that of small particle, but yet maintain the properties of latter. The hybrid composites have a surface smoothness and esthetics competitive with microfilled composite for anterior restoration.

5. **Nanocomposite/ Nanofillers :** Nanofillers and Nanocomposites the latest advancement in composite technology has been the use of nanotechnology in development of fillers.

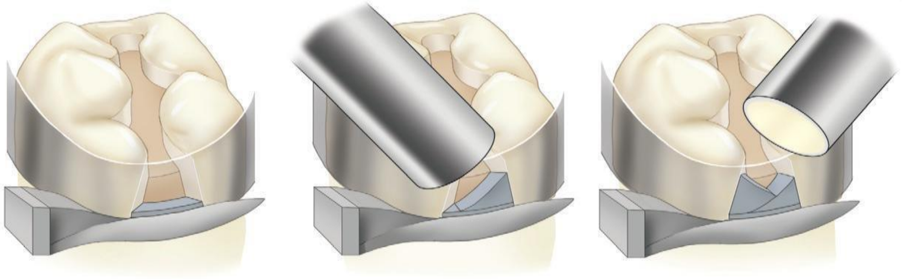
Manipulation of the composite: Composites used for restoring teeth are usually supplied in a kit containing the following:

- Syringes of composite resin paste in various shades.
- Etching liquid (37% phosphoric acid).
- Enamel dentin bonding agent.
- Shade guide.

The manipulation is

1. **pulpal protection**: with cavity liner
2. **Etching:** the enamel at the cavity margins is acid etched with **37% phosphoric acid** solution or gel for 30 seconds. Flush the acid away with water, and gently dry the surface with a stream of air.

3. **Bonding agent** an enamel and dentin bond agent is applied polymerized that provides micromechanical retention of the restoration. The cavity is now ready for the composite.
4. **dispensing:** For light-Cured Composites, dispense small increments and pack into the cavity preparation, while controlled setting time allows for the individual polymerization of small increments of composite which help in:
   A- Use of multiple shades of composite within a single restoration.
   B- Accommodating polymerization shrinkage within each increment.



For Self- and Dual-Cured Composites, Mix equal amount of base and catalyst pastes thoroughly for 20 to 30 seconds use plastic or wooden spatulas (avoid metal spatulas because the inorganic filler particles are abrasive and small amounts of the metal can abraded and discolor the composite.

5. **Insertion:** The composite can be inserted with a plastic instrument, which does not stick to the composite during insertion or It can be injected into the cavity preparation by a syringe
6. **Polymerization:** for light cure composite the exposure times vary from 20 to 60 seconds for a restoration **2 mm** thick depending on the type of light-curing unit and the (type, depth, and shade) of the composite. for Self-Cured Composites: After mixing, a working (or insertion) time is **1 to 1.5** minutes then the mix will begin to harden, the setting time is about **4 to 5** minutes from the start of the mix.

   For Dual-Cured Composites: They contain chemical accelerators and light activators, so polymerization can be initiated by light and then continued by the self-cured mechanism.
7. Finishing and polishing.

Glass ionomer cements: There are two main types of glass ionomers:

1. **Conventional glass ionomer**
2. **Resin-modified glass ionomer which is subdivided into:**

- **True light cure Glass Ionomer System**
- **Tri-Cure Glass Ionomer System**
- **Nanoionomer**

Uses of Glass Ionomers: both conventional and resin-modified glass ionomers are used for a variety of restorative applications, specially in:

1. High caries activity or where caries are likely to recur.
2. small caries lesions in non-stress-bearing restorations in permanent teeth
3. interim restoration in permanent teeth.
4. They make an excellent liner or base in all deep lesions
5. Resin-modified glass ionomers are often the material of choice for pediatric restorations and preventive applications

Properties of Glass Ionomers:

1. The physical and mechanical properties of GIs are lower than that of composite resins .
2. The coefficient of thermal expansion has been shown to be closer to tooth structure (dentin) than are resin composites. (Serve as good insulation against thermal shock, particularly when used as liners and bases).
3. Fluoride ion release and uptake these materials act as a **reservoir of fluoride ions**.
4. Good adhesion to tooth structure. Unlike composite materials (etching of the enamel or dentin surface is not needed). Hence these materials are sometimes referred to as being **self-adhesive**. 5. is radiopaque

Compomers: Compomers or poly acid–modified composites have fluoride-releasing silicate glasses. They are used for restorations in low stress–bearing areas, Compomers are recommended for patients at medium risk of developing caries.

Dental amalgam:

Is an alloy produced by mixing liquid mercury with solid particles of silver, tin, copper, and sometime zinc, palladium, indium 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.

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.

Composition: The amalgam alloy consists essentially of silver and tin. in lesser amounts Copper, zinc, and a trace of gold, palladium, indium, selenium.

Amalgam **type**	**Silver** (Ag)	**Tin** (Sn)	**Copper** (Cu)	**Zinc** (Zn)
Low copper (lathe-cut)	70.3 %.	25.9%.	2.8%	0.9%.
Low copper (spherical)	72 %.	25 %.	3 %.	-
High copper (admix)	69.5 %.	17.7 %.	11.8 %.	1 %.
High copper (spherical)	61%.	26 %.	13 %.	-

Function of each constituent :

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 .

Classification of Amalgam alloys

- **Based on copper content (most popular one)**

1) Low copper alloys: **irregular (lathe-cut) or spherical in shape.**
2) High copper alloys: either
   a. Admixed or dispersion or blended alloys
   b. Single compositional or uni composition alloys

- **Based on zinc content**

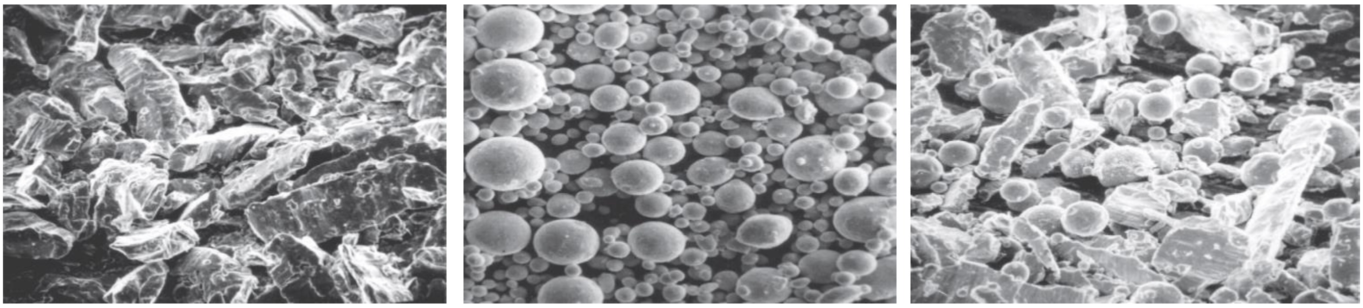
1) Zinc containing alloys: contain more than 0.01% Zinc. 2) Zinc Free alloys: contain less than 0.01% Zinc.

- **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 .



Lathe-cut spherical admixed

- **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 silvermercury 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,

γ=Ag_3Sn (powder form so strongest phase)
γ_1=Ag_2Hg_3 (Noble phase, main constituent of set amalgam) γ_2=Sn_8Hg (weakest phase causes tarnish and corrosion)

$Ag_3Sn + Hg$ ———— Ag_2Hg_3 + Sn_8Hg + Ag_3Sn

(□) gamma phase (□1) gamma one (□2) gamma two (□)

High copper alloy: They are preferred because of their improved mechanical properties, resistance to corrosion, and better marginal integrity (because the weakest (□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).

Setting reaction may be simplified as follows:-

Ag_3Sn + Ag-Cu + Hg ————Ag_2Hg_3 + Sn_8Hg +Ag_3Sn+AgCu

Eutectic (□1) (□2) (□) unreacted

and later Sn_8Hg + AgCu ———— Cu_6Sn_5 + Ag_2Hg_3

(□2) eutectic η Eta phase (□1)

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

AgSnCu + Hg $\longrightarrow$ Cu_6Sn_5 + Ag_2Hg_3
+ AgSnCu

(□ +E) (η Etaphase) (unreacted)

Properties of set amalgam:

1-Dimensional change: freshly mixed Amalgam would 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.

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).

Modern amalgams show a net contraction, whereas older amalgams always showed expansion. Two reasons for this difference are - :

- Older amalgams contained larger alloy particles and were mixed at higher mercury: alloy ratios.
- Hand triturating was used before ,Modern amalgams are mixed with high speed amalgamators (equivalent to increase in triturating time (

2-Strength:-Hardened amalgam has good compressive strength. But cannot with stand high tensile or bending strength.

- The factors affecting strength of the amalgam are:

1) **Effect of triturating**. Either under-trituration or over-trituration will decrease the strength of both low copper and high copper amalgams.
2) **Effect of mercury content**. Sufficient mercury should be mixed with the alloy wet each particle of the alloy.
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.

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. Causes of the porosity are :-
   A) Decrease plasticity of the mix caused by:
      1. Too low Hg\alloy ratio.
      2. Under trituration.
      3. Over trituration.
   B) Inadequate condensation pressure. Increase condensation pressures improve adaptation at margins and decrease the number of voids.
   C) Irregularly shaped particles of alloy powder. voids are not problem with spherical alloys
   D) Insertion of too large increments.

3-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**).

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 □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.

Bonding of Amalgam: Amalgam does not adhere to the tooth structure. At best it affords only a reasonably close adaptation to the walls of the prepared cavity. For this reason cavity varnishes are used to reduce the gross leakage that occurs around a new filling.

The use of dentin bonding agents with amalgam is another relatively new method to reduce microleakage. If the amalgam is properly inserted, leakage decreases as the restoration ages in the mouth. This may be caused by corrosion products that form in the interface between the tooth and the filling, sealing the interface and preventing leakage.

Manipulation of Amalgam .

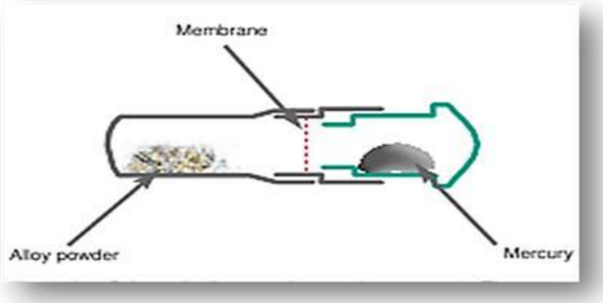
1. Proportion and Dispensers.
2. Trituration.
3. Condensation.
4. Carving.
5. Polishing.

1. Proportion and Dispensers: Because proportioning is important, manufacturers have developed some simple dispensers for alloy and mercury. Dispensers by volume are unreliable because it is affected by particle size and the degree of packing (trapped air and voids) in dispenser.

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.
2. More standardized procedure.
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.

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.

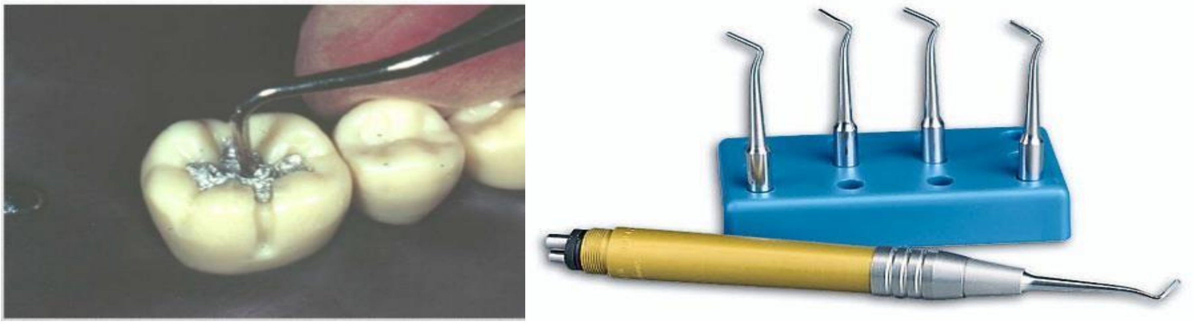
Increasing the condensation pressure results in a significant increase in compressive strength.

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).

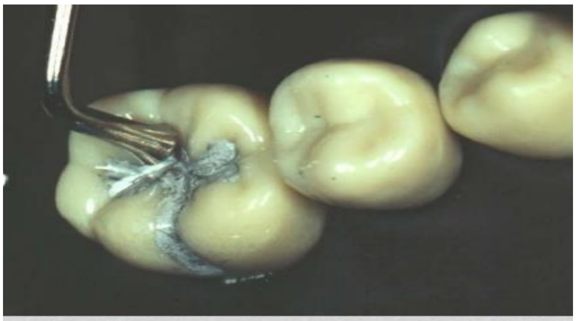
Mechanical condensation: These devices are useful for condensing irregularly shaped alloys when high condensation forces are required.

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.



Final shape and burnishing

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.

Preventive&obturating materials

Preventive materials

1. Chemotherapeutic agents
    a) Dentifrices
    b) mouth washes
    c) fluoride varnishes
2. Resin sealants
    a) self cure
    b) light cure
3. Glass ionomer sealants and resin modified glass ionomer sealants

Dentifrices(tooth paste)

- Function of tooth pastes
    1. Enhance cleaning of exposed tooth surfaces
    2. Removal of pellicle ,plaque ,and debris
    3. Carrier for fluoride, detergents, abrasives and whitening agents to improve esthetic of teeth.

General composition of tooth pastes

1. Colloidal binding agents: they act as carrier for the active ingredients ex: sodium alginate.

2. Preservatives to inhibit bacterial growth within the paste.

3. Flavouring agents: peppermints, wintergreen, cinnamon

4. Abrasives: aid in the removal of heavy plaque and adhered stains and calculus ,like calcium pyrophosphate.

5. Humectants :to stabilize the composition and reduce the water loss by evaporation

6. Detergents: like sodium lauryl sulfate to reduce surface tension and enhance removal of debris

7. Therapeutic agents: like stannous fluoride to improve resistance to caries 0.025-0.15%

8. Other chemicals: minor amounts to reduce corrosion, give color, remove discoloration.

Mouth washes: They are composed of three main ingredients:

1. Active agents which is selected for specific health care benefit such as anticarious activity, anti microbial effect, fluoride delivery or reduction of plaque adhesion
2. Solution of water or alcohol to dissolve the active agents
3. Surfactants: help to remove debris and dissolve other ingredients, flavoring agents to breath freshness like eucalyptol, menthol and thymol.

The main active ingredients are Chlorhexidine and fluoride

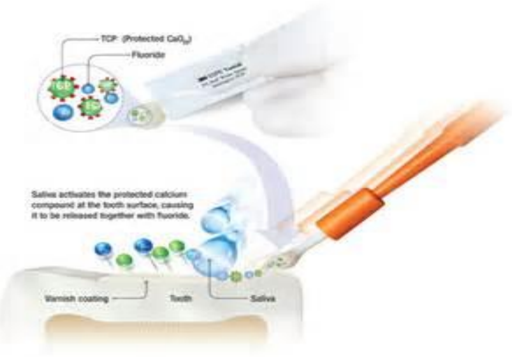
Disadvantages :

1. high ethanol content produce softening effect on resin restoration
2. Staining effect of chlorhexidine and euogenol in some mouth washes
3. Toxcicity with high ethanol content

<u>Fluoride varnishes:</u> The fluoride is dissolved in organic solvent that evaporate when applied or sets when exposed to moisture leaving thin film of calcium fluoride deposited on the tooth surface which later converted to fluroapatite by remineralization reaction. It differs from mouth wash its action last for several hours before vanish wears while the mouth wash for seconds.

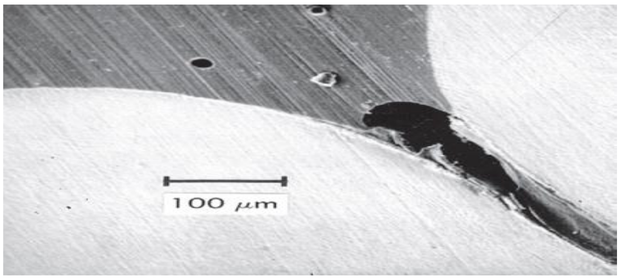
It is used in young children with high risk of caries ,also in old patients to prevent root caries

- <u>Disadvantages:</u> bitter taste and tooth discoloration which is transient.



<u>Pit and fissure sealants:</u> Deep pits and fissures are difficult to clean and more susceptible to caries and fluoride treatment was least effective in prevention of caries.

In 1965 the first technique was called occlusal sealing. Methyl -2-cyanoacrylate mixed with polymethyl methacrylate and inorganic powder. Then placed in the pits and fissures and cyanoacrylate polymerize when exposed to moisture.

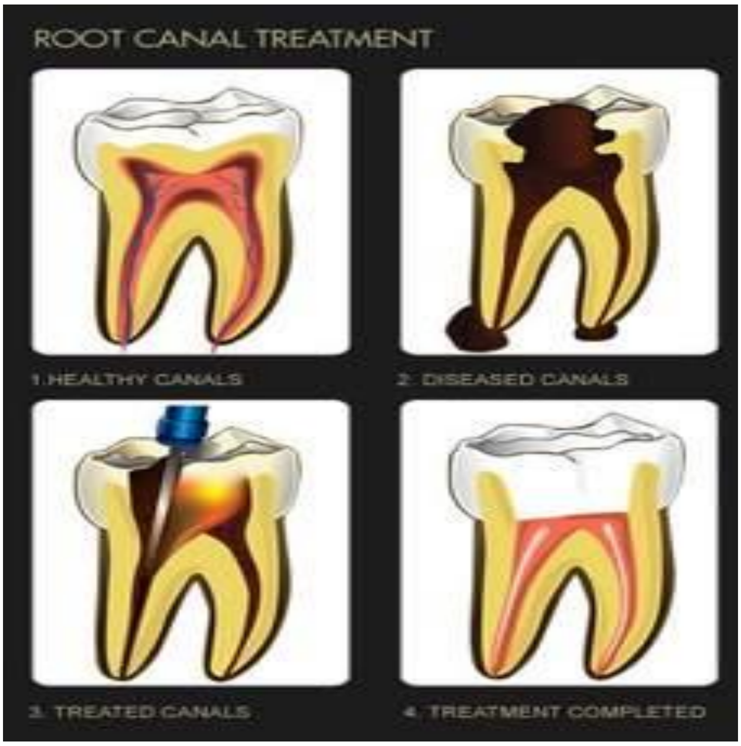


Glass ionomer sealants

Requirements of dental sealants:

1. high flow and good wetting to the surface
2. good wear resistance
3. high compressive strength and rigidity
4. tooth colored
5. less solubility
6. good bond to tooth
7. coefficient of expansion and contraction compatible with the tooth

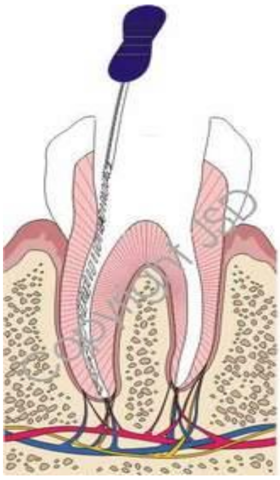
Root canal filling materials (obturating materials)

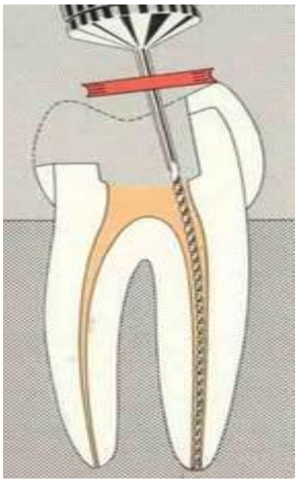


Endodontic instruments

These are instruments used to remove the pulp tissue during root canal treatments

1. **Stainless steal:** They are either hand use or motor driven , they are either reamers or files





- <u>Properties</u>
  a. High torsion strength
  b. High bending strength
  c. Corrosion resistant
  d. Good cutting ability
  e. Sterilization should not have bad effect on the cutting ability or on corrosion resistance.

2. **Nickel-titanium:** These have higher strength and lower modulus of elasticity and are super elastic than stainless steal instruments .

Obturating materials: material that will fill the canal space and may or may not be used with a sealer. ***Obturating materials can be classified as:***

1. Solid materials.
2. Semisolid (paste or softened form).

- **Desirable properties of obturating materials:**

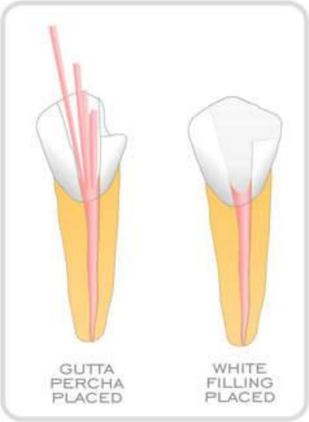
1. Easily introduced into the canal.
2. Seal the canal laterally and apically.
3. Not shrink after being inserted.
4. They should be impervious to moisture.
5. They should be bactericidal or reduced bacterial growth.
6. Radiopaque.
7. Not stain tooth structure.
8. Not irritant to periapical tissue or affect tooth structure.
9. Easily sterilized.
10. Easily removed from the root canal.

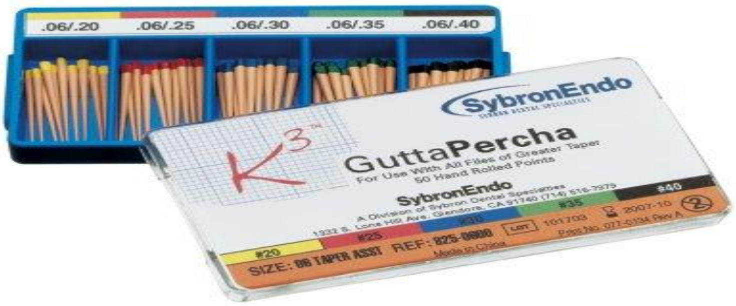
Solid Obturating materials: The most common type of these materials is: *Gutta- Percha and Synthetic resin- based core material.*

The major advantage of these materials is the ability to control length, as well as the reasonable ability to adapt to irregularities and to create an adequate seal.

Gutta- Percha: It is the standard to which other materials are compared because of its advantages like:

- Plasticity (it adapts with compaction to irregularities in prepared canal).
- Easy to manipulate.
- Easy to remove either partially or totally.
- It has relatively little toxicity.
- It tends to be self sterilizing (if there is a possibility to be contaminated they are predictably sterilized by immersion in 1% sodium hypochlorite for 1 minute).





- **Disadvantages:**

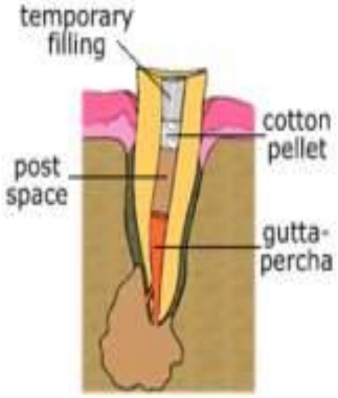
1. It lacks adhesion to dentine and a slight elasticity, which causes a rebound and pulling away from the canal wall.
2. Warmed gutta- percha shrinks during cooling, also after evaporation of a solvent when immersed for sterilizing.

- **Composition:**

1. Zinc oxide (± 75%).
2. Gutta- perch (20% give plasticity).
3. Binders.
4. Opaque material.
5. Coloring agents.

- **Shapes:** Gutta- Percha cones are available in two basic shapes:

1. ***Standardized cones*** are designed to have the same size and taper as the corresponding to endodontic instruments (No.40 cone corresponding to No.40 file).
2. ***Conventional cones*** the tip of the cone has one size and the body of the cone another.



Resin obturating material: As a potential replacement for Gutta- Percha, the core material is polycaprolactone with fillers of bioactive glass and other components; this combination an attempt to form a single entity or monoblock in the root canal system. **Shapes:** conventional and standardized.

- **Advantages of Resin obturating material:**

1. Noncytotoxic material.
2. Biocompatible.
3. No mutagenic.

Silver points: Silver points are pure silver, were designed to correspond to the last file size used in preparation and fill the root canal in all dimensions. Silver points are a poor long term choice as a routine obturating material.

- **Disadvantages:**

1. No adaptability.
2. Toxicity from corrosion.
3. Tight frictional fit and hardness; silver cones difficult to remove partially or totally.
4. If silver cones are contacted with a bur, their seal may be broken.

<u>Semisolid (paste) Obturating materials:</u> These materials include:

1. **<u>zinc oxide and eugenol</u>:** zinc oxide and eugenol may be mixed pure (no additives) to intermediate thickness. Other formulations combine ZnOE with additives like" opaque, metallic oxide or chlorides, steroids, plasticizer, paraformaldehyde, and various other ingredients". Use of these materials is below the standard of care.
2. **<u>Plastic</u>:** it has a resin- based sealer, such as AH26 and Diaket, be used as sole obturating material.

- **<u>Advantages:</u>**

1. Paste technique is simple.
2. Little equipment is needed.
3. Techniques are fast, easy to use and involve the use of a single material.

- **Disadvantages:**

1. Length control: difficult to avoid overfills or underfills, so radiographs should be made many times during obturation to assess length this leads to time consuming and subject the patient to needless radiation.
2. Sealability (unpredictability): may be related to three factors
   a) Large voids within the material or adjacent wall/
   b) Shrinkage of ZnOE on setting, which leaves a space for microleakage.
   c) Solubility of paste with tissue or oral fluids.

Endodontic sealers: Sealer is more important than the core obturating material; the objective for using a sealer to provide a fluid- tight seal. Sealer must be used in conjunction with the obturating material, regardless to technique or material used

Endodontic ZOE are used alone or with gutta-percha as root canal sealer

They are 2 types, conventional sealer are used with gutta-percha and therapeutic are used without a core material and are formulated with ingredients such as iodoform, paraformaldehyde or trioxymethylene which have therapeutic effect

- Requirements

1. High flow to penetrate into irregularities and accessory canals of the root
2. Low film thickness &low solubility
3. Radiopacity& dimensional stability

4. The sealer and its component should neither tissue destruction nor cell death.
5. Sealer should provide adequate working time for placement and manipulation of an obturating material.
6. Adhesiveness (a truly adhesive material would form an absolute bond between the core obturating material and dentine).
7. Remnants should not cause future stain of the crown.
8. Sealer should be soluble in a solvent (retreatment may be necessary).
9. Sealer should be insoluble to oral and tissue fluids.
10. Sealer should be bactericidal.

- **Types of sealers:** The four major types of sealers are: ***ZnOE based, plastic, glass ionomer cement, and those containing calcium hydroxide.***

DENTAL MATERIALS

RELINING MATERIALS

Relining is the procedure used to resurface the tissue side of the denture with new base material to make it fit more accurately. Relining materials are classified into 3 types:

Tissue conditioner.

Soft liners.

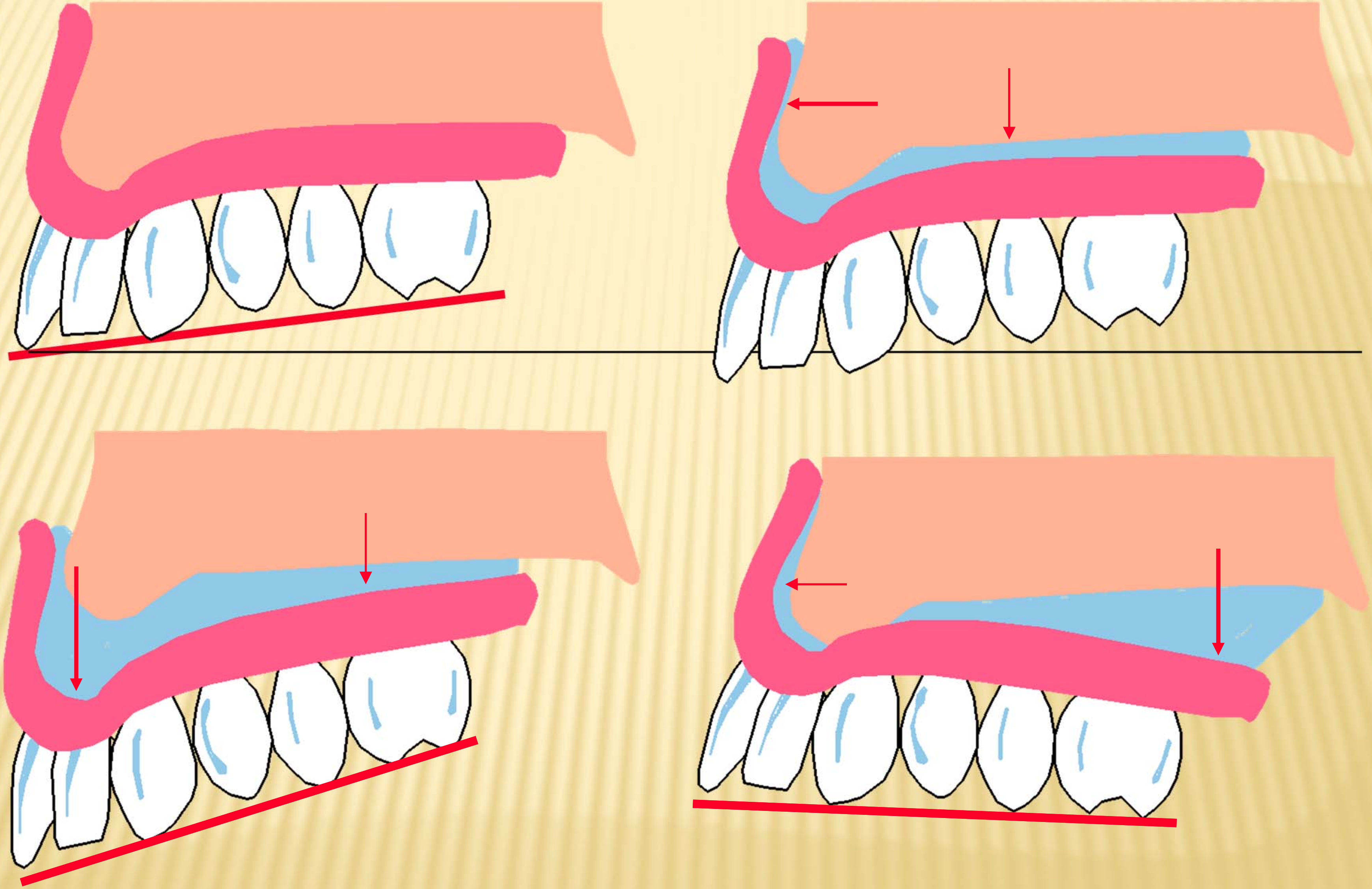
Hard reline materials.

TISSUE CONDITIONER

- They are soft plastic materials used primarily to treat and supporting the denture .They are used-for short term application and should be replaced every 3-days.


GC TISSUE CONDITIONER
1-1PKG.
LIVE PINK
GC
GC TISSUE CONDITIONER
GC TISSUE CONDITIONER

The purpose of using tissue conditioners is to absorb some of the energy produced by the impact of masticator forces-. It serves as shock absorber between the occlusal surface of the. Denture and the underlying oral tissue therefore they promote healing of the inflamed tissue.



Indication and uses:

1- It allows the patient to adapt to the new denture with minimum discomfort. Tissue conditioning before denture fabrication .

2- Record base stabilization Improve soft tissue healing underneath the denture.

3- Functional impression.

TISSUE CONDITIONER

- It is supplied as powder and liquid. Powder is polyethylmethacrylate
- liquid is ester plasticizer as butyl phathalyl, butyl gluconate and ethyl alcohol up to 30%

TISSUE CONDITIONER

- they are mixed and placed in the inner side of the denture and seated in the patient mouth .The mix pass into several phases from mixing to gelatin to elastic phase which lasts for several days then become hard and rough as the plasticizer and alcohol are leached rapidly and water is absorbed. There is weight loss of 4-9% after 24 hours

SOFT LINERS

Requirements:

1. has High bond strength to the denture base.
2. Dimensional stability of the liner during and after processing
3. Low solubility and water absorption
4. Permanent softness and resiliency.
5. Color stability
6. Easy manipulation and process
7. Biocompatible to tissue
8. Absence of odor and taste

Soft liners are classified into 2 types:

1- Silicon elastomeric:

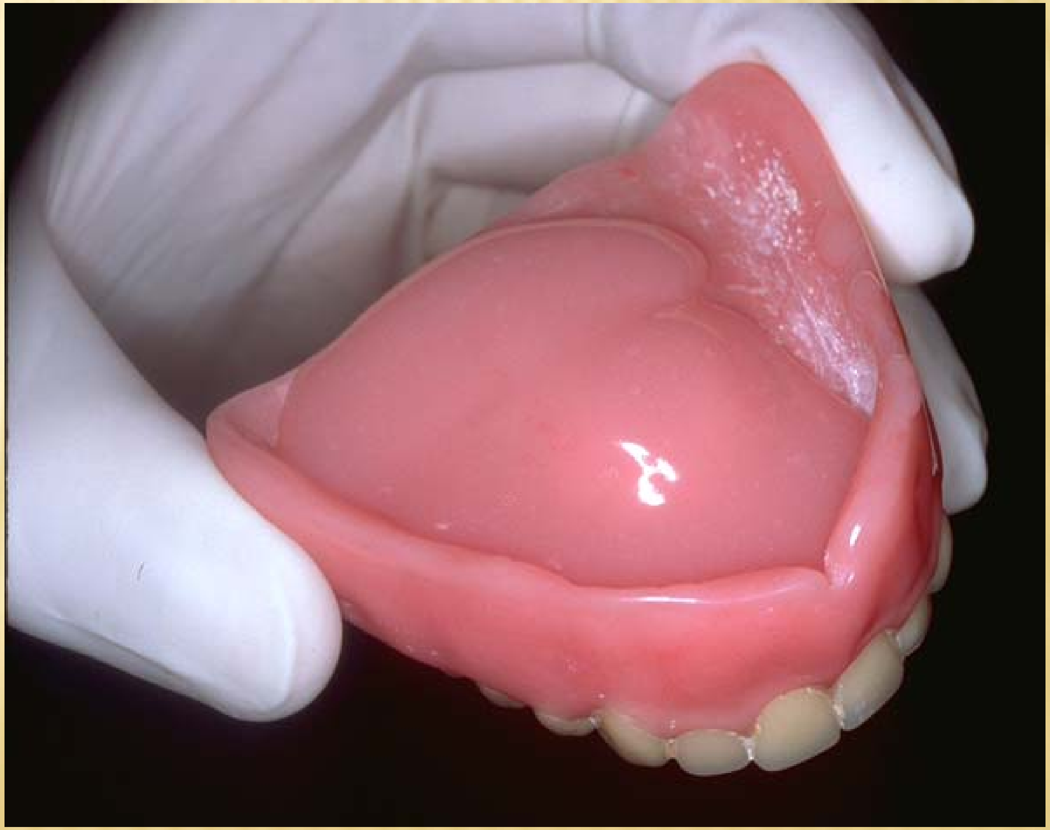
a. Auto polymerized.

b. Heat polymerized.

2- Soft acrylic:

a. Auto polymerized.

b. Heat polymerized.



SOFT LINERS

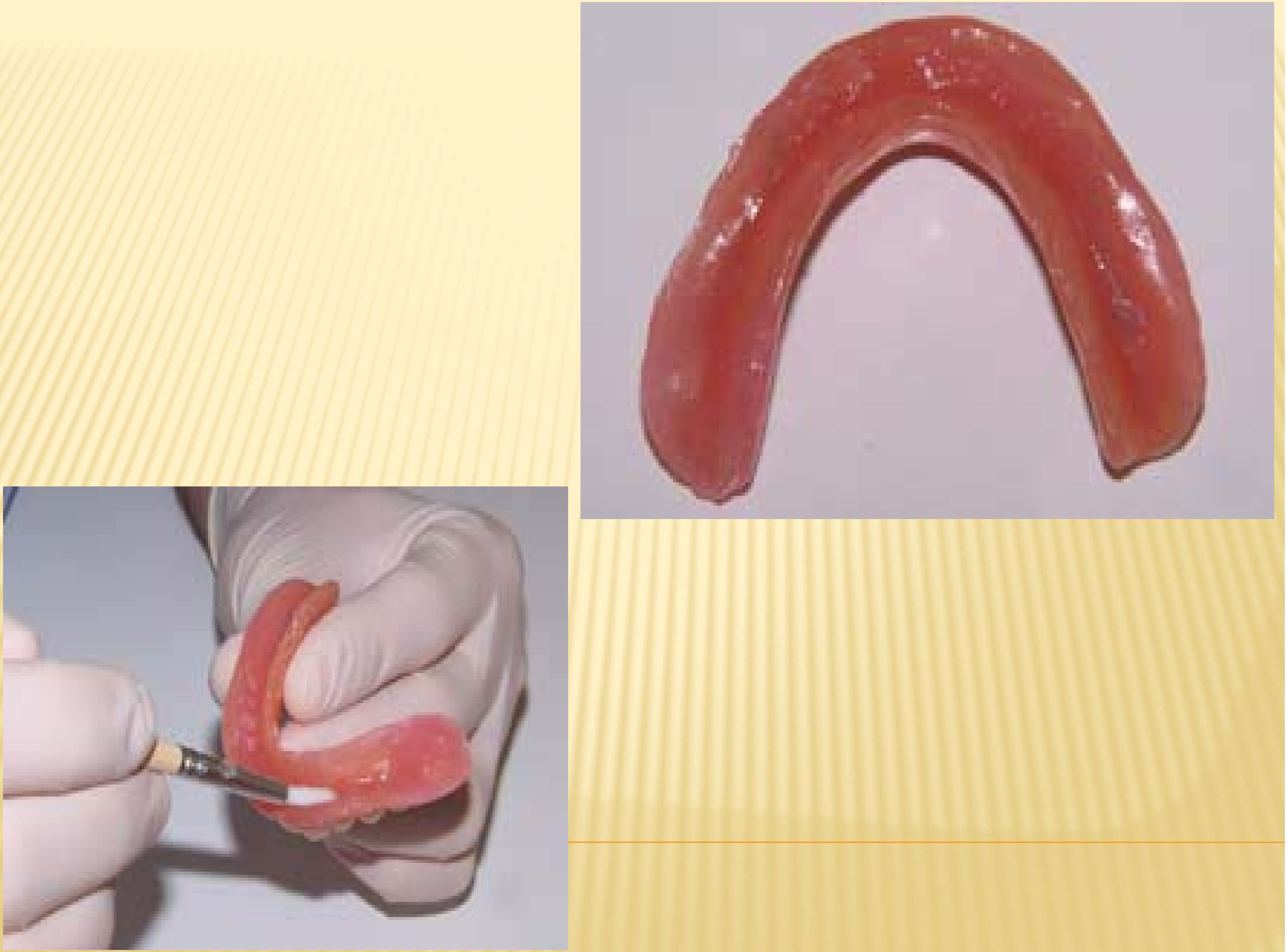
- <u>Silicon elastomeric soft liners</u>
- It is the most successful material for soft liners, they are not dependent on leach able plasticizer therefore they retain resiliency for prolonged period they are well tolerated by oral mucosa, odorless, tasteless, excellent elastic properties but they have poor adhesion to polymethylmethacrylte denture.

Auto cured silicon is supplied as paste and liquid

Paste: is hydroxyl terminated poly dimethyl siloxane.

Liquid: polymer and filler. Liquid is; tetra ethyl silicate and dibutyltindilurate.

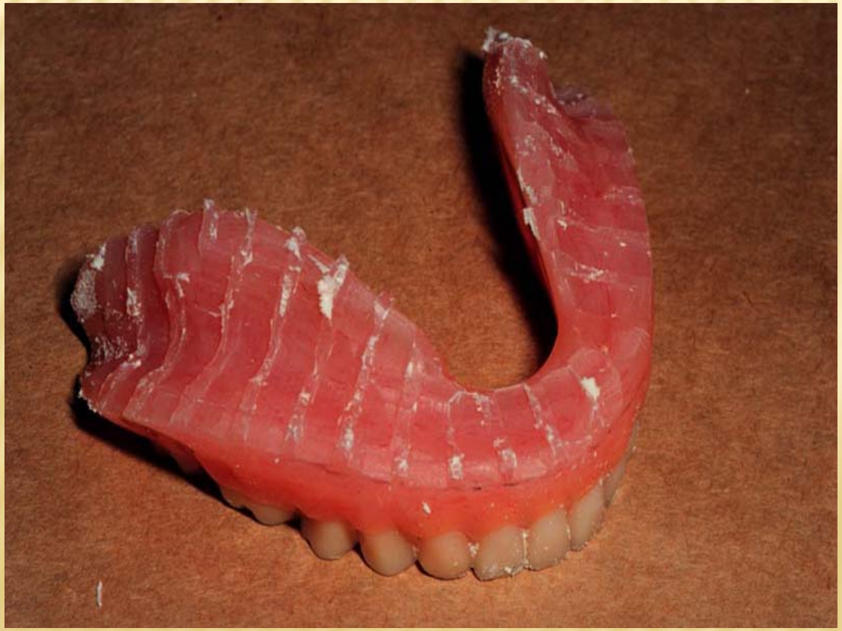
Setting is condensation reaction.

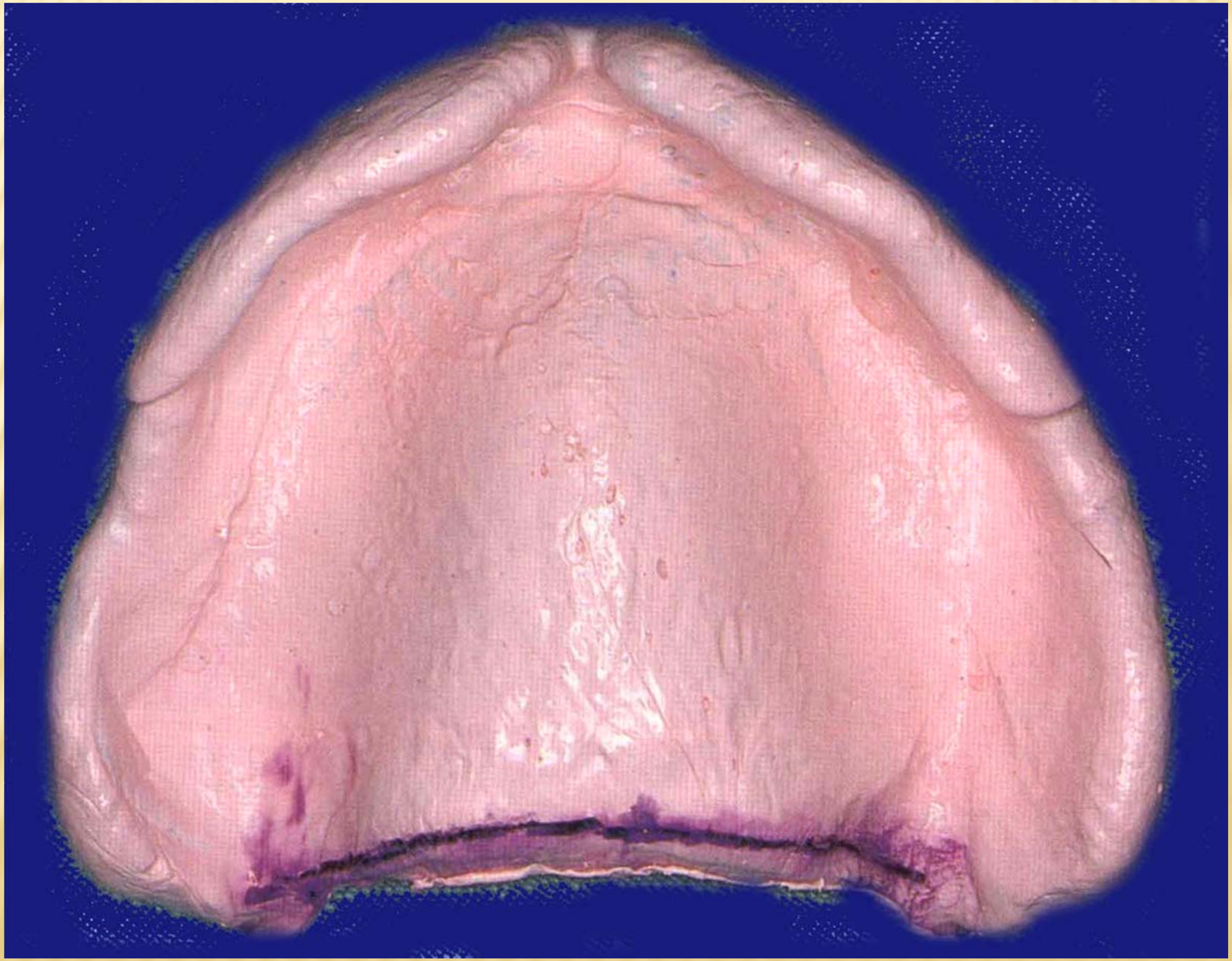


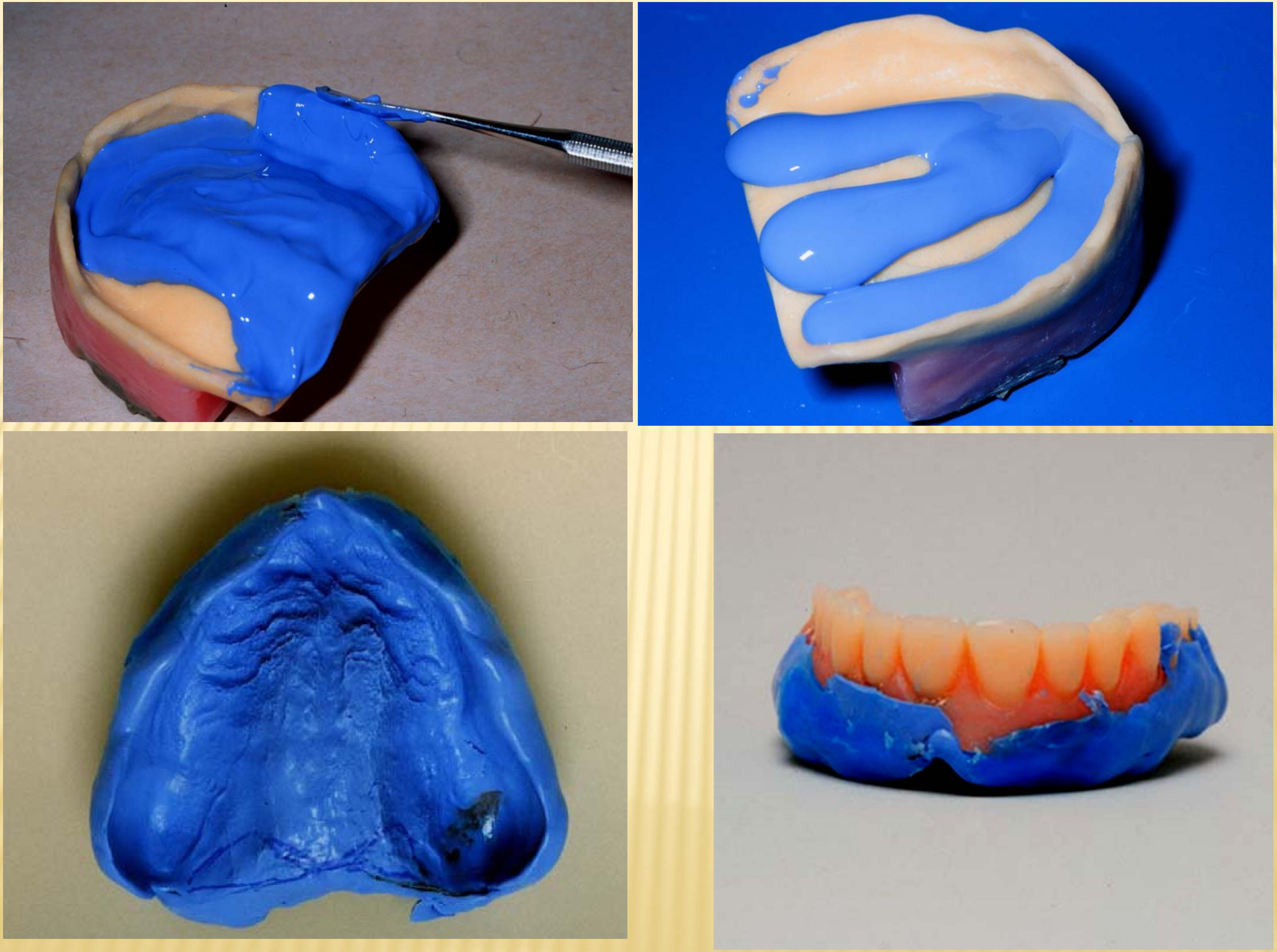
Heat cured silicon liner is supplied as one component system.

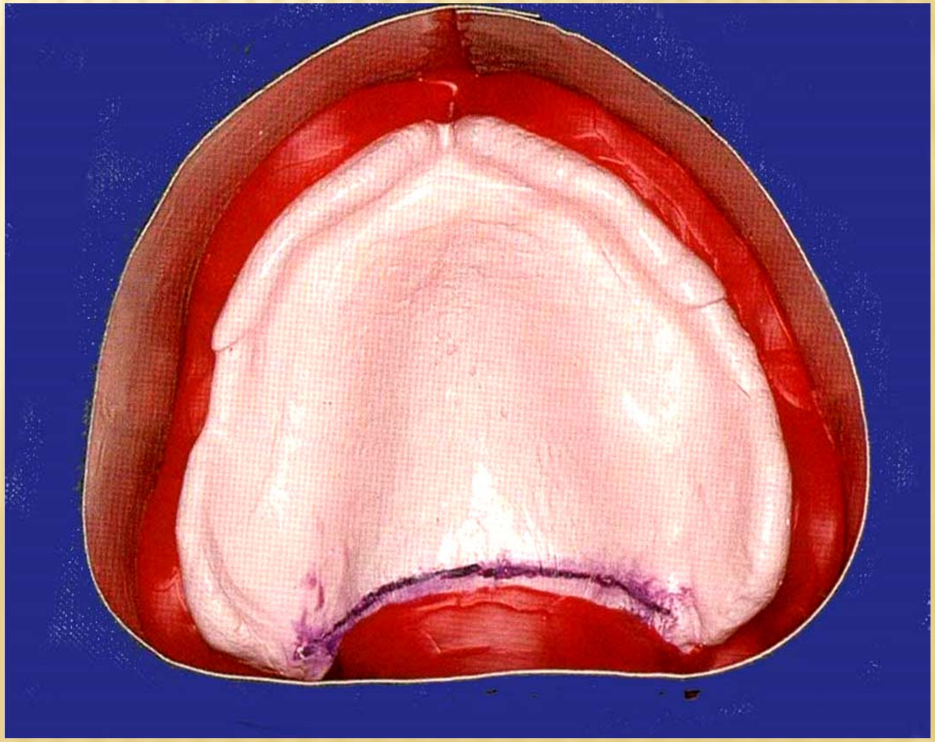
DENTURE PREPARATION:

REDUCE TISSUE BASE



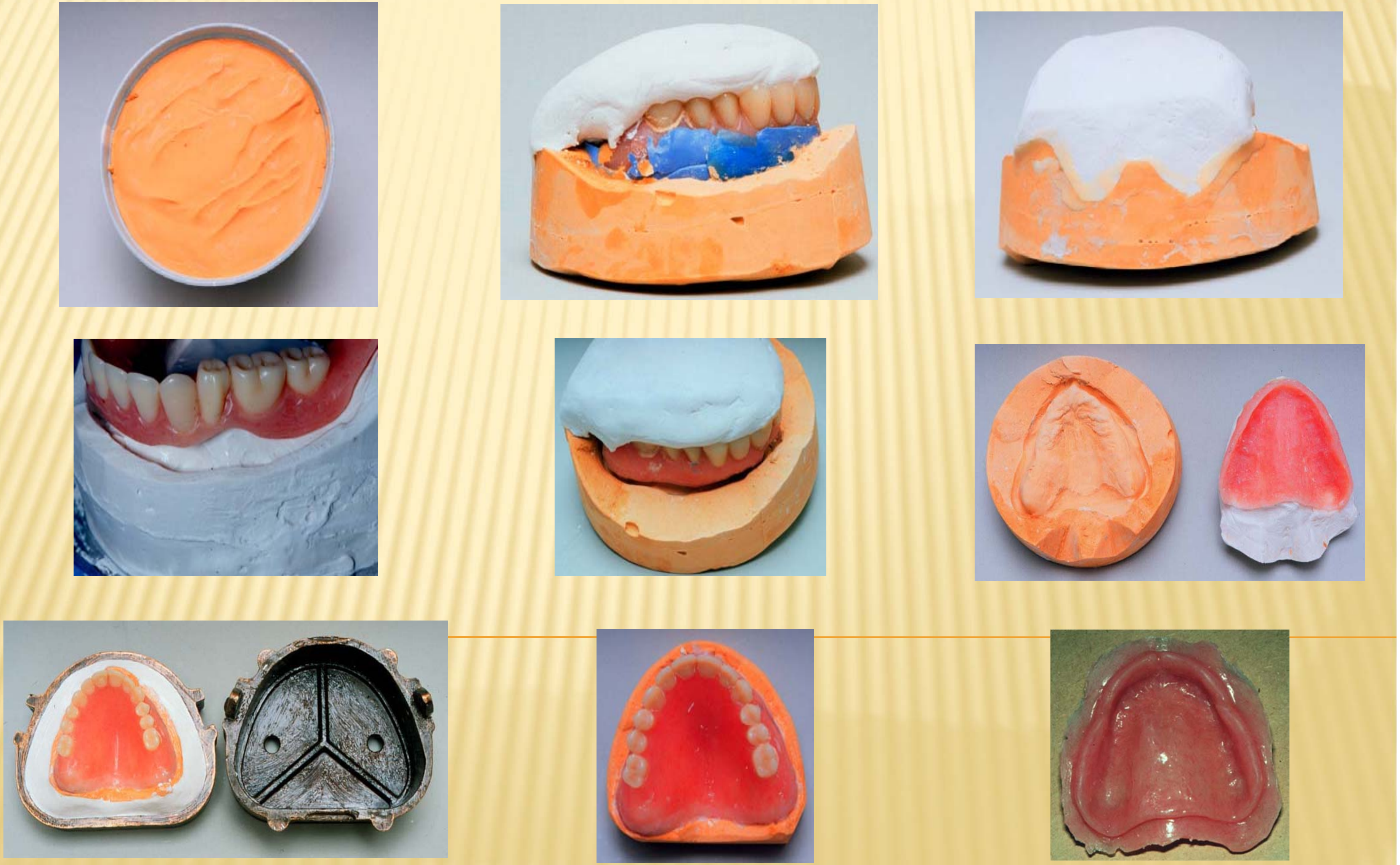


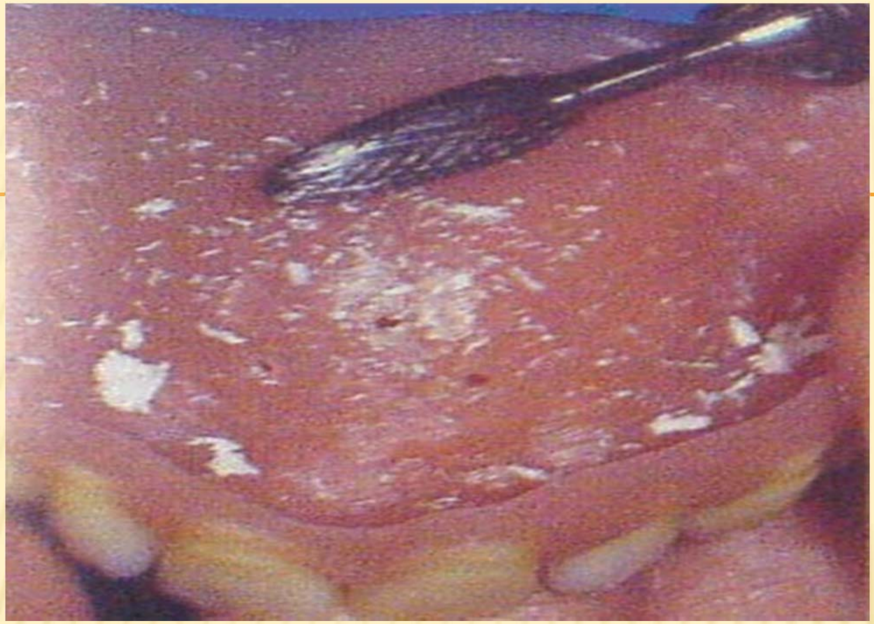


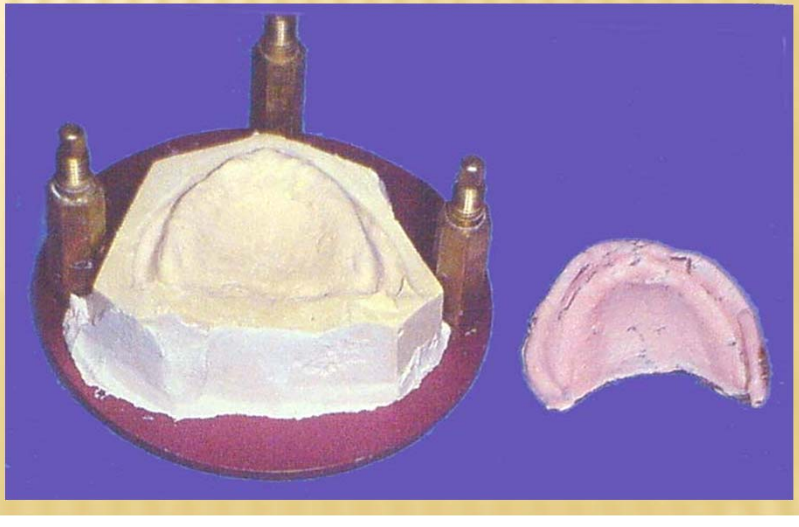


CHECK RELATIONS INTRAORALLY

SEND TO LAB FOR PROCESSING







SOFT ACRYLIC LINER

They are composed of plasticized acrylic polymers or copolymers which could be

1. Chemically activated.
2. Heat activated.

Self cure type is composed of:

1. <u>Powder:</u> of polymethyl or polyethyl methacrylate and peroxide initiator.
2. <u>Liquid:</u> is ester such as dibutyl phthalate and methyl methacrylate and tertiary amine activator. They are similar to tissue conditioner but they are not as soft as them and retain their-softness for longer-time

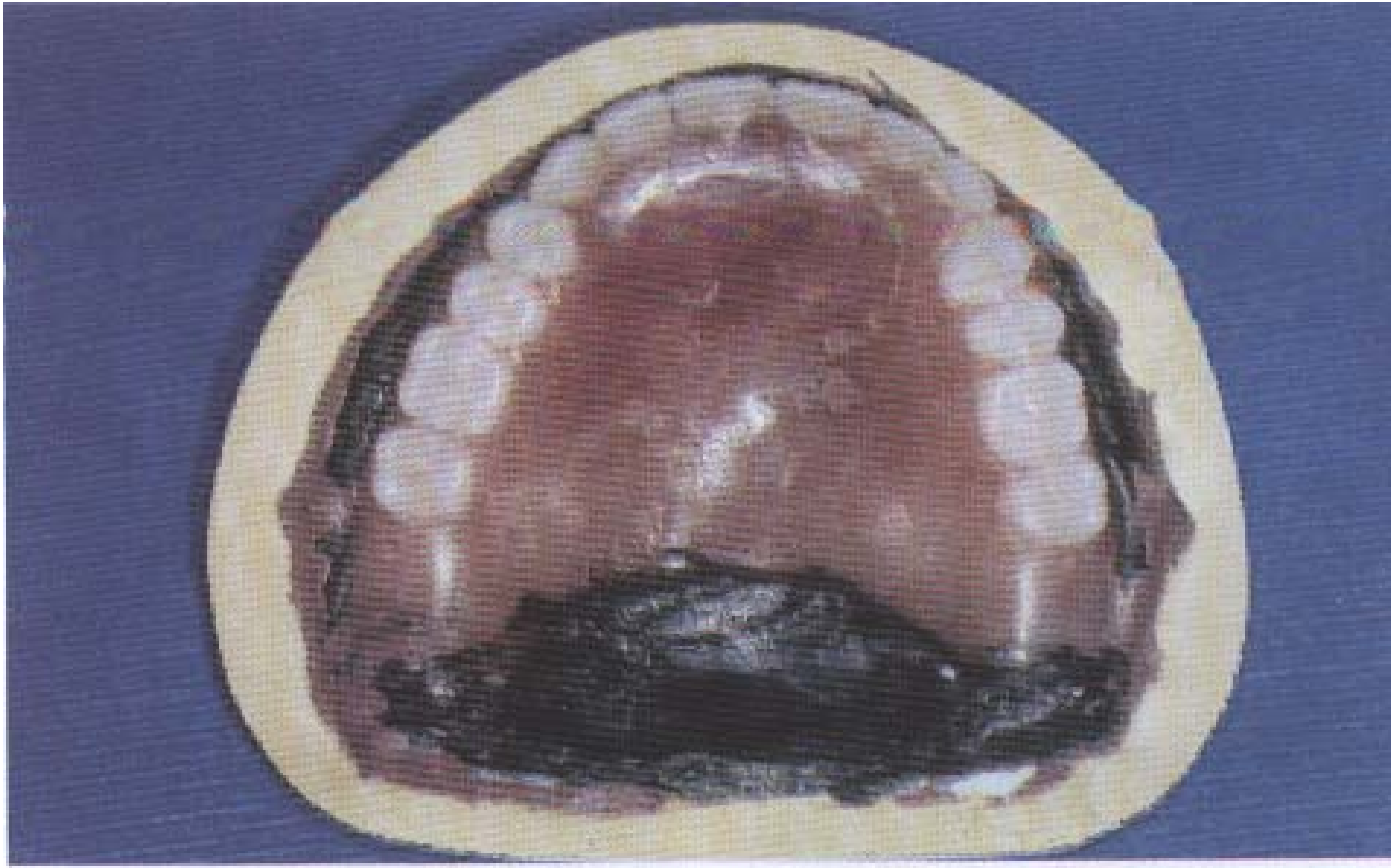


Fig. 16.1. The denture and cast (not separated) ready for mounting on the Hooper Duplicator.

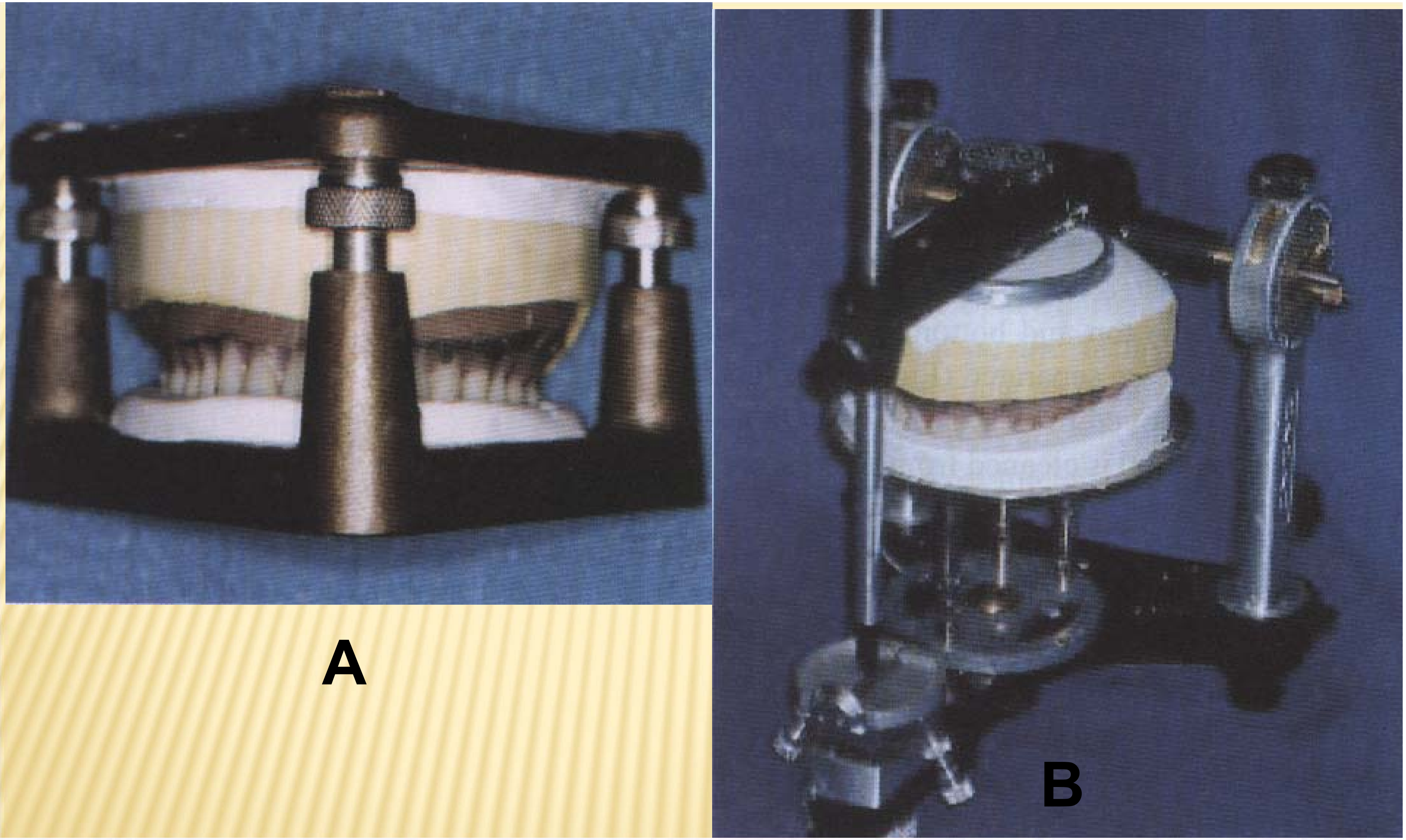


Fig. 16.2. Maxillary cast and denture mounted on upper member of Hooper Duplicator with an occlusal index formed on lower member of Duplicator or; (B) on an articulator.

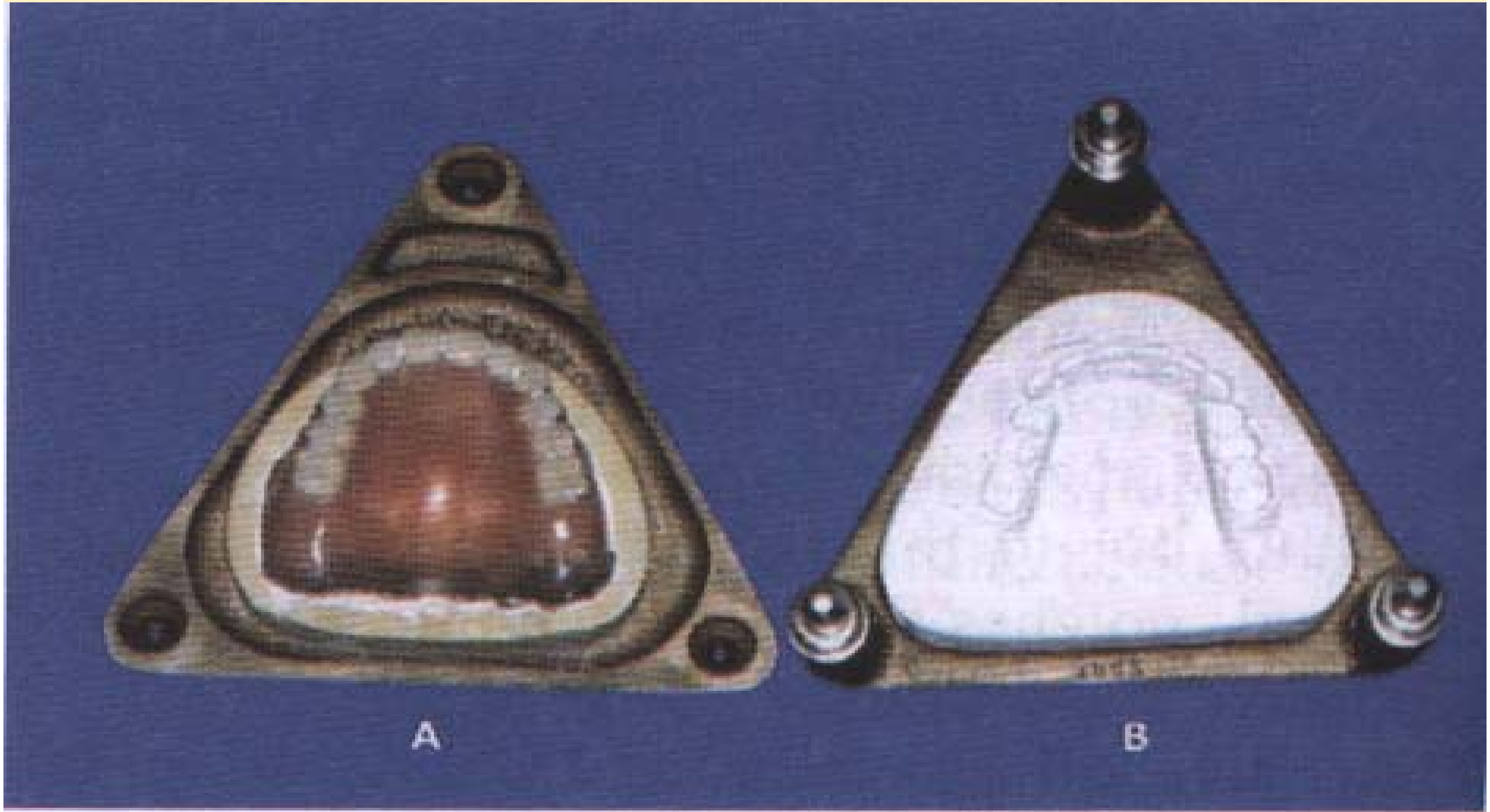


Fig. 16.3. Upper and lower members of Hooper Duplicator separated. Note the occlusal index on the lower member of the duplicator.

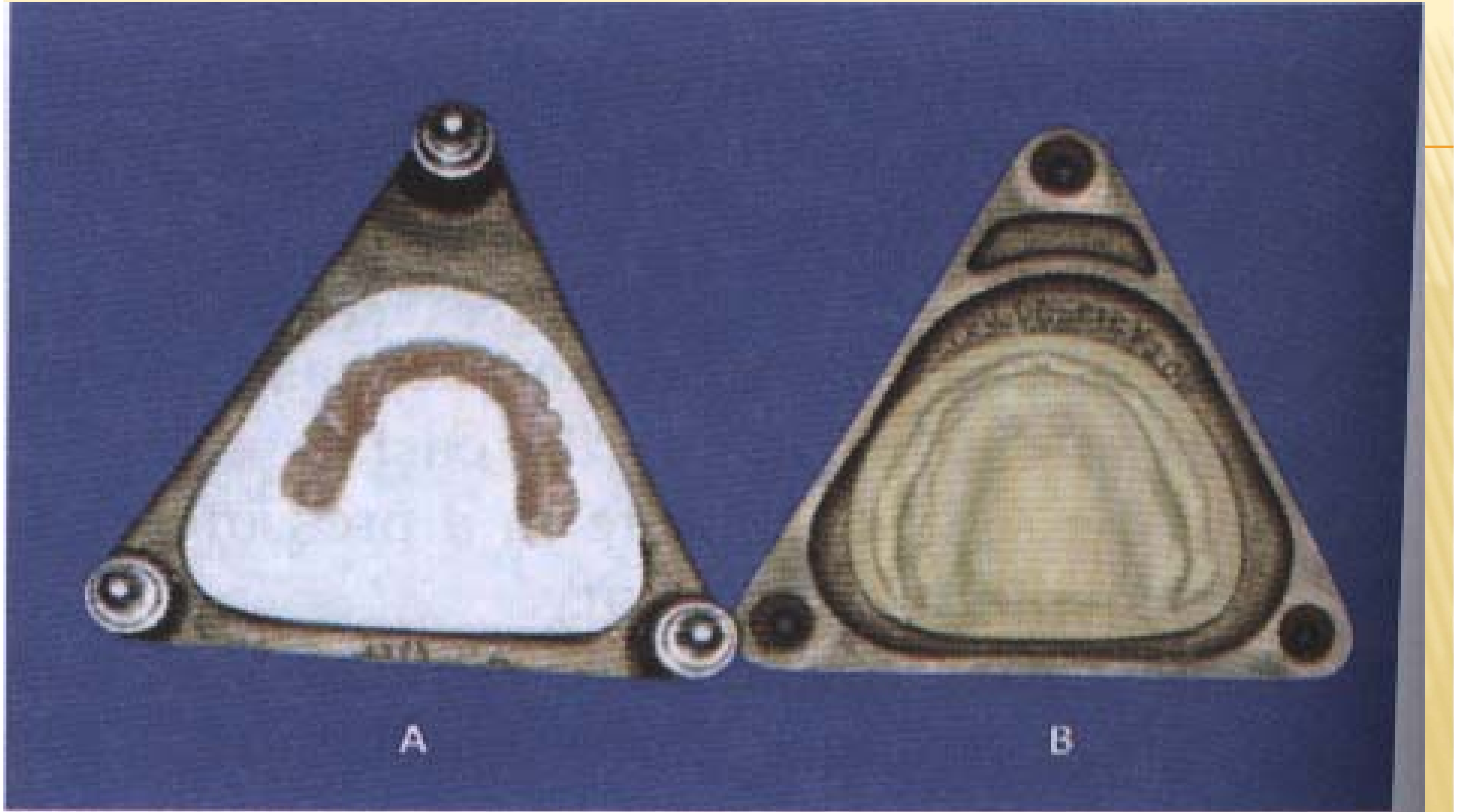


Fig. 16.4. Denture base has been ground close to the lingual surface of the teeth leaving only a narrow horseshoe of acrylic resin holding the arch of teeth.

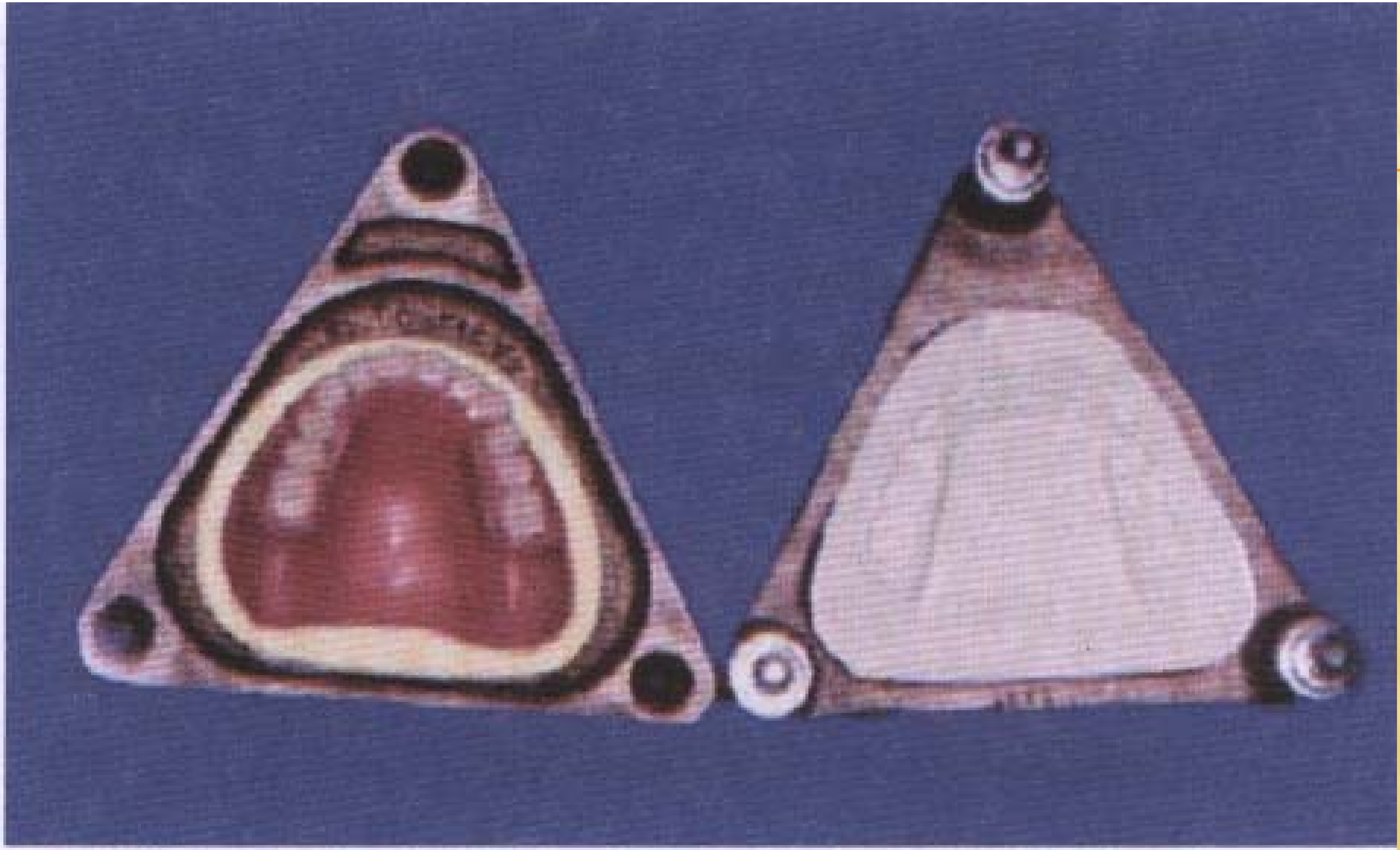


Fig. 16.5. After scraping the posterior palatal seal, a new denture base is waxed to the denture teeth.


10 cc
8 cc
6 cc
4 cc
2 cc
Powder
4 cc
2 cc
Liquid


Medscape

Uses of soft liners

- Improve the comfort or fit of old denture until the new denture is made for a period of several weeks
- Provide comfort for patients who can not tolerate occlusal pressure

such as in case of alveolar ridge resorption, knife edge ridge, and sharp lingual Mylohyoid ridge when surgery is contra indicated chronic soreness because of heavy bruxism or poor health, vitamin deficiency, with oral cancer treatment of congenital or acquired defects of palate .

none of the soft liners is permanent; it may last 6 months to be replaced.

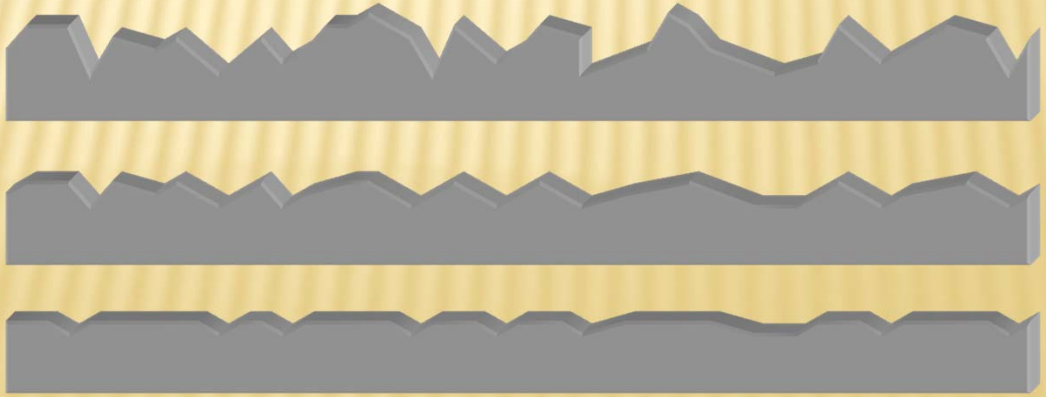

Caulk
Dentsply
Lynal®
TISSUE CONDITIONER AND TEMPORARY R
Caulk
Dentsply
Lynal
TISSUE CONDITIONER AND TEMPORARY RELINER
POWDER
120 G
LIQUID
90 ML

ABRASIVES: FINISHING AND POLISHING

Dental restorations are finished before placement in the oral cavity to provide:

1. good oral health.
2. function.
3. Asthetic.

good oral health is maintained by a. resisting the accumulation of food debris and pathogenic bacteria by reducing the roughness of the surface and the smooth surfaces are easier to maintain in hygienic




Acrylic Contouring & Finishing Kit

Good oral health is maintained by:

A. Resisting the accumulation of food debris and pathogenic Bacteria by reducing the roughness of the surface.

B. Smooth surfaces are easier to maintain in hygienic state, also with some metal restoration, tarnish and corrosion activity can be reduced if the surface is highly polished.

- Function is enhanced because food glides more freely over occlusal surface and embrasure surfaces during mastication.

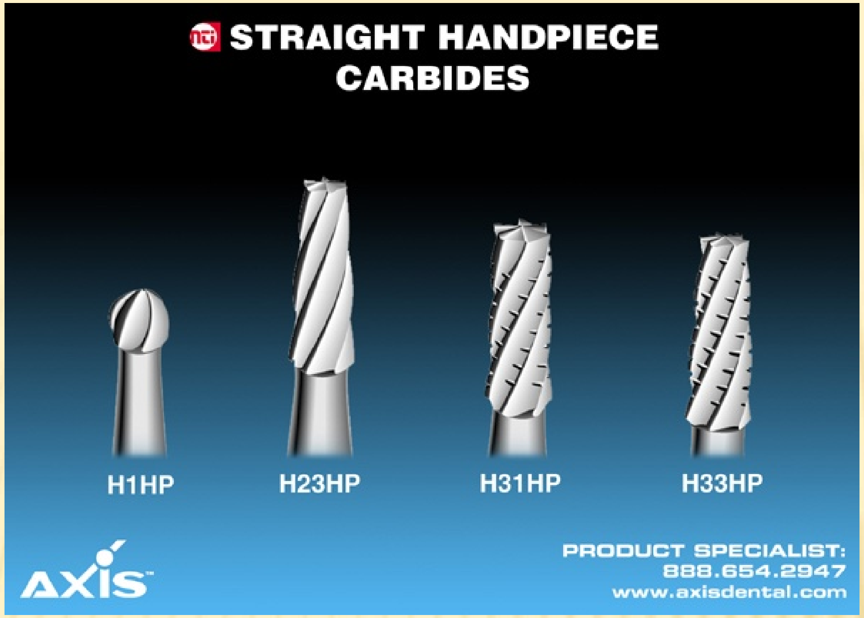
An abrasive material:

is a material which is harder than the material which need to be abraded (restoration or appliance). The abrasive particles should posse's sharp edges that cut rough surface of the abraded material.

The abrasive particles could be bonded together to form grinding wheel or may be carried a cross the surface of bristles of a revolving brush or "buff' or bonded to a piece of cloth or paper & rubbed across the surface.

The smoothness of the surface depends on:

- Hardness & shape of the abrasive particles. The abrasive particles should be harder than the material which is abraded & should be strong & its elastic limit should equal to its maximum strength so that it will fracture cleanly to form new cutting edges without permanent deformation.
- Size of the particles. Large particles have wide cutting edge & cut more than smaller size, start with large size then fine size.



- Speed of movement. The slower speed of movement, the deeper the scratches which are produces but in slow speed and in high speed, the total amount of material removed will be approximately the same (1450-3000 rpm).

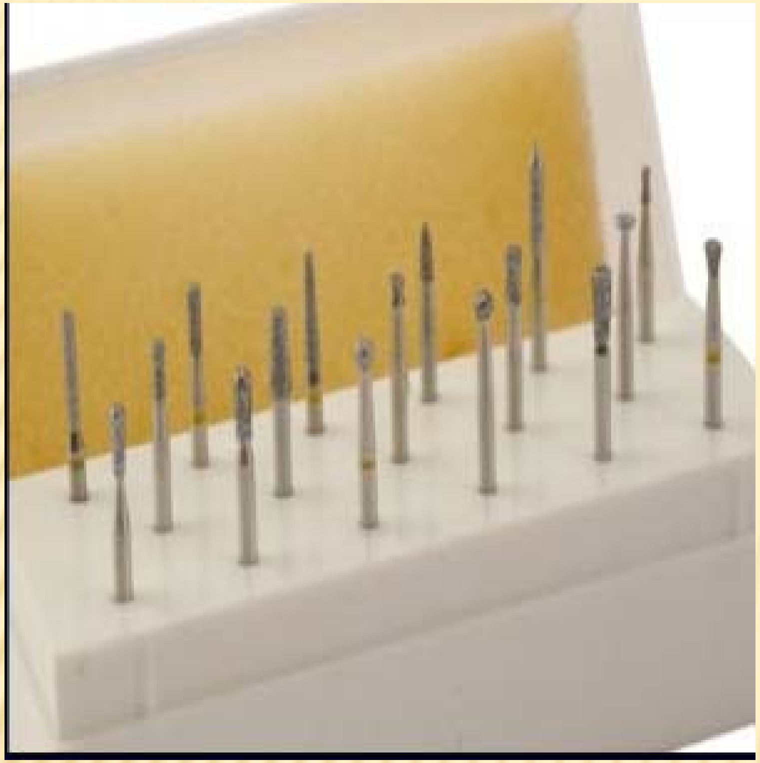
To increase the speed of the abrasive, it is suggested to use compressed air to blast an abrasive powder on to the surface (sand-blasting). It is useful for CO/ CR alloy or to use ultra-sonic frequency vibration.

Pressure. Always, only slight guiding pressure should be applied, high pressure will lead to increase the rate of wear of the abrasive, also lead to heat produced.

Carbides: extremely hard & brittle, used for cutting tooth surfaces & for metal, ceramic & plastic.

Quartz particles obtained by crushing sand stone & bonded to paper.

Sand: an intermediate abrasive for removing the coarse scratches its irregularly shaped sand.



Diamond dust: could be embedded in porcelain binder which is the most efficient abrasive for dental use.

Pumice: fine abrasive, the powder is obtained by crushing pumice stone; porous volcanic rock. It is excellent for denture polymer; it's suitable for gold alloy, tooth surface & amalgam. Pumice powder is mixed with water & some times with glycerin with low speed.

Emery: natural oxide of aluminum (corundum).

Garnet: silicate of any combination of aluminum, cobalt or magnesium.

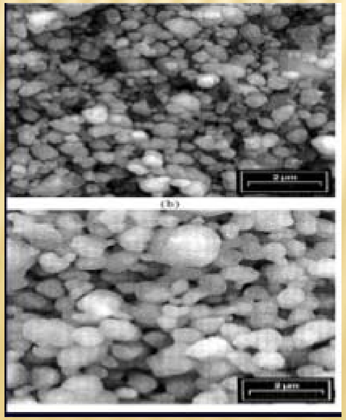
POLISHING

- It is the material which causes the fine scratches to be filled & to produce smooth surface probably due to that; the rapid movement of the polishing agent across the surface heats the top layer of the material & cause it to flow & fill in the scratches.

Rough: iron oxide. Its red powder or cake, it's rather dirty to handle but it produce excellent shine on gold alloy but not used with stainless steel but we use chromic oxide.

Whiting: (precipitated chalk) it is mild abrasive used for softer materials & polymers, mixed with water.

Tripoli: obtained from porous rocks



Tin oxide: extremely fine used for polishing teeth & restoration inside the mouth.

DENTURE CLEANSERS

- The most satisfactory method to keep the denture clean is by regular **cleaning** with soft brush, soap and water. Coarse abrasives cause rapid wear of denture polymer & patient should not use them.

Generally denture cleansers are of four types:

- **Powder and paste,** which consist mainly of finely divided chalk, Zirconium, or pumice & flavoring agents, its quite abrasive and should not be used vigorously over a period of time.
- **Peroxide cleanser, powder or tablets** contain sodium perborate mixed with alkaline material such as tri-sodium phosphate also detergent & flavoring.

From the powder a solution with water is made and the denture is immersed in it for a period of time.

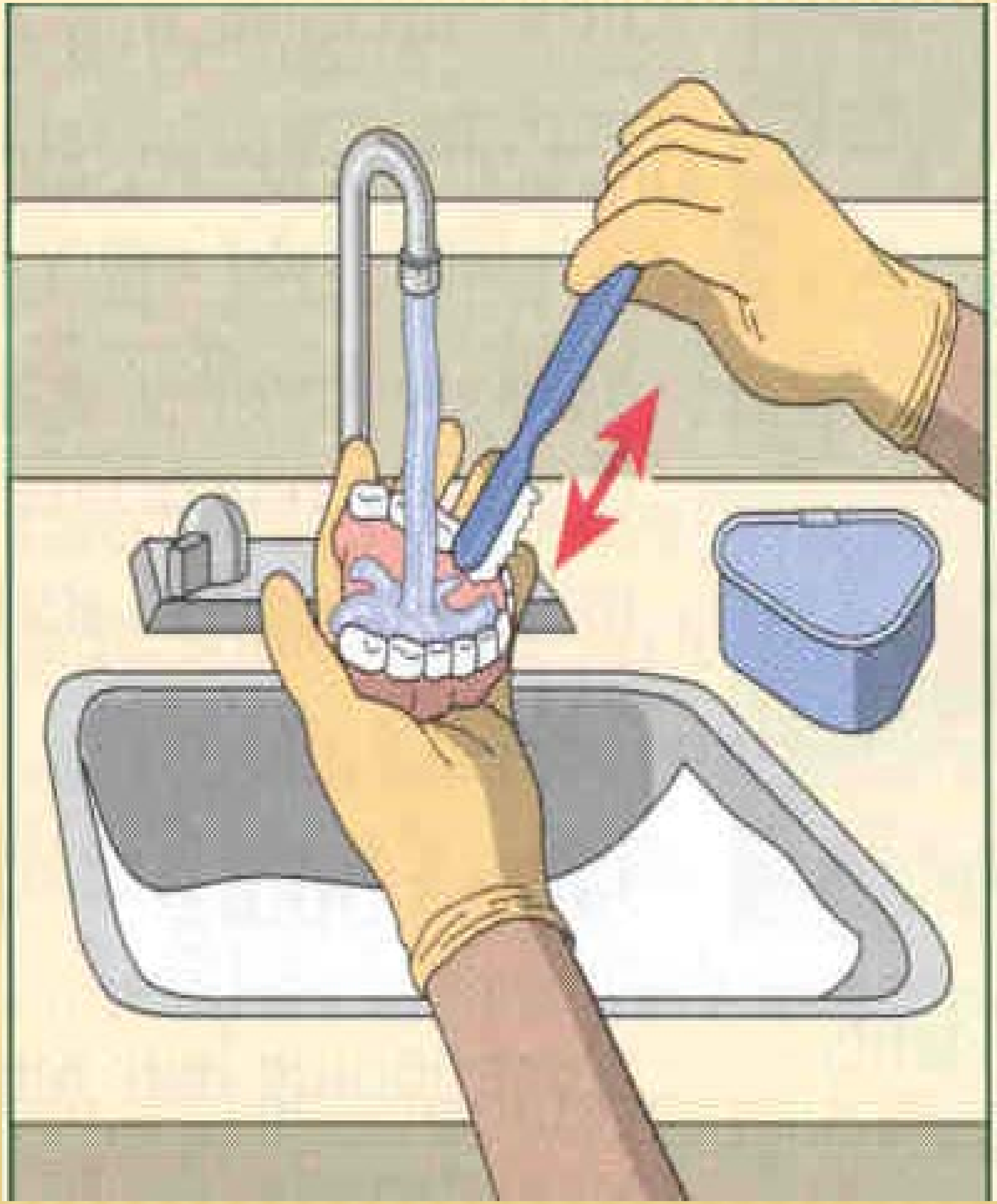
Dilute hypochlorite solution (chlorine) should not be used with metals, if high concentration is used it may bleach the polymer if immersed regularly in it.

Dilute hydrochloric acid: this dissolves calcified deposits; it is applied locally to heavily contaminated areas of denture. House hold cleansers & bathroom abrasives are contra-indicated; dentifrice with chloroform is contraindicated.


*Compare to the performance of Efferdent®
freshmint®
DENTURE CLEANSER
ANTI-BACTERIAL TABLETS
• Controls Odor
• Removes Stains
• Kills Millions of Bacteria
40 TABLETS


CVS® pharmacy
Compare to Efferdent®*
DENTURE CLEANSER
ANTI-BACTERIAL
• Kills millions of bacteria
• Fights odor
• Removes stains
40 TABLETS

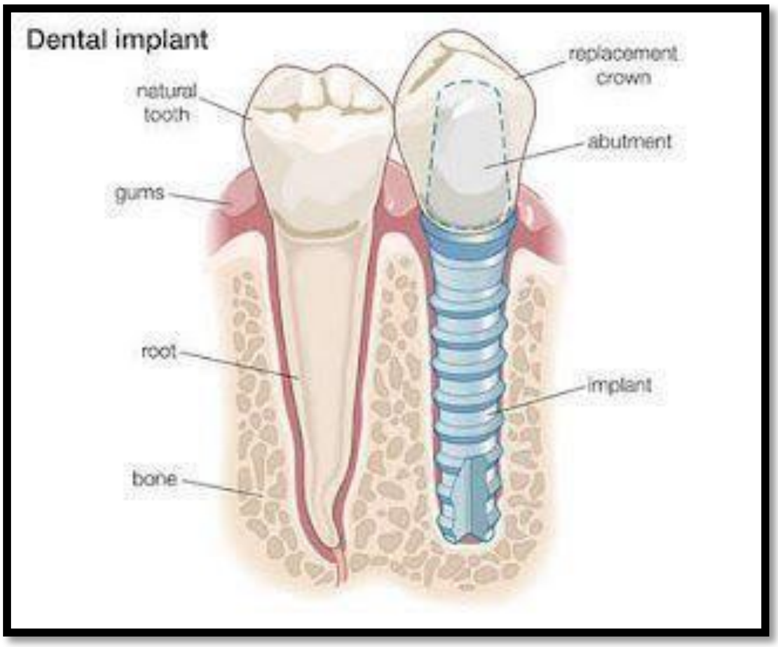

Renew®
PROFESSIONAL STRENGTH
NETTOYANT PROFESSIONNEL
DENTURE CLEANER
PROTHÈSES DENTAIRES
RENEW® CANADA
200 g (7 oz)



FINISH

Materials for construction of implant

Dental implants are fixtures that serve as replacements for the root of a missing natural tooth. Implants may be placed in the mandible or maxilla. When properly designed and placed, dental implants bond with bone over time and serve as an anchor for dental prostheses. Dental implants are used to replace a single missing tooth or many teeth, or to support a complete removable denture



Osseointegration was initially defined on the light microscopic level as “a direct structural and functional connection between ordered, living bone and the surface of a load-carrying implant

CLASSIFICATION

Dental implants fall into 1 of the following 3 primary groups: *(1)* metals, *(2)* ceramics, and *(3)* polymers. In addition, biomaterials can be classified based on the type of biologic (tissue) response when implanted and the interaction that develops with the host tissue (bone) . Three major types of dental implants : *(1)* biotolerant, *(2)* bioinert, and *(3)* bioactive

Bioinert Biomaterials

- The term bioinert refers to any material that once placed in the human body has minimal interaction with its surrounding tissue, examples of these are stainless steel, titanium, alumina, zirconia, and ultra high molecular weight polyethylene.
- Bioinert materials allow close apposition of bone on their surface, leading to contact osteogenesis.

Bioactive Biomaterials

- Bioactive refers to a material, which upon being placed within the human body interacts with the surrounding bone that is chemically equivalent to the mineral phase in bone.
- examples of these materials are synthetic hydroxyapatite $[Ca_{10}(PO_4)_6(OH)_2]$, glass ceramic and bioglass

- Bioactive materials also allow the formation of new bone, active carbonate apatite (CHAp) layer on the implant by ion exchange with host tissue leads to the formation of a chemical bond along the interface (bonding osteogenesis)

Biotolerant

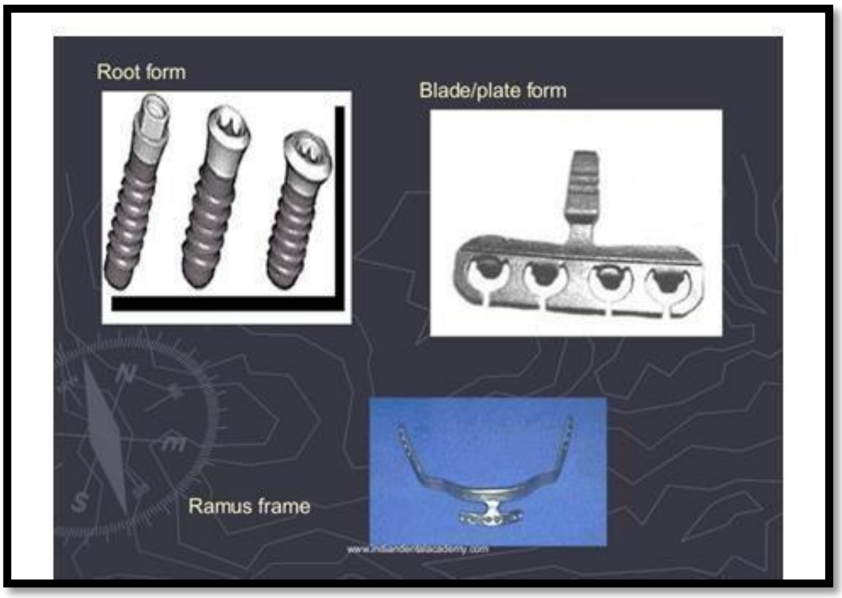
- Gold ,Co-Cr alloys , Polyethylene ,Polyamide Polymethylmethacrylate
- Biotolerant materials are those that are not necessarily rejected when implanted into living tissue, but are surrounded by a fibrous layer in the form of a capsule

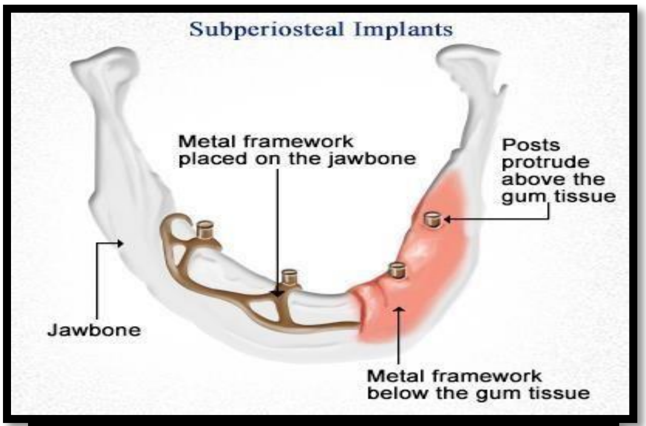
Historically, dental implants have been classified according to their design and placement within the tissues. The three types of implants commonly used are : The subperiosteal implant, the transosteal implant, and the endosseous implant .

Endosseous Implant

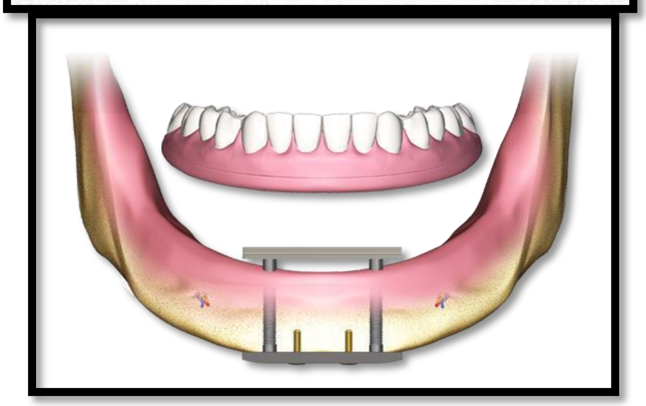
Endosseous implants are the most common type of implant placed today. Implants are placed directly into the mandible or maxilla

Endosseous implant





Subperiosteal implant: is a type of implant where the artificial tooth is placed beneath the periosteum that overlies the cortex.



Transosteal implant: This type of implant can, also, be referred to as staple bone implant, mandibular staple implant or transmandibular implant. This type of implant is a combination of both the endosteal components and those of subperiosteal. The implant penetrates the two cortical plates.

Properties of an implant biomaterial

Modulus of elasticity: Implant material with modulus of elasticity comparable to bone (18 GPa) must be selected to ensure more uniform distribution of stress at implant and to minimize the relative movement at implant bone interface.

Metals possess high strength and ductility, whereas the ceramics and carbons are brittle materials

Tensile, compressive and shear strength: An implant material should have high tensile and compressive strength to prevent fractures and improve functional stability. Improved stress transfer from the implant to bone is reported interfacial shear strength is increased, and lower stresses in the implant.

Yield strength, fatigue strength: An implant material should have high yield strength and fatigue strength to prevent brittle fracture under cyclic loading.

Ductility: According to ADA a minimum ductility of 8% is required for dental implant. Ductility in implant is necessary for contouring and shaping of an implant.

Hardness and Toughness: Increase in hardness decreases the incidence of wear of implant material and increase in toughness prevents fracture of the implants.

Metallic implants

Titanium

- Bioinert
- Lightweight
- biocompatible
- corrosion resistant (dynamic inert oxide layer , $TiO2$)
- It is 6 times stronger than compact bone
- Its modulus of elasticity is 5 times greater than that of compact bone (102-110 GPs) (thus equal mechanical stress transfer)
- Most commonly used –Commercially pure (CP) titanium – Titanium-aluminum-vanadium alloy (Ti-6Al-4V) - stronger & used with smaller diameter implants

Cobalt-chromium-molybdenum alloys generally consist of 63% cobalt, 30% chromium, and 5% molybdenum with small amounts of carbon, manganese, and nickel. Molybdenum is a stabilizer and provides strength; chromium provides the passivating effect to ensure corrosion resistance through the oxide surface; and carbon serves as a hardener. Co-Cr-Mo alloys have a high elastic modulus and resistance to corrosion. Co-Cr-Mo and stainless steel alloy continue to be used for some implants, such as subperiosteal and transosteal implants and ramus frames, because of their castability, mechanical properties, and lower cost.

Ceramic implant

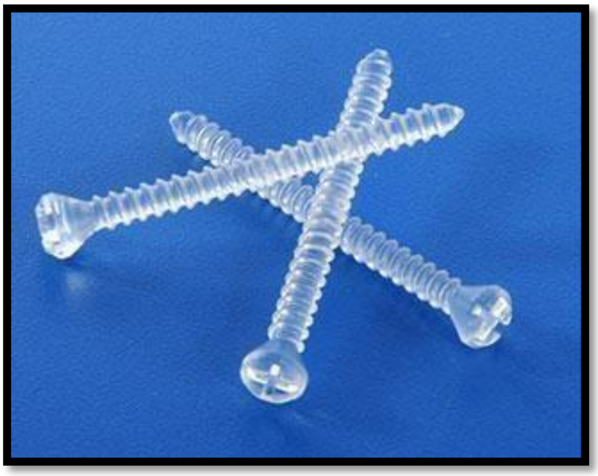
Ceramics are inorganic, nonmetallic materials . Ceramic implants can withstand only relatively low tensile or shear stresses induced by occlusal loads, but they can tolerate quite high levels of compressive stress. Aluminum oxide (Al_2O_3) is used as a standard biomaterial for ceramic implants because of its inertness (biostability).

Zirconia (ZrO_2) has also demonstrated a high degree of inertness.
These types of ceramic implants are not bioactive in that they do not promote the formation of bone. They have high strength, stiffness, and hardness and function very well for some designs of dental implants
Hydroxyapatite (HA), or $Ca_{10}(PO_4)_6(OH)_2$, and tricalcium phosphate (TCP), $Ca_3(PO_4)_2$ promote and achieve a direct bond of the implant to hard tissues, they are classified as bioactive.

POLYMERS

The early work with the methyl methacrylate resin implants met mostly with failures .

There are some disadvantages: (1) inferior mechanical properties; (2) lack of adhesion to living tissues; and (3) adverse immunologic reactions.



Peek (Polyetheretherketone) as dental implants

The major beneficial property for peek is its low elastic modulus (3-4 GPs) being close to human bone , good resistance to degradation, lack of toxicity, good chemical and sterilization resistance, lighter in weight,

PEEK combines high strength with a relatively low Young’s modulus which is closer to that of human bone than titanium. This property may minimize the stress by distributing it in more physiological manner thus supporting bone formation around the implant and reducing osteolysis.

Materials for construction of maxillofacial prosthesis

Acquired and congenital defects of the face create an unfortunate condition for the person to live comfortably and these persons need treatment using maxillofacial prosthesis.

Maxillofacial prosthetics is the branch of prosthodontics concerned with the restoration and/or replacement of the stomatognathic and craniofacial structures with the prosthesis .

Maxillofacial prosthetic materials are classified in two main groups: extraoral and intraoral prosthetic materials.

Extra oral prosthetic materials include vinyl chloride polymers, poly (methyl methacrylate), silicone, and polyurethane , these materials are used for facial prosthetics. At present silicones and polyurethane materials are considered most desirable for their strength, even though both are difficult to color.

Intraoral prosthetic materials include silicones, poly (methyl methacrylate), Tantalum, Vitallium, and Titanium mesh materials. Also silicone is particularly valued for its tissue tolerability. Metallic mesh materials have the advantage of permitting granulated tissue to migrate through the mesh.

Ideal Requisites for Maxillo-facial Materials:

1. Materials used should be biocompatible (not irritate the surrounding tissues, noncarcinogenic) .
2. Strength: it should be strong enough about the periphery to endure.

3. Flexibility: Should be flexible at temperatures from 4.4°C to 60°C.
4. Chemical and environmental stability (It should be resistant to various chemicals such as ether, oil and to sunlight, heat, and cold).
5. Thermal conductivity: Poor conductor of heat.
6. Ease of processing and ease of duplication.
7. Weight: Light and easily retained in position and be comfortable to the patient.
8. easy to sterilize.

Physical and mechanical properties are:

1. **Tear strength** –Defined as the resistance of a material to tearing force and is important in thin sections such as the areas surrounding the nasal and eye prosthesis. The thin glued prosthesis is susceptible to tearing while removal, permanently damaging the prosthesis.

2. **Ultimate Tensile Strength and Percent (Maximum) Elongation**: The total percent elongation, which includes both the elastic and plastic elongation, is helpful as different parts of the face have different requirements in terms of stretching the elastomers to accommodate the facial movements. Thus it also gives us an idea about the flexibility of the material. Tensile strength is in the range 300 to 1,000 psi (2.0 to 7 MPa).

3. **Hardness**- defined as the resistance to abrasion and it is preferred that the prosthesis possess the same hardness as that of the missing facial structure.
4. **Water Sorption**- Represents the amount of water adsorbed on the surface and into the body of the material during fabrication or whiles the restoration is in service. Prosthesis may absorb saliva, sweat or water while washing the prosthesis which

may affect the physical properties including the colour perception . The prostheses should not distort when boiled in water or sterilized in steam.

5. **Weight** – The materials should be light weighted so that they are comfortable for the patient and aids in the retention of the prosthesis.
6. **The material should be dimensionally stable** when exposed to insults like sunlight, ultraviolet rays, and extreme conditions or to the adhesives and their solvents.

Materials

1. Acrylic resins

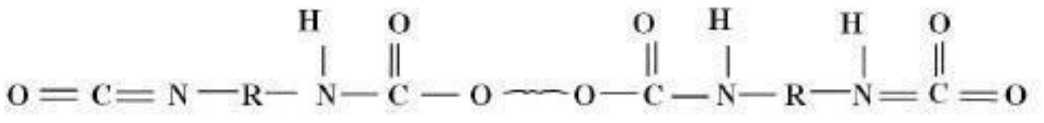
Polymethyl methacrylate was used before on the facial defects where the little movement occurs in the tissue bed during the function.

Advantages of the material are compatible with most of the adhesive systems; good strength , color stability, can be easily relined and repaired. disadvantages: rigidity ,discomfort.

2. Polyvinylchloride and copolymers

Introduced in the mid-1940s as plastisols. Most widely accepted are (polyvinyl chloride) and mediplas (polyvinyl acetate chloride), A clear, tasteless and odorless material and has been used widely for maxillo-facial applications with advantages like being flexible, adaptable to both intrinsic and extrinsic staining .
they are susceptible to the degradation or destruction by UV light, ozone, peroxide and they are relatively rigid and must be made flexible by the use of a plasticizer.

3. Polyurethane elastomer



$$O{=}C{=}N{-}R{-}\overset{H}{\overset{|}{N}}{-}\overset{O}{\overset{\|}{C}}{-}O\sim\sim O{-}\overset{O}{\overset{\|}{C}}{-}\overset{H}{\overset{|}{N}}{-}R{-}\overset{H}{\overset{|}{N}}{=}\overset{O}{\overset{\|}{C}}{=}O$$

Polyurethane

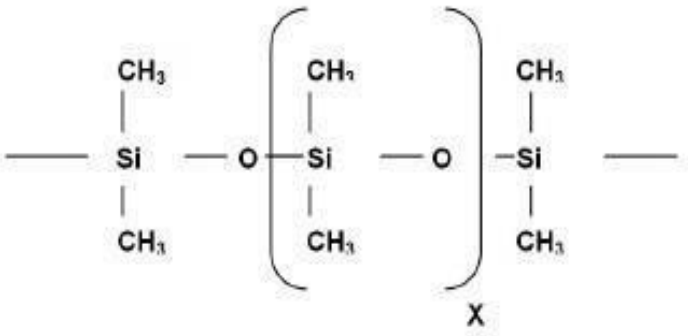
Advantages:
These have good stability; higher tear resistance, low modulus without use of plasticizers, good ultimate strength and elongation. They can accept intrinsic coloration .
disadvantages include poor colour stability, poor compatibility with adhesive systems and moisture sensitivity leading to gas bubbles during processing and porous prosthesis.

Application, used for maxillofacial prosthetics because these prosthesis require greater softness and flexibility.

4. Silicones also known as polydimethyl siloxane is the most successful maxillofacial prosthetic material till now.

These became more popular over other materials as they have a range of good physical properties (such as excellent tear and tensile strength) over a range of temperature, easier to manipulate, high degree of chemical inertness, low degree of toxicity, and high degree of thermal and chemical stability.

Further they can be stained intrinsically and/or extrinsically to give them more lifelike natural appearance. with simple cleaning these materials are relatively safe . Silicone is a combination of organic and inorganic compounds and chemically they are termed as polydimethyl siloxane. The inorganic backbone makes the unique difference of this material as siloxane bonds Si—O—Si in the main chains, as well as Si—C bonds where side groups are bonded to silicone, are extremely flexible and have a great freedom of motion.



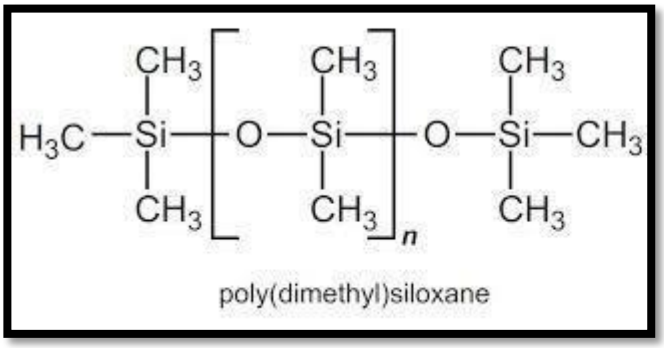
Where X is the degree of polymerization

Polydimethyl Siloxane

Polysiloxanes must be cross-linked to form solid elastomer materials.
Depending whether the vulcanizing process uses heat or not, silicones are available as heat vulcanized (HTV) or room temperature vulcanized (RTV) and both exhibits advantages and disadvantages.

HTV silicone

Heat-vulcanized silicones (High-temperature vulcanized - silicones) are used for maxillofacial prostheses. It is usually a white, opaque material with a highly viscous in consistency. It is available as one component or two component putty.



Requires heat for vulcanization. Catalyst or vulcanizing agent is dichlorobenzoic acid (for condensation polymerization), platinum salts (for addition polymerization) (so no by product).. These silicones require advanced equipment for processing and have better physical properties.

The processing temperature is 180°C- 220°C for about 30 min under pressure using metal molds.

Advantages:-

1. Excellent tear strength and highest tensile strength at 5.87 MPa (polyurethane the lowest at 0.83 MPa.).
2. Excellent thermal, colour and chemical stability (rendering it more biologically inert).
3. High percent elongation.

Disadvantages:-

1. Poor esthetics due to opacity.
2. Less elasticity.

3. Technique sensitive.

RTV silicone (Room temperature vulcanizing)

Room-temperature-curing silicones are supplied as single-component materials that cure by evaporation of acetic acid. Prostheses are polymerized by bulk multiple packing. Recently epoxy resins and stainless steel molds are being used .

Advantages of the RTV silicone material

Use of stone molds, ease of manipulation and ease of colouring. Other advantages are colour stability and biological inertness.

The comparison of properties of HTV and RTV are summarized in the table

Properties	HTV	RTV
Ultimate tensile strength (MPa)	5.87	4.20
Maximum Elongation (%)	441	445
Modulus (MPa)	4.66	2.12

RTV silicones are not as strong as the HTV silicones,
In comparison to other materials, both HTV and RTV have high tear resistance, because the samples do not tear but stretch, as in tensile elongation and high percent elongation ranging from 422% to 445%.

Elastomers with a high dynamic modulus are rather rigid materials. RTV has the lowest dynamic modulus of 2.12 MPa .