ABRASION AND POLISHING
ABRASION

- It occurs when a hard, rough surface slides along a softer surface and cuts a series of grooves.

- **Defined As:** The wearing away of a substance or structure through a mechanical process, such as grinding, rubbing or scraping.

- **TYPES OF ABRASION** Abrasion may be
  - A two body process, e.g. action of a diamond bur on enamel.
  - A three body process, e.g. pumice applied with a bristle brush.
FIGURE 11-4 The mechanics of high-speed rotary instrumentation. A, The blue circular arrow indicates that the high-speed diamond bur rotates in a clockwise direction when viewed from the head of the handpiece. The green arrows indicate the direction that the instrument should be drawn to counteract the rotational force of the bur and achieve the most rapid abrasive action of the bur. B, Incisal view of the forces generated during high-speed rotary tooth preparation. As the bur rotates in a clockwise direction, it generates a rotational force at the tooth surface, $F_R$ (blue arrow that represents schematically the force of tooth structure against the bur). The operator of the instrument must generate an opposing force, $F_O$ (green arrow), which will exceed the rotational force of the bur, $F_R$, and carry the instrument against the tooth surface where the surface will be abraded.
FIGURE 11-5 Illustrations of two-body abrasion, three-body abrasion, and hard-particle erosion. A, Two-body abrasion occurs when abrasive particles are tightly bonded to the abrasive instrument that is removing material from the substrate surface. B, Three-body abrasion occurs when abrasive particles are free to translate and rotate between two surfaces. C, Hard-particle abrasion (also called "air abrasion") is produced when abrasive particles are propelled against a substrate by air pressure.
- **SUPPLIED AS** In dentistry the abrasive is applied to the work by a variety of tools

- Paper/plastic coated: The abrasive particles may be glued on to a paper or plastic disk that can be attached to a handpiece. Sand paper falls in this group.

- Coated strips: The abrasive (e.g. diamond) may be attached to stainless steel or plastic strips (used for proximal stripping of teeth). This category is similar to the above.

- Electroplating: bonding In case of diamond rotary instruments the diamond chips are attached to steel wheels, disks and cylinders by electroplating with nickel based matrix.

- Bonded stones: In grinding wheels and dental stones, the abrasive particles are mixed with a bonding agent that holds the particles together. Before hardening, the matrix material with the abrasive is moulded to form tools of desired shapes.

- Powder: form An abrasive may also be mixed with water or glycerine to form a paste or slurry. It is applied with rubber cup or brush and used for smoothening irregularities, e.g. pumice powder (Fig. 22.2A).

- Paste: form The abrasive is made into a paste and supplied in a tube, e.g. Ivoclar polishing paste, tooth paste, etc.
Coated strips

Electroplated diamond

Bonded stone

Pumice powder
GOALS OF FINISHING AND POLISHING

- 1- obtain desired anatomy, proper occlusion
- 2- reduction of roughness to get smooth surface
- 3- resist bacterial adhesion and plaque accumulation
- 4- enhance strength of restorative surface
- 5- improve esthetic
MECHANISM OF ABRASIVE ACTION

In a cutting tool, e.g. carbide or steel bur (Fig. 22.3), the blades or cutting edges are regularly arranged and the removal of material corresponds to this regular arrangement.

An abrasive tool on the other hand has many abrasive points that are not arranged in an ordered pattern. Thus, innumerable random scratches are produced. The action of an abrasive is essentially grinding action.

Each tiny particle presents a sharp edge that cuts through the surface similar to a chisel. A shaving is formed which crushes to a fine powder. This powder clogs the abrasive tool and frequent cleaning is required.
STRESS, STRAIN AND HEAT PRODUCTION DURING ABRASION

- In denture resins, rigorous abrasion introduces stresses. The generation of heat during abrasion partially relieves such stresses but if it is too great, it may relieve processing stresses and a warpage may result. The resin surface may even melt.

- Similarly high speed cutting of tooth structure generates excessive heat which can lead to pulpal damage. Therefore, it is very important to control the heat by
  1- air/water spray and
  2- intermittent cutting (rather than continuous cutting).

- ABRASIVE MOTION

- The motion of abrasive instruments is classified as rotary, planar, or reciprocal. In general, burs act in a rotary motion and discs in a planar motion, and reciprocating handpieces provide a cyclic motion

- Reciprocating handpieces especially provide the benefit of accessing interproximal and subgingival areas to remove overhangs, finish subgingival margins without creating ditches, and create embrasures.
The rate of abrasion of a given material by a given abrasive is determined primarily by three factors.

1. **Size of the abrasive particle**: Larger particles cause deeper scratches in the material and wear away the surface at a faster rate. The use of course abrasive is indicated on a surface with many rough spots or large nodules. The scratches caused by the coarse abrasive must then be removed by finer ones.

2. **The pressure of the abrasive agent**: Heavy pressure applied by the abrasive will cause deeper scratches and more rapid removal of material. However, heavy pressure is not advisable as it can fracture or dislodge the abrasive from the grinding wheel, thus reducing the cutting efficiency.
3. Speed at which the abrasive particle moves across the surface being abraded.

Speed The higher the speed, the greater the frequency per unit of time the particles contacts the surface. Thus increasing the speed increases the rate of abrasion. Rotational Speed and Linear Speed should be differentiated. The speed with which the particles pass over the work is its linear speed or it is the velocity with which the particles pass over the work.

Rotational speed is measured in revolutions per minute (RPM or r/min), whereas, linear speed is measured in meters per second.

Linear speed is related to rotational speed according to the following formula \( V = CR \), where:
- \( V \) = linear speed
- \( C \) = circumference of the bur or disc
- \( R \) = revolutions per minute
CLASSIFICATION

- **A. Finishing abrasives:** Finishing Abrasives Finishing abrasives are hard, coarse abrasives which are used initially to develop contour and remove gross irregularities, e.g. coarse stones.

- **B. Polishing abrasives:** have finer particle size and are less hard than abrasives used for finishing. They are used for smoothening surfaces that have been roughened by finishing abrasives, e.g. pumice, etc.

- **C. Cleansing abrasives** are soft materials with small particle sizes and are intended to remove soft deposits that adhere to enamel or a restorative material.
TYPES OF ABRASIVES

- **Aluminum Oxide** Pure alumina is manufactured from bauxite, an impure aluminum oxide. It can be produced in fine grain sizes. Pure alumina is also used as a polishing agent. Alumina is used in sandblasting machines (Figs. 22.7 and 22.8).

- **Garnet** It is composed of different minerals which possess similar physical properties and crystalline form. The mineral comprises of silicates of aluminium, cobalt, iron and manganese. Garnet is coated on paper or cloth with glue. It is used on disks, which are operated on handpieces.

- **Diamond** It is the hardest and most effective abrasive for tooth enamel. The chips are impregnated in a binder or plated on to a metal shank to form the diamond ‘stones’ and disks so popular with the dental profession.
- **Pumice** It is a highly siliceous material of volcanic origin and is used either as an abrasive or polishing agent depending on particle size. Its use ranges from smoothening dentures to polishing teeth in the mouth.

- **Rouge** is a fine red powder composed of iron oxide. It is used in cake form. It may be impregnated on paper or cloth known as ‘crocus cloth’. It is an excellent polishing agent for gold and noble metal alloys but is likely to be dirty to handle.

- **Chalk** It is calcium carbonate prepared by precipitation method. There are various grades and physical forms available for different polishing techniques. It is sometimes used in dentifrices.

- **Sand** as well as other forms of quartz is used as sand paper or as powder in sandblasting equipment.

- **Carbides Silicon** carbide and boron carbide are manufactured by heating silicon and boron at a very high temperature to effect their union with carbon. The silicon carbide is sintered or pressed with a binder into grinding wheels or disks. Most of the stone burs used for cutting tooth structure are made of silicon carbide.
DESIRABLE CHARACTERISTICS OF AN ABRASIVE

1. It should be irregular in shape so that it presents a sharp edge.

2. Abrasive should be harder than the work it abrades. If it cannot indent the surface to be abraded, it cannot cut it and the abrasive dulls or wears out.

3. The abrasive should possess a high impact strength. The abrasive particle should fracture rather than dull out, so that a sharp edge is always present. Fracture of an abrasive is also helpful in shedding the debris accumulated from the work.

4. They should have attrition resistance, so that it does not wear
BINDER

- The abrasives on a disk and wheel are held together by a binder. Commonly used binders in dentistry are:
  - Ceramic bonding is used for silicon carbide or corundum in a mounted abrasive point.
  - Electroplating with nickel is often used to bind the diamond chips on to the diamond rotary instruments (Fig. 22.4).
  - For soft grade abrasion, rubber (Fig. 22.5) or shellac may be used. These wear rapidly, but they are useful in some dental operations in which delicate abrasion is required.

- The type of binder is related to the life of the tool in use. In most abrasives the binder is impregnated throughout with an abrasive of a certain grade so that, as a particle is removed from the binder during use another takes its place as the binder wears. Furthermore, the abrasive should be so distributed that the surface of the tool wears evenly, particularly if the disk or wheel is used for cutting along its periphery.
- **DIAMOND BURS** The cutting efficiency of diamond rotary instruments depends on whether the diamonds used are natural or synthetic, the grit size, the distribution and the extent of plating that attaches the particles to the instrument shank. The larger the grit size the greater the abrasion.

- Some companies indicate the grit size by color coding (Fig. 22.6).
POLISHING

It is the production of a smooth mirror-like surface without much loss of any external form. If the particle size of an abrasive is reduced sufficiently, the scratches become extremely fine and may disappear entirely.

The surface then acquires a smooth shiny layer known as a polish. The polishing agents remove material from the surface in stepwise approach.

In the process, fine scratches and irregularities are filled in by powdered particulates being removed from the surface. The microcrystalline layer is referred to as polish layer or Beilby layer.
DIFFERENCE BETWEEN ABRASION AND POLISHING

1- particle size A given agent having a large particle size acts as an abrasive, producing scratches. The same abrasive with a smaller particle size is a polishing agent.

2- Material removed Very little of the surface is removed during polishing—not more than 0.005 mm (0.002 inch).

3- Speed The optimum speed for polishing is higher than that for abrading. Linear speed as high as 10000 ft/min may be used. It varies with the polishing agent. Average speed is approximately 7500 ft/min.
NONABRASIVE POLISHING

- Polishing is usually achieved by an abrasive process. However a smooth shiny surface can also be achieved through nonabrasive means. These include

- **1. Application of a glaze layer**

- Glazing of composites
  
  Composite Glazing
  
  A layer of glaze or gloss (a clear transparent liquid made of unfilled resin) is applied over the restoration and cured. This results in a smooth glossy surface.

- Glazing of ceramics
  
  Ceramics are difficult to polish conventionally. The finished restoration is subjected to high temperatures. Alternatively a glaze layer can be applied and fired to obtain a shiny surface.
2. **Electrolytic polishing** (Fig. 22.7) is not true abrasion. Although material is removed, it is removed through an electrochemical process rather than abrasive process.

This is the reverse of electroplating. The alloy to be polished is made the anode of an electrolytic cell. As the current is passed, some of the anode is dissolved leaving a bright surface. This is an excellent method for polishing the fitting surface of a cobalt–chromium alloy denture. So little material is removed, that the fit of the denture is virtually unaltered.

3. **Burnishing**. It is related to polishing in that the surface is drawn or moved. Instead of using many tiny particles, only one large point is used. A special blunt bur revolving at high speed can be used.
STEPS IN FINISHING AND POLISHING

**Bulk reduction**
Removal of excess material
*Instrument:* diamond, carbide burs

**Contouring**
Achieved during bulk reduction
*Instrument:* Finer carbide burs used

**Finishing**
Provide blemish free fine smooth surface
*Instrument:* Fine and super fine diamond burs
Methods of Abrasion may be carried out

1. Manually, e.g. proximal stripping of enamel using abrasive strips.

2. Rotary instruments, e.g. burs, wheels, cups, discs etc.

3. Blasting The object is blasted with a steady stream of abrasive, e.g. prophy-jet polishing of enamel, sandblasting (Figs. 22.8 and 22.9) to remove investment of castings etc.

– Smoothen work with a coarse abrasive or bur (Fig. 22.10A) which leaves large scratches. These scratches are removed with finer abrasives but the difference in fineness should not be too great (Fig. 22.10B).

– After changing to a finer abrasive, the direction of abrasion should be changed each time if possible, so that new scratches appear at right angles to the coarser scratches, for uniform abrasion.

– When the scratches are no longer visible to the eye, the preliminary polishing can be accomplished with pumice flour applied with a canvas buff wheel [used for resin dentures (Fig. 22.11)].

– The work is cleaned to remove all traces of abrasives and the particles of the material removed by the abrasive.
- A paste is formed of pumice and water to a sticky ‘muddy’ consistency. The buff wheel is turned at high speed. Apply the paste to the work and carry it to the buff. Hold the work firmly but without excessive pressure. Repeat this over the entire surface till the surface is bright and well polished.

- Clean the work with soap and water. Change to a flannel buff wheel. Rotate at high speed. The work is held against the wheel and turned, so that all of the surfaces are polished uniformly. A light pressure is used to avoid excess heat generation (especially in resins).
**FIGURE 22.8** Sandblasting.

**FIGURE 22.9** The term sandblasting is misleading. The process actually uses 250 micron alumina ($\text{Al}_2\text{O}_3$).

**FIGURES 22.10A AND B** Sequence of finishing is important. One should proceed from coarse to fine.

**FIGURE 22.11** Canvas buff wheel with pumice is used for polishing complete dentures.
ALL-CERAMIC RESTORATIONS
ALL-CERAMIC SYSTEMS

The all-ceramic restorations are made without a metallic core or sub-structure. This makes them esthetically superior to the metal-ceramic restoration. Unfortunately, all-ceramic restorations had lower strength, thus, metal-ceramics continued to be the restoration of choice for the majority of restorations till the 1990s.

The all-ceramic restorations are grouped according to their type and method of fabrication:

1. Condensed sintered
   - Traditional feldspathic porcelain jacket crown
   - Porcelain jacket crown with aluminous core (Hi-Ceram)
   - Ceramic jacket crown with leucite reinforced core (Optec HSP).
2. Cast glass ceramics (Dicor).
3. Injection molded (leucite reinforced) glass ceramic (IPS Empress).
4. Slip cast-glass infiltrated ceramics
   - Glass infiltrated aluminous core restorations (In-Ceram)
   - Glass infiltrated zirconia core (In-Ceram Zirconia).
5. Milled ceramic restoration or cores
   - CAD/CAM restorations – Copy milled restorations
PORCELAIN JACKET CROWN

These are crowns made entirely of feldspathic porcelain. They are constructed on a platinum foil matrix which is subsequently removed.

TYPES

1. Porcelain jacket crown (traditional).
2. Porcelain jacket crown with aluminous core.
3. Porcelain jacket crown with leucite reinforced core.

TRADITIONAL PORCELAIN JACKET CROWN

They were made from conventional feldspathic porcelains. As mentioned before these were very brittle and fractured easily.

The marginal adaptation was also quite poor. Because of these problems they gradually lost popularity and are no longer used presently.
The problems associated with traditional PJCs led to the development of the PJC with an alumina reinforced core (Fig. 28.18).

The increased content of alumina crystals (40 to 50%) in the core strengthened the porcelain by interruption of crack propagation. In spite of the increased strength they were still brittle and therefore not indicated for posterior teeth and their use was restricted to anterior teeth.

Technical considerations The porcelain jacket crowns are made using the platinum foil matrix technique

Platinum foil matrix A platinum foil is adapted to the die (Figs. 28.19A and B) with a wooden point. The platinum foil functions as matrix. It supports the porcelain during condensation and firing.
FIGURE 28.18 The porcelain jacket crown with aluminous core.
Condensation and firing The core porcelain is carefully condensed on to the foil (Fig. 28.19C). The foil with the condensed porcelain is carefully removed from the die. It is then placed in the furnace and fired. After cooling, the rest of the crown is built up with conventional feldspathic porcelain. Removing the foil After completion of the restoration the platinum foil is gently discarded. This can be quite difficult.
Optec HSP is a feldspathic porcelain with a higher leucite crystal content (leucite reinforced). Its manipulation, condensation and firing is quite similar to the alumina reinforced porcelain jacket crowns (using platinum foil matrix).

Uses Inlays, onlays, veneers and low stress crowns.

Advantages
1. They are more esthetic because, the core is less opaque (more translucent) when compared to the aluminous porcelain.
2. Higher strength.
3. No need of special laboratory equipment.

Disadvantages
1. Fit is not as good as metal ceramic crowns.
2. Potential marginal inaccuracy.
3. Not strong enough for posterior use.
CASTABLE GLASS CERAMIC

This is the only porcelain restoration made by a centrifugal casting technique. The subsequent ‘ceramming’ process is also quite unique to this porcelain.

Glass ceramics are materials that are formed initially as glass, and then transformed into ceramic usually by a controlled heat treatment.

The heat induces partial devitrification (crystallization within the glass) which increases the strength as well as improves esthetics by making it less transparent and more tooth-like.

The glass-ceramics used in dentistry include the castable, machinable and hot-isostatically pressed glass-ceramics.
SUPPLIED AS: The first commercially available castable glass-ceramic for dental use was ‘Dicor’. They are supplied as glass ingots.

A precrystallized form called Dicor MGC is also available as machinable blanks for CAD/CAM.

FEATURES: The Dicor glass-ceramic crown is very esthetic. This is because of its greater translucency (unlike some other porcelains which have more opaque core).

It also picks up some of the color from the adjacent teeth (chameleon effect) as well as from the underlying cement. Thus the color of the bonding cement plays an important role.

USES Inlays, onlays, veneers and low stress crowns.
FIGURES 28.20A AND B  Castable glass ceramics (Dicor). (A) Wax pattern. (B) Cast glass.
FABRICATION OF A DICOR CROWN: To understand the salient features of this material, the step-by-step construction of a crown will be described:

1. The pattern is first constructed in wax (Fig. 28.20A) and then invested in refractory material like a regular cast metal crown.

2. After burning out the wax, nuggets of Dicor glass are melted and cast into the mold in a centrifugal casting machine.

3. The glass casting (Fig. 28.20B) is carefully recovered from the investment by sandblasting and the sprues are gently cut away.

4. The glass restoration is then covered with an embedment material to prepare it for the next stage called ceramming.

5. Ceramming is a heat treatment process by which the glass is strengthened. Ceramming results in the development of microscopic crystals of mica, which improves the strength and toughness of the glass.
– Improves the esthetics of the restoration (it reduces the transparency of the glass making it more opaque and less glass-like).

6. The cerammed glass can be built up with special veneering porcelain and fired to complete the restoration. Surface stains may be applied to improve the esthetics.

ADVANTAGES:

1. Ease of fabrication.
2. Good esthetics (greater translucency and chameleon effect).
3. Improved strength and fracture toughness.
4. Good marginal fit.
5. Very low processing shrinkage.

DISADVANTAGES:

1. Inadequate strength for posterior use.
2. Internal characterization not possible. Has to be stained externally to improve esthetics.
HEAT PRESSED (HOT-ISOSTATICALLY PRESSED) CERAMICS

This is another ceramic material which again is quite unlike the previous ceramics because of its unique way of fabrication (injection molding).

It is a precerammed glass-ceramic having a high concentration of reinforcing crystals.

The material supplied in the form of ingots is softened under high temperatures and forced into a mold created by a lost wax process. Synonyms Injection moulded or Heat-pressed glass-ceramics.

TYPES AND MODE OF SUPPLY Heat pressed ceramics are supplied as ingots (Figs. 28.21 and 28.22) of various compositions. These include

1. Heat pressed glass ceramics – Leucite
   – Lithium disilicate reinforced.

2. Heat pressed veneering ceramics (Fig. 28.22), are available for use as a pressed layer over machined zirconia cores.
FIGURE 28.21 IPS Empress ingots.

FIGURE 28.22 IPS Zir Press.

FIGURE 28.23 The pressing furnace.

FIGURE 28.24 Schematic representation of the pressing process.
USES: Inlays, onlays, veneers (Fig. 28.25D) and low stress crowns.

MICROSTRUCTURE

IPS Empress—contains 35 to 40% vol of leucite crystals.

IPS Empress 2—consists of 65 to 70% by volume of interlocked elongated lithia disilicate crystals.

The crystal size varies from 0.5 to 4 µm in length. The crystals within the structure improve the fracture resistance by reducing crack propagation.

ADVANTAGES

1. Better fit (because of lower firing shrinkage).
2. Better esthetics due to the absence of metal or an opaque core.

DISADVANTAGES

1. Need for costly equipment.
2. Potential of fracture in posterior areas.
FABRICATION

1. The wax (Fig. 28.25B) patterns of the restorations are invested in refractory material and heated to 850 °C in a furnace to burn off the wax and create the mold space.

2. It is then transferred to the pressing furnace (Fig. 28.23). A ceramic ingot and an alumina plunger is inserted in to the sprue (Fig. 28.24).

3. Pressing temperature for IPS Empress—1075 to 1180 °C

4. Pressing temperature for IPS Empress 2—920 °C

5. The pressing is done under air pressure of 1,500 psi.

6. The core or restoration (Fig. 28.25C) is retrieved from the flask.

7. Compatible veneering porcelains are added to the core to build up the final restoration (Fig. 28.25D).
FIGURES 28.25A TO D  IPS empress.  
(A) Teeth prepared for veneers.  (B) Wax patterns.  (C) Pressed ceramic still attached to the sprue.  (D) The completed restorations.
GLASS INFILTRATED CERAMICS

These are specialized core ceramics reinforced by an unique glass infiltration process. They are also sometimes referred to as slip-cast ceramics.

Types Currently there are three types depending on the core material used.

1. Glass infiltrated alumina core (In-Ceram Alumina).
2. Glass infiltrated spinell core (In-Ceram Spinell).
3. Glass infiltrated zirconia core (In-Ceram Zirconia).

Supplied as Oxide powder (alumina, spinell or zirconia) with mixing liquids, glass powder and veneering ceramics (Figs. 28.26 to 28.28).
GLASS INFILTRATED ALUMINA CORE (IN-CERAM ALUMINA)

This ceramic system has a unique glass infiltration process and the first of its kind claimed for anterior FDP fabrication. The glass infiltration process compensates for firing shrinkage.

Indications 1. Anterior and posterior crowns, and
2. Short span anterior fixed dental prostheses.

Fabrication (Figs. 28.29A to I)

1. refractory die material.

2. Preparing the slip—Measured quantity (38 g) of alumina powder is added slowly into a beaker containing 1 ampoule of mixing liquid and a drop of additive liquid.

Mixing is done with the help of a special ultrasonic unit (Vitasonic). The prepared slip should be smooth and homogenous. The slip is applied on to the refractory die using the slip cast method.

Once started the slip should not be allowed to dry out before the coping is completed. The process is continued until an alumina coping of sufficient thickness is obtained.
**FIGURE 28.27** Glass powder.

**FIGURE 28.28** Vita VM7 is a veneering ceramic designed for In-Ceram.
FIGURES 28.29A TO I  Fabrication of an In-Ceram restoration. (A) Slip casting. (B) In-ceram furnace. (C) Sintering of the slip. (D) Sintered coping. (E) Glass slurry application. (F) Embedded in investment. (G) Glass infiltration furnace. (H) Glass infiltrated coping. (I) The completed restoration.
3. The fragile slip cast alumina coping is dried at 120 °C for 2 hours.

4. The coping is sintered (Inceramat furnace) for 10 hours at 1120 °C.

5. After sintering the copings are tested for cracks using a special dye.

6. The next step is glass infiltration. Glass powder is mixed with distilled water. One or two thick coats (1-2 mm) is applied on to the sintered alumina coping (outer surface only) and fired for 2-3 hours at 1110 °C on a platinum foil. The glass melts and infiltrates into the porous alumina coping through capillary action.

7. The excess glass forms a glassy layer on the surface which is trimmed off using special diamond burs, followed by sandblasting. A glass control firing (1000 °C) is carried out.

8. The coping is then built up using special veneering ceramics (Vita VM 7).
Advantages:

1. Good fit and marginal adaptation.
2. Good strength when compared to the earlier all ceramic crowns. Claimed to be strong enough for posterior single crowns and anterior FDP use.

Disadvantages:

1. Comparatively less esthetic because of the opacity of the alumina core.
2. Quite tedious to fabricate.
3. Not all the FDPs were successful, a few of them did fracture occasionally.

Uses

1. In addition to inlays, onlays, veneers and low stress (anterior and posterior) crowns, this material can be used to construct low stress anterior FDPs. Because of its occasional tendency to fracture when used for FDP construction its use should be carefully selected.
2. For people allergic to metal based restorations.
3. Where esthetics is absolutely critical.
In-Ceram Spinell is an offshoot of In-Ceram Alumina. Because of the comparatively high opacity of the alumina core,

a new material was introduced known as In-Ceram spinell. It uses spinel (MgAl2 O4 ) instead of alumina.

The In-Ceram Spinell is more translucent and therefore more esthetic compared to the InCeram Alumina core.

Since the strength is lower, its use is limited to low stress situations. So it a material of choice for crowns and restorations in esthetic (anterior crowns) and stress free zones.
Zirconia (ZrO2) is a naturally occurring mineral. Crystals of Zirconia are used as a substitute for diamond. In-Ceram Zirconia is the strongest of the three glass infiltrated core materials.

The final glass infiltrated ICZ cores contains around 30 wt% zirconia and 70 wt% alumina.

Indications Its high strength makes it a material of choice for posterior crowns and short span fixed partial dentures in high stress areas (posterior FDPs).

It is not particularly suited for esthetic zones because of its greater opacity. However, in cases where there is severe discoloration, In-Ceram Zirconia helps mask the discolored tooth structure because of its greater opacity.
Pure ZrO2 has a monoclinic crystal structure at room temperature and transforms to tetragonal and cubic zirconia at elevated temperatures. The large volume expansion that occurs during the transformation of nondoped zirconia from cubic to tetragonal and tetragonal to monoclinic phases leads to structural expansion and high tensile stresses that cause zirconia to crack during cooling from the processing temperatures.

To solve this problem, stabilizing oxides such as magnesium oxide (MgO), yttrium oxide (Y2O3), calcium oxide (CaO), and cerium oxide (Ce2O3) are added to zirconia.

When sufficient stress develops in the tetragonal structure and a crack in the area begins to propagate, the metastable tetragonal crystals (grains) or precipitates next to the crack tip can transform to the stable monoclinic form. In this process a 3% expansion by volume of the ZrO2 crystals or precipitates occurs that places the crack under a state of compressive stress.
GENERAL PROPERTIES OF FUSED CERAMICS

Strength: The early porcelains were weak and brittle and tended to break easily (fracture or chipping). Current porcelain systems have considerably improved in strength and toughness.

Flexure strength: It is a combination of compressive, tensile, as well as shear strength. Flexure strength of dental ceramic restorations vary from 70 MPa for feldspathic veneering porcelains to 1200 MPa for machined zirconia core restorations.

Tensile strength: Porcelains are inherently brittle materials. Tensile strength is low because of the unavoidable surface defects like porosities and microscopic cracks. When porcelain is placed under tension, stress concentrates around these imperfections and can result in brittle fractures.

Factors affecting strength:

1. Composition
2. Surface integrity: Surface imperfections like micro-cracks and porosities reduce the strength. Thus grinding should be followed by glazing or polishing.
3. Improper condensation: Poor condensation introduces voids and reduces density of the porcelain.
4. Firing procedure: Inadequate firing and overfiring weakens the structure.
ABRASIVENESS OF CERAMICS

- Wear of opposing teeth is a concern when using ceramic restoration.
- Unglazed or unpolished porcelain can cause severe wear of natural teeth especially if dentin is exposed. This can happen in cases of occlusal interferences or when excessive masticatory forces are involved as in bruxing. Thus, ceramic restorations are contraindicated in bruxers. Porcelain restorations must always be glazed or polished after grinding.
- Wear of enamel occurs by the gouging action caused by asperities (projecting crystals) on the ceramic surface. The abrasiveness of the ceramic depends on the type of asperities present. Alumina and zirconia are more abrasive than plain glass.
- Ceramics having smaller crystal size or finer particles show reduced enamel wear.
THERMAL PROPERTIES

- Thermal conductivity Porcelain has low thermal conductivity which is important to prevent extreme cold or heat transmission to the sensitive dentin and pulpal tissues in cases of restorations in vital teeth.

- Coefficient of thermal expansion The CTE is an important property for dental ceramics especially for layered restorations. Extreme differences can induce a lot of stresses in the ceramic leading to immediate or subsequent failure.

- Some of the veneering ceramics for metal-ceramic have value is close to that of natural teeth.

- The CTE values for metal-ceramic alloys have to be lowered to improve its compatibility with ceramics.
CHEMICAL STABILITY

It is insoluble and impermeable to oral fluids. Also it is resistant to most solvents. However, hydrofluoric acid causes etching of the porcelain surface.

A source of this is APF (acidulated phosphate fluoride), which are used as topical fluorides. resulted in surface roughness which may lead to subsequent staining.

Hydrofluoric acid is used to etch the porcelain. Ceramic etchants are also used for intraoral repair of fractured ceramic.
CAD/CAM
CERAMICS
Constructing a dental ceramic restoration is technique sensitive, labor intensive and time consuming.

Machined ceramics were introduced to overcome some of these problems. They are also known as milled or machined ceramics. Machinable ceramic systems can be divided into two categories

1. CAD/CAM systems
2. Copy milled systems
ESSENTIALS OF A CAD/CAM SYSTEM

The CAD/CAM system consists of 5 essentials

1. Scanner or digitizer – Virtual impression
2. Computer – Virtual design (CAD)
3. Milling station – Produces the restoration or framework
4. Ceramic blanks – Raw material for the restoration
5. Furnace – For post sintering, ceramming etc.
FIGURE 28.30 Schematic representation of CAD/CAM production.
The dimensions of the prepared tooth (or die or wax pattern) are picked up and digitized in order to create a 3 dimensional image of the prepared tooth in the computer. This is achieved by scanning of the preparation or the die.

The 2 types of digitizers currently employed are

1. **Contact probes** Physically contacts the die as it moves along its surface while transmitting the information to the computer. E.g. Procera Forte contact scanner.

2. **Scanners** Unlike contact probes, scanners are optical devices. These include
   - **Intraoral hand-held wands** (Fig. 28.31A) These are chairside scanners.
   - **Laboratory scanners** These are larger devices that scan the cast or die using different technologies.
Tooth preparation may be scanned directly in the mouth with a **hand held scanner**.

The preparation may also be scanned from a cast by **3d Dental Scanner**.
FIGURE 28.32A AND B  (A) Light beam scanner (Kavo Everest). (B) Laser conoscopic holography (new Procera optical scanner).
**COMPUTER (CAD PROCESS)**

The restoration or the core is designed in the computer (Fig. 28.31C). Most manufacturers have their own software for the CAD process. The CAD process aids.

A recording of the bite registration (the imprint of the opposing or antagonist tooth in a wax-like or rubbery material) is also added to the data.

The combined information together with the 3D optical impression of the prepared tooth establishes the approximate zone in which the new restoration can exist.

The proposed restoration can then be morphed to fit into this zone in an anatomically and functionally correct position.
Milling stations: The earlier models ground only the internal surface. The external surface had to be manually ground.

Current CAD/CAM machines can grind the external surface also. Signals from the computer control the milling tool which shapes the ceramic block according to the computer generated design.

To begin the process the ceramic block is attached to the machine via a frame or built-in handle(s).
Schematic representation of movement of laser milling machine
A variety of ceramic blanks in various sizes, shades and shapes are available for milling. Multiple units can be produced from the larger blocks. The smaller blanks may produce only a single coping or restoration.
Classification of machinable ceramic blanks

- Feldspathic porcelain blanks [Vitablocs Mark II (Vita)].
  1. Tetrasilicic fluormica based glass ceramic [Dicor MGC (Dentsply)]
  2. Leucite based [ProCad (Ivoclar),
- Glass ceramic blanks
- Glass infiltrated blanks
  1. Alumina (Vita In-Ceram Alumina)
  2. Spinell (Vita In-Ceram Spinell)
  3. Zirconia (Vita In-Ceram Zirconia).
- Pre sintered blanks
  1. Alumina (Vita In-Ceram AL)
  2. Ytrria stabilized Zirconia (Vita In-Ceram YZ).
- Sintered blanks
  1. Alumina (Vita In-Ceram AL)
  2. Ytrria stabilized Zirconia (Vita In-Ceram YZ).
(Fig. 28.33) Feldspathic restorations can be milled to full contour. The restoration is glazed after milling.

Optional processing includes veneering and staining.

- inlays, laminates and anterior crowns.

(Fig. 28.36) These are usually machined as cores or FDP substructures. Subsequent processing includes glass infiltration, veneering, and glazing.

- In Ceram Spinell is recommended for anterior single crowns copings. In-Ceram Alumina is indicated for anterior and posterior crowns and 3 unit anterior FDP substructures.

In-Ceram Zirconia can be used for anterior and posterior crowns and 3 unit FDP substructures.
Pre sintered zirconia (Figs. 28.37 and 28.38): These are usually used as cores for crown or FDPs. They are milled to a slightly (20%) larger size, to compensate for the subsequent sintering shrinkage. Following milling they have to be sintered (called post sintering).

- Sintering is done in a furnace. Sintering time and temperature varies between brands. Sintering time – 6 to 7.5 hours • sintering temperature – 1350 to 1530 °C Because of the high temperatures involved special furnaces are required for zirconia sintering.

- The restoration may be immersed in special coloring liquid to improve the esthetics. The restoration is then built up with compatible veneering ceramics.

**Uses**—core construction for crowns and long span anterior and posterior FDPs.

Sintered zirconia (Figs. 28.39 and 28.40) Since these materials are already fully sintered, post sintering is not required. This material is milled in 1:1 ratio as no shrinkage is expected.

Because of its extreme hardness milling takes more time and causes more wear of the milling tool. Subsequent processing includes build up with compatible veneering ceramics.

**Uses**— core construction for crowns and long span anterior and posterior FDPs.
**FIGURE 28.33** Feldspatic porcelain.

**FIGURES 28.35A AND B (A)** Milled lithia disilicate crown in the presintered state can be tried in the mouth. This is possible because there is no shrinkage during the subsequent ceramming process. Note the color change after heat treatment (B). (Courtesy: Dr. Hanan Abuasi, MOH, Kuwait).

**FIGURE 28.36** CAD/CAM blanks for glass infiltration method.

**FIGURE 28.37** Presintered zirconia blank for multiple units.

**FIGURE 28.38** Presintered Zirconia. Blank with bar code is shown on the inset.
## COPY MILLED (CAM) SYSTEMS

<table>
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<td>Restoration designed virtually</td>
<td>Restoration designed manually</td>
</tr>
<tr>
<td>Object milled from virtual pattern</td>
<td>Restoration mills replica of pattern</td>
</tr>
</tbody>
</table>

Comparison of CAD/CAM and copy-milling

Commercial systems available Examples of commercially available copy-milling systems are

1. Celay (Figs. 28.41A to C) (Mikrona AG, Spreitenbach, Switzerland).
2. Cercon (Degudent, Dentsply). Cercon has both CAD/CAM and copy-milling systems.
3. Ceramill system (Fig. 28.42). Fabrication of a copy-milled restoration substructure.
The Cercon system: will be described (Figs. 28.43A to I).

A stone die is prepared from the impression of the preparation.

A pattern of the restoration is created using wax.

The pattern is fixed on the left side of the milling machine (Cercon Brain).

A presintered zirconia blank is attached to the right side (milling section) of the machine.
FIGURES 28.43A TO I Fabrication of a zirconia restoration with the Cercon system. (A) Cercon brain (milling unit). (B) Zirconia blanks. (C) Wax pattern. (D) Blank in position. (E) Milling. (F) Separating. (G) Sintering (cercon heat). (H) A completed substructure. (I) A completed prosthesis.
the Ceramill system (Fig. 28.42) is based on the pantograph type of copy milling which, according to the company, “puts the material back in the hands of the technician”.
YTTRIA STABILIZED ZIRCONIA
CERAMICS

Zirconium is one of the most abundant elements in the earth’s crust. Zirconia is the oxide of zirconium (ZrO2). Zirconium oxide is a white crystalline oxide ceramic with unique properties.

The addition of minor components to the zirconia, such as yttrium, can produce a crystal that is both strong and resistant to crack generation because of the unique “transformation toughening” that occurs when zirconia goes from a tetragonal phase to a monoclinic phase. It is this monoclinic phase of zirconia that is resistant to breakage when used in full-coverage restorations.

When a stress is applied to the zirconia as in the beginning of a crack formation, it reverts back to its monoclinic form locally with an accompanying increase in volume. The local increase in volume introduces compressive stresses around the crack and slows its growth. This is also known as ‘tension expansion’.
FRACTURE OF ZIRCONIA RESTORATIONS

Zirconia is a very strong material that can support an FDP. Nevertheless, chipping of the veneering ceramics has been reported, especially in the molar region. Low-fusing porcelains may be less resistant to cracking than high-fusing porcelains and the porcelain density is lower.

Also, fast cooling may create stress in the porcelain, which could lead to cracking.

Any surface adjustment, such as grinding, sandblasting, and even polishing, can change the phase on the surface of the zirconia and may affect the stability and strength of the zirconia as well as the veneer porcelain.

Fracture of zirconia restorations Occasionally, total fracture of the zirconia core itself have been observed especially in the region of the second molars and over implants in the posterior region.

Excessive or coarse grinding can cause cracks, which penetrate into the zirconia substructure, causing transformation that may initially hold these cracks closed. However, over time with exposure to the oral environment and reversal of the transformation stress, the cracks can begin to propagate.
Wear of opposing teeth Studies using natural teeth have shown that zirconia causes excessive wear of the natural tooth structure. Glazing alone is not sufficient as the glaze wears off exposing the rough surface underneath. Polishing, in addition to glazing is recommended currently to reduce wear of natural teeth.
ADVANTAGES AND DISADVANTAGES OF CAD/CAM CERAMIC RESTORATIONS

• Advantages

• 1. Less waiting period. In some cases same day restorations are possible.
• 2. Stronger porcelain. Milled ceramic is stronger
• 3. the scanning is done directly in the mouth so there is no need to make impression.
• 4. Reduced porosity, therefore greater strength.
• 5. Lab equipment can be minimized as equipment involved with metal casting and processing are not required.
• 6. Ability to copy the original form of the tooth can produce restorations that are duplicates of the original tooth.
Disadvantages

1. Costly equipment.
2. Scanning the preparation is technique sensitive.
3. Still not as strong as PFM restorations.
4. Problem of chipping of veneering ceramic in case of zirconium core ceramics
Dental Casting Alloys
ALLOY: An alloy is defined as 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.

Noble metals: have been used for inlays, crowns and FDPs because of their resistance to corrosion in the mouth. Gold, platinum, palladium.

PRECIOUS METALS: All noble metals are precious but all precious metals are not noble. Referring to their high economic values.

BASE METALS: These are non-noble metals. They are important components of dental casting alloys because of their influence on physical properties, control of the amount and type of oxidation and their strengthening effect. Examples Chromium, cobalt, nickel.
Gold: Pure gold is a soft and ductile metal with a yellow ‘gold’ hue. Gold has a good luster and takes up a high polish. It has good chemical stability and does not tarnish and corrode under normal circumstances.

Silver: Sometimes described as the ‘whitest’ of all metals. It has the lowest density and melting point among the precious casting alloys.

Palladium: has a higher melting point and lower when compared to gold.

Platinum: It has the highest density, highest melting point among the four precious metals.
CLASSIFICATION OF DENTAL CASTING ALLOYS

- **BASED ON MECHANICAL PROPERTIES**
  - **Type 1** - Intended for low stress bearing single-tooth fixed restorations, e.g. veneered or unveneered one-surface inlays,
  - **Type 2** - Intended for single tooth fixed restorations,
  - **Type 3** - Intended for multiple unit fixed restorations, e.g. bridges.
  - **Type 4** - Intended for appliances with thin sections that are subject to very high forces, e.g. removable partial dentures, clasps, thin veneered crowns,
  - **Type 5** - Intended for appliances in which parts require the combination of high stiffness and strength, e.g. thin removable partial dentures, parts with thin cross-sections, clasps.
based on use of dental casting alloys

- A. Alloys for all metal and resin veneer restorations – High noble – Noble – Predominantly base metal – Base metal
- B. Alloys for metal-ceramics restorations – High noble – Noble – Predominantly base metal – Base metal
- C. Alloys for casting large structures – High noble – Noble – Predominantly base metal – Base metal
GENERAL REQUIREMENTS OF CASTING ALLOYS

1. They must not tarnish and corrode in the mouth.
2. They must be sufficiently strong for the intended purpose.
3. They must be biocompatible (nontoxic and nonallergenic).
4. They must be easy to melt, cast, cut and grind (easy to fabricate).
5. They must flow well and duplicate fine details during casting. This property is also termed castability.
FUNCTIONAL MECHANICAL PROPERTIES OF CASTING ALLOYS
• Elastic modulus

This property represents a proportional constant between stress and strain during the elastic deformation of a material.

Material with high elastic modulus is rigid. For a dental prosthesis, it is equivalent to its flexure resistance.

• YIELD STRENGTH

Reflects the capacity of a cast prosthesis to withstand mechanical stresses without permanent deformation. Ideally, the alloys should have a high yield strength.”
• **HARDNESS**

Hardness of the metal should be high enough to resist scratching and abrasion and also to maintain the smoothness of the prosthesis in the oral environment.

• **FATIGUE RESISTANCE**

This phenomenon occurs when a material is subjected to repeated loading and unloading below its elastic limit. Most fractures of prostheses and restorations develop progressively over many stress cycles.
ALLOYS FOR ALL METAL RESTORATIONS

- The early alloys were mostly gold alloys.
- **WHY** currently, the use of these alloys are slowly declining?
  - **Because of** 1- Increased esthetic awareness has reduced the trend for metal display.
  - 2- Increasing popularity of all-ceramic and metal-ceramic restorations.
  - 3- Resin facings have a number of disadvantages.
    - – They wear rapidly (poor wear resistance).
    - – They may change color (color instability and stain absorption).
    - – They are porous. They tend to absorb food material and bacteria. This makes it unhygienic and gives it a bad odor.
CLASSIFICATION

- **TYPE I SOFT** Small inlays, Class III and Class V cavities which are not subjected to great stress. They are easily burnished.

- **TYPE II MEDIUM** Inlays subject to moderate stress, thick 3/4 crowns, abutments, pontics

- **TYPE III HARD** Inlays, crowns and bridges, situations where there may be great stresses involved.

- **TYPE IV EXTRA-HARD** Inlays subjected to very high stresses, partial denture frameworks and long span bridges
Why do we alloy gold?

Because pure gold is a soft and ductile metal and so is not used for casting dental restorations and appliances in its pure state. An increase in the platinum, palladium and silver content of modern alloys have resulted in whiter colored gold alloys. Thus, there are ‘yellow gold alloys’ and ‘white gold alloys’.
GOLD CONTENT Traditionally, gold content of dental casting alloys was called

Karat

Fineness

KARAT It refers to the parts of pure gold present in 24 parts of alloy, e.g. 24 karat gold is pure gold. 22 karat gold is 22 parts pure gold and 2 parts of other metal.

FINENESS of a gold alloy is the parts per thousand of pure gold. Pure gold is 1000 fine. Thus, if 3/4 of the gold alloy is pure gold, it is said to be 750 fine.
These alloys were introduced as a cheaper alternative to gold alloys. It is predominantly silver in composition. Palladium (at least 25%) is added to provide nobility and resistance to tarnish. They are white in color.
Metal-ceramic alloys are those alloys that are compatible with porcelain and capable of bonding to it. A layer of porcelain is fused to the alloy to give it a natural tooth-like appearance.

Porcelain being a brittle material fractures easily, so these alloys are used to reinforce the porcelain.
REQUIREMENTS OF ALLOYS FOR PORCELAIN BONDING

O 1. Its melting temperature should be higher than porcelain firing temperatures.
O 2. It should be able to resist creep at these temperatures.
O 3. They should be able to bond with porcelain.
O 4. It should have a high stiffness (modulus of elasticity). Any flexing of the metal framework may cause porcelain to fracture or delaminate.
O 5. It should not stain or discolor porcelain.
TYPES (CLASSIFICATION) OF METAL-CERAMIC ALLOYS

1. High noble (commonly referred to as gold alloys)
   - Gold-palladium-platinum alloys – Gold-palladium-silver alloys

2. Noble (commonly referred to as palladium alloys)
   - Palladium-silver alloys – Palladium-gold alloys –

COMMON FEATURES of METAL-CERAMIC ALLOYS
Gold based alloy range from white to gold depending on the gold content. The whitening alloys are palladium and platinum. The gold color when present can enhance the vitality of the porcelain thus improving the esthetics.

palladium-based) metal-ceramic alloys: Color They are white in color.

nickel-chromium alloys They are white in color.
Gold based alloy
Porcelain is fired at a temperature of 900–960 °C. Thus obviously these alloys must have melting temperatures much higher than the temperatures at which porcelain is fired.

Palladium-based metal-ceramic typical melting range is 1155–1304 °C. This is desirable to ensure that these alloys do not melt during porcelain firing.

Nickel-chromium alloys
A typical melting range is 1155–1304 °C. Melting range of these alloys like the gold ceramic alloys are high.
Gold based alloy: These alloys are relatively softer when compared to the base metal alloys and so are extremely easy to work with. They are easy to cut, grind and polish.

Hardness and workability

palladium-based) metal-ceramic alloys: Workability
Like the gold alloys these alloys are extremely easy to work with. They are easy to cut, grind and polish.

Hardness They tend to be slightly harder than the high noble metal-ceramic alloys.

nickel-chromium alloys: They tend to be much harder than the high noble metal ceramic alloys. Unlike the gold alloys these alloys are extremely difficult to work with in the laboratory.
Gold based alloy: The presence of an oxide layer on the surface of metal ceramic alloys assists in chemical bonding of porcelain to the alloy. Pure noble metal alloys rarely form an oxide layer. To induce the formation of an oxide layer, nickel-chromium alloys may be used. A dark oxide layer may be seen at the porcelain metal junction.

Palladium-based metal-ceramic alloys: Porcelain bonding. Like the gold alloys, base metals like tin, indium, etc. are added to enhance porcelain bonding.
Gold based alloy are resistant to tarnish and corrosion under normal oral conditions. This is due to their high noble content. Noble metals are less reactive.

TARNISH AND CORROSION RESISTANCE

palladium-based) metal-ceramic alloys:
Because of their high noble metal content, these alloys are extremely stable in the oral environment.

nickel-chromium alloys
These alloys are highly resistant to tarnish and corrosion. This is due to the property known as passivation. These alloys can maintain their polish for years.
Gold based alloy: This indicates the stiffness/flexibility of the metal. Gold alloys are more flexible than base metal alloys.

Palladium-based metal-ceramic alloys: High elastic modulus, strength, and hardness than gold.

Nickel-chromium alloys: Base metal alloys are twice as stiff as the gold ceramic alloys. Practically, this means that we can make thinner, lighter castings or use it in long span FDPs.
Gold based alloy: High noble alloys have had a good and safe track record. They are not known to cause any problems in the mouth.

Biological considerations

Palladium-based) metal-ceramic alloys: These alloys are very safe and biocompatible. Some concerns have been expressed over the copper content.

Nickel-chromium alloys: Nickel may produce allergic reactions in some individuals. It is also a potential carcinogen.
TITANIUM AND ITS ALLOYS FOR METAL-CERAMIC APPLICATIONS

USES
1. Metal-ceramic restorations.
2. Dental implants.
3. Partial denture frames
5. Bar connectors
PROPERTIES OF COMMERCIALLY PURE TITANIUM

- **Color**: It is a white color metal.
- **Modulus of elasticity**: It is only half as rigid as base metal alloys. However, this appears to be sufficient for most dental uses.
- **Melting point**: Its melting point is quite high (1668 °C). Special equipment is needed for casting titanium.
- **Tarnish and corrosion**: Titanium has the ability to self-passivate. The metal oxidizes almost instantaneously in air to form a tenacious and stable oxide layer. The oxide layer protects the metal from further oxidation. In addition, the oxide layer allows for bonding of fused porcelains, adhesive polymers or, in the case of endosseous implants.
- **Biocompatibility**: It is nontoxic and has excellent biocompatibility with both hard and soft tissues.
Advantages
1. High strength.
2. Light weight.
3. Low tarnish and corrosion because of ability to passivate.

Disadvantages
1. Poor castability.
2. Highly technique sensitive.
3. Requires expensive machines for casting and machining.
Cobalt-chromium alloys have been available since the 1920s. They possess high strength.

Their excellent corrosion resistance especially at high temperatures, makes them useful for a number of applications.

These alloys are also known as ‘stellite’ because of their shiny, star-like appearance.

They are bright lustrous, hard, strong and possess non tarnishing qualities.
The cobalt-chromium alloys have replaced Type IV gold alloys, especially for making RPDs, because of their lower cost and good mechanical properties.

- Fusion temperature: Thus casting temperature of this alloy is considerably higher than that of gold alloys (1250 °C to 1480 °C).
- Modulus of elasticity: They are twice as stiff as gold alloys. Thus, casting can be made thinner, thereby, decreasing the weight of the RPD.
- Hardness: These alloys are 50% harder than gold alloys. Thus, cutting, grinding and finishing are difficult. It wears off the cutting instrument. Special hard, high speed finishing tools are needed.
- Tarnish and corrosion resistance (passivation): Formation of a layer of chromium oxide on the surface of these alloys prevents tarnish and corrosion in the oral cavity. This is called ‘passivating effect’. Caution: Hypochlorite and other chlorine containing compounds that are present in some denture cleaning solutions will cause corrosion in base metal alloys.
Dental Casting and Metal Fabrication Procedures
* CASTING *

*Casting* can be defined as the act of forming an object in a mold. The object formed is also referred to as ‘a casting’

*A SPRUE FORMER* is made of wax, plastic or metal.

*SPRUE DIAMETER*: diameter that is approximately the same size as the thickest area of the wax pattern.

*SPRUE POSITION*: the ideal area for the sprue former is the point of greatest bulk in the pattern to avoid distorting thin areas of wax.

*SPRUE ATTACHMENT*: Flaring of the sprue former may act in much the same way as a reservoir, facilitating the entry of the fluid alloy into the pattern area. It is best for the molten alloy to flow from a thick section to surrounding thin areas.

*SPRUE LENGTH*: The length of the sprue former depends on the length of the casting ring. the sprue length should be adjusted so that the top of the wax pattern is within 6 mm of the open end of the ring for gypsum-bonded investments. With the higher-strength phosphatebonded investments, within 3 to 4 mm of the top of the investment.
*FUNCTIONS OF SPRUE FORMER/SPRUE داخل*

*1. To create a channel for the elimination of wax during burnout.*

*2. Forms a channel for entry of molten alloy during casting.*

*3. Provides a reservoir of molten metal which compensates for alloy shrinkage during solidification.*
A ring liner is placed inside of the casting ring.

**TYPES OF NONASBESTOS RING LINERS**

1. Fibrous ceramic aluminous silicate
2. Cellulose (paper)
3. Ceramic-cellulose combination

**FUNCTIONS OF THE RING LINER**

1. Allows for mold expansion (cushion effect).
2. When the ring is transferred from the furnace to the casting machine it reduces heat loss as it is a thermal insulator.
3. Permits easy removal of the investment after casting.
WAX ELIMINATION (BURNOUT) AND THERMAL EXPANSION

The purpose of burnout is

1. To eliminate the wax (pattern) from the mold.
2. To expand the mold (thermal expansion).
Two stage burnout and expansion technique. The ring is placed in a burnout furnace and heated gradually to 400 °C in 20 minutes.

Maintain it for 30 minutes. Over the next 30 minutes, the temperature is raised to 700 °C and maintained for a further 30 minutes.

Single stage burnout and expansion (Rapid technique): Place molds directly into preheated oven at 700-850 °C. Hold for 30-40 minutes and cast.
CASTING MACHINES

1. Centrifugal force type FIGURE A
2. Air pressure type FIGURE B

Centrifugal machines. The main advantage of the centrifugal machines is the simplicity of design and operation, with the opportunity to cast both large and small castings on the same machine.

In air pressure type of machine, either compressed air or gases like carbon dioxide or nitrogen, can be used to force the molten metal into the mold.

Attached vacuum system Casting machines (both centrifugal and gas pressure type) with attached vacuum system are available. The vacuum creates a negative pressure within the mold, which helps to draw the alloy into the mold.
* Casting machines be grouped based on heating system employed

* Torch melting
  * A. Mixing zone
  * B. Combustion zone
  * C. Reducing zone
  * D. Oxidizing zone

A reducing flame is preferred as it does not contaminate the alloy and is the hottest part of the flame.

**FIGURE 21.7** Flame melting.

**FIGURE 21.8** Parts of the flame (A) Mixing zone. (B) Combustion zone. (C) Reducing zone. (D) Oxidizing zone.
*Induction melting:* is the process of heating an electrically conducting object (usually a metal) by electromagnetic induction. Induction melting is useful for melting high fusing alloys like metal-ceramic and base metal alloys.
*Arc melting* is used to melt industrial alloys like steel. Arc melting produces very high temperatures and is used to melt high fusion metals like titanium.
Crucibles The crucible is a heat resistant container in which the alloy is melted prior to casting.

SANDBLASTING is the process by which particles of an abrasive is projected at high velocity using compressed air in a continuous stream. The casting is held
*PICKLING* Surface oxides (e.g. black castings) from the casting are removed by pickling in 50% hydrochloric acid. HCl is heated but not boiled with the casting in it (done for gold alloys).

*RECOVERY OF CASTING* The investment is removed and the casting recovered.

*TRIMMING* The sprue is sectioned off with a cutting disc. The casting is trimmed, shaped and smoothed with suitable burs or stones.

*POLISHING* Minimum polishing is required if all the procedures from the wax pattern to casting are followed meticulously.
### Casting Defects

<table>
<thead>
<tr>
<th>A. Metal excess</th>
<th>(nodules, fins, larger castings)</th>
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<tr>
<td>B. Metal deficiency</td>
<td>(smaller casting, incomplete casting, porosity)</td>
</tr>
<tr>
<td>C. Distortion of the casting</td>
<td></td>
</tr>
<tr>
<td>D. Chemical contamination of the casting</td>
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</tbody>
</table>
* Casting defects may be described as follows
  * 1. Casting size mismatch
  * 2. Distortion
  * 3. Surface roughness
  * 4. Nodules
  * 5. Fins
  * 6. Porosity
  * 7. Incomplete casting
  * 8. Contaminated casting
CASTING SIZE MISMATCH: The restoration should retain its dimensions after casting. Thus the casting may be 1. Too small 2. Too large. Casting size problems affect the fit of the restoration.

DISTORTION: Distortion of the casting is usually due to distortion of the wax pattern. Wax distortion is minimized by manipulating the wax at high temperature.
**SURFACE ROUGHNESS** Surface irregularities can range from surface roughness to larger nodules and fins. Causes of surface roughness

* 1. Type of investment
* 2. Particle size of investment Larger particle size of investment produces coarse castings.
* 3. Improper W-P ratio 4. Prolonged heating causes disintegration of the mold cavity.
* 5. Too high or too low casting pressure.
* **SURFACE NODULES** Nodules (Fig. 21.16) on the inner surface of a casting can affect the fit of the restoration. They are usually caused by air or gas bubbles trapped on the wax pattern. Minimized by •Proper mixing of investment •Vibration of mix •Vacuum investing

* **Cracks** are usually caused by weak investment or too rapid a heating of the investment. Minimized by •Proper water powder ratio for improved strength of investment. •Avoid prolonged and rapid heating of the mold.
1. Those caused by solidification shrinkage
   - Localized shrinkage porosity
   - Suck back porosity (Irregular in shape)
   - Microporosities

2. Those caused by gas
   - Pin hole porosity
   - Gas inclusions
   - Subsurface porosity

3. Those caused by air trapped in the mold
   - Back pressure porosity
* **Pin hole porosity** Many metals dissolve gases when molten. Upon solidification the dissolved gases are expelled causing tiny voids.

* **Gas inclusion porosities** are also spherical voids but are larger than the pin hole type.

* **Back pressure porosity** This is caused by inadequate venting of the mold. Air is trapped in the mold and is unable to escape. Avoided by: • Using adequate casting force. • Use investment of adequate porosity. • Place pattern not more than 6 to 8 mm away from the end of the ring.
FIGURES 21.19A TO C  Suck back porosity. (A) Correct sequence of hardening. (B) Suck back porosity caused by incorrect sequence of solidification. (C) Suck back porosity in a casting.

PINHOLE/GAS INCLUSION POROSITY
Back pressure porosity

- Sometimes referred to as entrapped-air porosity.

Causes
- Inability of the air in the mold to escape through the pores in the investment
**INCOMPLETE CASTING** An incomplete casting (Fig. 21.20) may result when

* 1. Insufficient alloy used.
* 2. Alloy not sufficiently molten or fluid.
* 3. Alloy not able to enter thinner areas of mold.
* 4. Mold is not heated to proper temperature.
* 5. Premature solidification of alloy.
* 6. Sprue blocked with foreign bodies.
* 7. Back pressure due to gases in mold cavity.

**CONTAMINATION** A casting can be contaminated due to

* 1. Oxidation, caused by - Overheating the alloy - Use of oxidizing zone of flame
* 2. Sulfur compounds, formed by the breakdown of the investment when the ring is overheated.

**BLACK CASTING** Can be due to two reasons.

* 1. Overheating the investment above 700 °C causes it to decompose liberating sulfur or sulfur compounds. 2. A black casting can be also due to incomplete elimination of the wax pattern
Dental Ceramics
WHAT ARE CERAMICS?

- The term *ceramic* refers to any product made from a nonmetallic inorganic material usually processed by firing at a high temperature to achieve desirable properties.

- The more restrictive term *porcelain* refers to a specific compositional range of ceramic materials originally made by mixing *kaolin* (hydrated aluminosilicate), *quartz* (silica), and *feldspars* (potassium and sodium aluminosilicates), and firing at high temperature.

- Dental ceramics for *metal-ceramic* restorations belong to this compositional range and are commonly referred to as *dental porcelains*.

- However, a variety of machinable ceramics are also available for chair-side fabrication of all-ceramic restorations by computer-aided design/computer aided manufacturing (CAD/CAM).

- Dental ceramics: are nonmetallic, inorganic structures, primarily containing compounds of oxygen with one or more metallic or semi-metallic elements (boron, calcium, magnesium, phosphorus, potassium, silicon, and zirconium). Many dental ceramics contain a crystal phase and a silicate glass matrix phase.
Properties

1. Ceramics are more resistant to corrosion than plastics.
2. Chemical inertness is an important characteristic because it ensures that the chemically stable surface of dental restorations does not release potentially harmful elements, and it reduces the risk for surface roughening.
3. They also remain stable over long time periods. Excellent wear resistance.
4. They exhibit good to excellent strength and fracture toughness.
5. One of the strongest and toughest ceramics, zirconium dioxide, has a flexural strength similar to that of steel, but its fracture toughness is much lower than that of steel.
6. Dental ceramics have thermal insulating properties (low thermal conductivity and low thermal diffusivity), and their freedom from galvanic effects (low electrical conductivity).
7. Most ceramics are characterized by their biocompatibility,
8. Esthetic potential.
USES AND APPLICATIONS

- 1. Inlays and onlays.
- 2. Esthetic laminates (veneers) over natural teeth.
- 3. Single (all ceramic) crowns.
- 4. Short and long span (all ceramic) FDP.
- 5. As veneer for cast metal crowns and bridges (metal ceramics).
- 6. Artificial denture teeth (for complete denture and partial denture use).
- 7. Ceramic post and cores.
- 8. Ceramic orthodontic brackets
CLASSIFICATION OF DENTAL PORCELAINS

ACCORDING TO FIRING TEMPERATURE:
1- High fusing 1300 °C or above
2- Medium fusing 1101 °C to 1300 °C
3- Low fusing 850 °C to 1100 °C
4- Ultra low fusing less than 850 °C

ACCORDING TO MICROSTRUCTURE
1- Glass ceramics
2- Crystalline ceramics
3- Crystal containing glasses

Classification by Fabrication Method
1- Sintering is the process of firing the compacted ceramic powder at high temperature to ensure optimal densification.
2- slip-casting,
3- heat-pressing, and
4- CAD/CAM machining.
• ACCORDING TO ITS FUNCTION WITHIN THE RESTORATION داخل
• 1-Core ceramics – Supports and reinforces the restoration in all-ceramic restorations
• 2-Opaquer ceramics – Masks or hides the metal or underlying core ceramic. Bonds ceramic to underlying metal
• 3-Veneering ceramics
• – Body or dentin – Simulates the dentin portion of natural teeth
• – Incisal – Simulates the enamel portion of natural teeth
• – Gingival – Simulates the darker gingival portion of teeth
• – Translucent – Simulates translucent incisal enamel seen some times in natural teeth
• 4-Stains – Used to color ceramics to improve esthetics
• 5-Glaze – Imparts a smooth glossy surface to the restoration
MECHANICAL PROPERTIES OF DENTAL CERAMICS

• BRITTLNESS

• Although ceramics are strong, and resilient, these materials are brittle and may fracture without warning when flexed excessively or when quickly heated and cooled (i.e., under thermal shock conditions).

• It is generally believed that dental ceramics fail primarily because of their brittleness, which is inversely related to its ductility or percent elongation.

• two fracture mechanics properties may better explain this behavior.

• 1-FRACTURE TOUGHNESS: which is designated as K\textsubscript{IC}, describes the critical stress intensity factor (tensile loading perpendicular to the crack plane) crack opening under tensile stress. For dental ceramics, K\textsubscript{IC} varies between 0.75 MPa\(\cdot\)m\(1/2\) for feldspathic porcelain to 8 MPa\(\cdot\)m\(1/2\) or more for yttria-stabilized zirconia.
Another property that is used to describe the brittle fracture resistance of ceramics is the

**2-CRITICAL STRAIN ENERGY RELEASE RATE**, which is designated as G. The energy release rate failure criterion is that a crack will grow when the energy release rate is greater than or equal to a critical value, Gc, which is referred to as the fracture energy. This property is a measure of the unit strain energy that is released per unit increase in crack area as a ceramic with flaws or cracks is loaded progressively.
PORCELAIN/CERAMIC SYSTEMS

- The entire restoration may be made of just one type of porcelain or it may be layered with different types of porcelains. Many crowns and FDPs are fabricated as layered restorations.
- A layered restoration can be divided into 2 basic parts.
- **Core (or substructure)**: The core provides support and strength for the crown.
- The core is usually dense and opaque and generally unesthetic.
- **Veneer (outer layer)**: The core is veneered with various layers of specialized porcelains called dentin, enamel, cervical and translucent.
Core is for support and may be made of metal in case of a metal ceramic crown or a dense strong ceramic in case of an all ceramic crown.
CLASSIFICATION AND DESCRIPTION OF CERAMIC SYSTEMS

- Based on the substructure or core material used there are two basic groups. They are further divided based on the fabrication method.
  - A. Metal-ceramic restorations
    - 1. Cast metal-ceramic restorations
      - Cast noble metal alloys
      - Cast base metal alloys
      - Cast titanium (ultra low fusing porcelain).
    - 2. Burnished foil metal ceramic restorations
      - Capillary casting [sintered gold alloy foil coping Renaissance, Captek]
      - Bonded platinum foil coping.
• B. All ceramic restorations
  • 1. Platinum foil matrix condensed porcelain restorations
    • - Conventional feldspathic porcelain restorations
    • - Porcelain restorations with aluminous core
  • 2. Castable glass ceramics (Dicor)
  • 3. Pressable glass-ceramics
  • 4. Glass infiltrated core porcelains - Glass infiltrated aluminous core (In-Ceram)
    • - Glass infiltrated zirconia core (In-Ceram Zirconia)
  • 5. Ceramic restorations from CAD/CAM ceramic blanks
    • - Feldspathic porcelain blanks (Vitablocs Mark II)
    • - Glass infiltrated blanks (Alumina, Spinell, Zirconia)
METAL-CERAMIC RESTORATIONS

**FIGURE 28.4** Cross section through a metal ceramic crown fused to nickel chromium alloy.

**FIGURE 28.5** Parts of a metal ceramic crown. Transparent is used to duplicate the thin translucent enamel seen in some natural teeth.
TYPES OF METAL-CERAMIC SYSTEMS

• 1. Cast metal ceramic restorations
  • – Cast noble metal alloys (feldspathic porcelain)
  • – Cast base metal alloys (feldspathic porcelain)
  • – Cast titanium (ultra low fusing porcelain).
• 2. Burnished foil metal ceramic restorations
  • – Capillary cast [sintered gold alloy foil (Renaissance, Captek)]
  • – Bonded platinum foil coping.
CAST METAL-CERAMIC RESTORATIONS

- **USES:**
  - 1. Single anterior and posterior crowns.
  - 2. Short and long span anterior and posterior FDPs.

- **COMPOSITION OF CERAMIC FOR METAL BONDING:**
  - Feldspathic porcelains are used for metal bonding. A special opaquer porcelain is needed to mask the underlying metal.

- **SUPPLIED AS:**
  - 1. Enamel porcelain powders in various shades (in bottles) (Fig. 28.6)
  - 2. Dentin porcelain powders in various shades (in bottles)
  - 3. Liquid for mixing enamel, dentin, gingival and transparent
  - 4. Opaquer powders in various shades/ and liquid for mixing (Fig. 28.7)
  - 5. Gingival porcelain powder in various shades
FIGURE 28.6 Enamel and dentin powders with the modelling liquid.

FIGURE 28.7 Opaquer powder is mixed and applied to hide the metal. It is mixed with the liquid to produce a sandy mix. A glass spatula is used for mixing as metal might abrade and contaminate the porcelain.
The requirements of alloys and porcelains used for the construction of MC restorations

1- the metal framework must not melt during porcelain firing and also must resist high-temperature “sag” deformation.

2- Both the metal and the ceramic must have coefficients of thermal expansion and contraction that are closely matched such that the metal must have a slightly higher value to avoid the development of undesirable residual tensile stresses in the porcelain.

If the contraction coefficients are not nearly equal, stresses may occur that weaken both the porcelain and the bond.

thermally compatible systems: in which fracture is unlikely to occur except in cases of extreme stress concentration or extremely high intraoral forces.

3- high proportional limit and high modulus of elasticity of these materials. Alloys with a high modulus of elasticity share a greater proportion of stress than the adjacent porcelain.
MANIPULATION AND TECHNICAL CONSIDERATIONS

• METAL PREPARATION: A clean metal surface is essential for good bonding. The surface is finished with ceramic bonded stones or sintered diamonds. Final texturing is done by sandblasting with an alumina air abrasive, which aids in the bonding. Finally, it is cleaned ultrasonically, washed and dried.

• DEGASSING AND OXIDIZING: The casting (gold porcelain systems) is heated to a high temperature (980°C) to burn off the impurities and to form an oxide layer which help in the bonding. Degassing is done in the porcelain furnace.
• داخل

• **OPAQUER:** The opaquer is a dense yellowish white powder supplied along with a special liquid.

• condensed on the oxidized surface at a thickness of approximately 0.3 mm

• The opaquer has two important functions.

• 1-It is used to cover (mask) the metal frame and prevent it from being visible.

• 2-It also aids in bonding the veneering porcelains to the underlying frame.
• **DENTIN AND ENAMEL:** The dentin powder (pink powder) is mixed with distilled water or the supplied liquid. A glass spatula should be used. The bulk of the tooth is built up with dentin. A portion of the dentin in the incisal area is cut back and enamel porcelain (white powder) can be added (Fig. 28.12) building the restoration. After the build-up and condensation is over (Fig. 28.13), it is returned to the furnace for sintering.

• **ADDITIONS:** Large or difficult restorations may be built up and fired in two or more stages. After each firing (Box 28.2) the porcelain may be shaped by grinding and additional porcelain is placed in deficient areas. Each additional firing is done at a lower temperature. Caution The restoration should not be subject to too many firings. Excessive firings can give rise to a over translucent, lifeless restoration.
• CONDENSATION: The process of packing the powder particles together and removing the excess water is known as condensation.

• Purpose: Proper condensation packs the particles together. This helps minimize porosity, improve strength and reduce firing shrinkage. It also helps remove the excess water.

• Condensation techniques

• Vibration: Mild vibration by tapping or running a serrated instrument (Fig. 28.10) on the forceps holding the metal frame helps to pack the particles together and bring out the excess water which is then blotted by an absorbent paper (Fig. 28.11).

• Spatulation: A small spatula is used to apply and smoothen the wet porcelain. This helps to bring out the excess water.

• Brush technique (Dry powder): Dry powder is placed on the side opposite a wet increment. The water moves towards the dry powder pulling the wet particles together.
FIGURE 28.10 Condensing with mild vibration.

FIGURE 28.11 Blotting to remove excess water.

FIGURE 28.12 Building the restoration.

FIGURE 28.13 The built up crown.
vibrated to condense the particles together onto the substructure, expelling the liquid. The liquid is removed by absorption, and the particles interlock with one another.
Firing of porcelains

• **Firing**: The process of sintering and fusing the particles of the condensed mass is known as firing. It is done in a porcelain furnace.

• **The Porcelain Furnace**: Modern furnaces are computer controlled and have built-in programs to control the firing cycle. The programs can also be modified by the operator.

• **Firing Cycle**: The firing cycles vary depending on the stage - opaquer firing, dentin firing, glaze firing, etc. The firing temperature is lowered gradually for each subsequent firing cycle.

• **Preheating**: Modern furnaces have a mechanism whereby the work is gradually raised into the furnace. This is known as preheating.

• **Vacuum Firing**: This helps to reduce the porosity in the ceramic. The vacuum is later released raising the pressure in the furnace. The vacuum is not activated during the glaze firing.

• **Cooling**: The cooling of the fired porcelain should be well controlled. Rapid cooling can cause the porcelain to crack or it can induce stresses inside which weaken the porcelain. Cooling is done slowly and uniformly and is usually computer controlled.
• **GINGIVAL AND TRANSPARENT PORCELAIN**: The enamel of some natural teeth may appear transparent. This is usually seen near the incisal edges. If present it can be duplicated using transparent porcelain. The cervical portions of natural teeth may appear more darker (e.g. more yellow) than the rest of the tooth. When indicated cervical porcelains are used to duplicate this effect (they are also referred to as gingival or neck dentin).

• **GLAZING**: Glazing provides a smooth glossy surface to the restoration.

  • Objectives of glazing
  • 1. Glazing enhances esthetics.
  • 2. Enhances hygiene.
  • 3. Improves the strength. The glaze inhibits crack propagation.
  • 4. Reduces the wear of opposing teeth. The rough surface on unglazed porcelain can accelerate wear of the opposing natural teeth.
• **Types**

  • **1-Over glaze:** The glaze powder is mixed with the special liquid and applied on to the restoration. The firing temperature is lower than that of the body porcelain. The firing cycle does not usually include a vacuum.

  • **2-Self glaze:** A separate glaze layer is not applied. Instead the restoration is subject to a controlled heating at its fusion temperature. This causes only the surface layer to melt and flow to form a vitreous layer resembling glaze.
PORCELAIN-METAL BOND

• Falls into two groups

• CHEMICAL BONDING Currently regarded as the primary bonding mechanism. An adherent oxide layer is essential for good bonding. In base metal alloys, chromic oxide is responsible for the bond. In noble metal alloys, indium and tin oxide and possibly iridium oxide does this role.

• MECHANICAL INTERLOCKING In some systems mechanical interlocking provides the principal bond. Sandblasting is often used to prepare the metal surface. Presence of surface roughness on the metal oxide surface improves retention, especially if undercuts are present.
Durability of metal-ceramic bonding

- Three factors control the bonding:
- (1) mechanical interlocking or interatomic bonding at the interface between porcelain and the metal oxide;
- (2) interatomic bonding across the oxide-porcelain interface; and
- (3) the type and magnitude of residual stress in the veneering ceramic.
- Atomic or chemical bonding is primarily responsible for metal-porcelain adherence.
ADVANTAGES AND DISADVANTAGES OF METAL-CERAMIC RESTORATIONS

• ADVANTAGES
  • 1. Better fracture resistance because of the metal reinforcement.
  • 2. Better marginal fit because of the metal frame.

• DISADVANTAGES
  • 1. Poor esthetics when compared to all-ceramic restorations because the underlying metal and opaquer reduces the overall translucency of the tooth.
  • 2. The metal frame and the lack of translucency sometimes shows through the gingiva resulting in the characteristic dark margins.
DENTAL IMPLANT MATERIALS
A dental implant is a material or device placed in and/or on oral tissues to support an oral prosthesis.

**TYPES OF IMPLANTS**

A. Subperiosteal—a framework that rests upon the bony ridge but does not penetrate it (Fig. 26.1).

B. Transosteal—penetrates completely through the mandible (Fig. 26.2).

C. Endosseous—partially submerged and anchored within the bone (Figs. 26.3 and 26.4).
FIGURE 26.1 Subperiosteal implant radiograph (left). Intraoral view (right).

FIGURE 26.2 Transosteal implant.

FIGURE 26.3 Linkow’s blade vent endosseous implants were widely used prior to the era of cylindrical implants.

FIGURE 26.4 Radiograph showing an endosteal implant.
IMPLANT MATERIALS

Materials used in fabrication of dental implant generally classified into two different way:

- chemical point- metals and ceramics

- biological point- biodynamic materials: bio-tolerant, bio-inert, bioactive

Bio-tolerant: that are not necessarily rejected when implanted into living tissue

Bio-inert: material allow close approximation of bone to their surface leading to contact osteogenesis

Bioactive: tissue integrated engineered materials designed to mimic specific biological process
MATERIALS USED

1. Metals
   — Stainless steel
   — Cobalt-chromium-molybdenum based
   — Titanium and its alloys
   — Surface coated titanium

2. Ceramics
   — Hydroxyapatite
   — Bioglass
   — Aluminum oxide

3. Polymers and composites

4. Others — Gold, tantalum, carbon, etc.
Commerially pure titanium is currently the most widely used material for implants (Fig. 26.5). It has become the material of choice because of its:

1. Low density (4.5 gm/cm²) but high strength.
2. Minimal biocorrosion due to its passivating effect.
3. Excellent biocompatibility.
4. Titanium also has good stiffness.
CERAMICS Their applications are still limited because of their low tensile strength and ductility. Currently they are primarily used as surface coats on titanium implants. They are available in screw or blade form and are used as abutments in partially edentulous mouths.

STAINLESS STEEL had been tried as an implant material. It has high strength and ductility. Currently these materials are rarely used.

Precautions Since it contains nickel, it should be avoided in nickel sensitive patients. It is most susceptible to pit and crevice corrosion so the passivating layer must be preserved. Direct contact of the implant with a dissimilar metal crown is avoided to prevent galvanism.

POLYMERS AND COMPOSITES Polymers have been fabricated in porous and solid forms for tissue attachment and replacement augmentation. However, in some implants they are mainly used within the implants as connectors for stress distribution (shock absorption).
Basic implant design Since endosseous cylindrical root form implants are the most widely used design, Implants can range from complex, having multiple components to more simple designs.

Most endosseous implants can be divided into two basic parts (Fig. 26.6).

**Fixture**—embedded in bone

**Abutment**—supports the crown

The implant may be

**One piece**—Implant and abutment are joined together (Fig. 26.7A)

**Two-piece**—Implant and abutment are separate. The abutment is secured to the implant by means of an abutment screw (Fig. 26.7B)
Implant fixture the most favored form is the cylindrical screw or the tapered screw (Figs. 26.8A to D). The implant is inserted through a surgical procedure. The abutment is usually screwed onto the implant at a later date. The crown is then constructed and either screwed on or cemented onto the abutment thus completing the restoration.

The components are usually specific for the particular system and are usually not interchangeable. Some of them become part of the implant itself while others aid in the various stages of implant placement and tooth restoration. These include the drills, healing caps, impression copings, implant analogue, laboratory accessories, etc.
Implant abutments is that portion of a dental implant that serves to support and/or retain any fixed or removable dental prosthesis.

Classification of abutments

A. According to fabrication procedure 1. Stock abutment 2. Custom 3. CAD/CAM


C. According to angulation 1. Angled 2. Nonangled
Stock abutments  Also known easy, or direct abutments. They are factory produced and provide the most accurate fit to the implant. They can be modified at the chairside or in the laboratory. They come in varying sizes and emergence profiles.

Custom Cast  They were first popularized provided a means for waxing custom emergence profiles of the subgingival portion of the abutment, flexibility in margin level placement, and for correction of angulation problems.

CAD/CAM  State of the art software and milling machines utilize the scan data from the patient’s dental casts and the computer generated abutment design to enable production of an abutment specific for the patient.

Angled abutments  Angled abutments are used to correct the implant-crown alignment, e.g., upper central incisors often need angled abutments.

Zirconia abutments  Zirconia is a strong tooth colored ceramic material. These are indicated for patients demanding an increased level of esthetics.

One-piece implant-abutment  Some manufacturers do not provide separate abutments, rather the abutment is combined with the implant and is, therefore, inserted along with the implant.
**EQUIPMENT AND PARTS ASSOCIATED WITH IMPLANT SURGERY**

**Implant motor** These are high torque motors with foot control and saline stand (Fig. 26.9). The handpiece is contra angled and has a nozzle for saline irrigation. Having low speed but high torque is important for implant drilling.

**Implant drills** The pilot drill is the first drill used. It helps to establish direction of the subsequent drilling and implant placement. Subsequent drills are introduced in series of increasing size (Fig. 26.10). Drills are usually made of stainless steel.

**Cover screw** Implant surgery is usually done in two stages. In the first stage the implant is inserted in the bone and left to integrate for a period of 2 months. After the implant is placed, a cover screw (Fig. 26.11) is used to cover the coronal end of the abutment. The cover screw prevents bony ingrowth and keeps the abutment chamber patent while the implant is integrating.
FIGURE 26.9 Implant motor with saline irrigation.

FIGURE 26.10 Implant drills.

FIGURE 26.11 Cover screw.
HEALING ABUTMENT

The healing abutment is usually placed 2–3 months later at the second stage. The cover screw is removed and a healing abutment placed instead.

The healing abutment exposes the implant to the oral cavity (Fig. 26.12C) and prepares the space for the future abutment. The healing abutment may be cylindrical or anatomic in design (Figs. 26.12A and B).

Function of healing abutment

1. Allows the punched out tissue to heal.
2. Promotes the development of sulcus epithelium.
3. Helps to develop papilla and marginal gingiva, thus improving the soft tissue esthetics.
4. Helps to develop a proper emergence profile from the implant platform to the crown, thus improving the restoration esthetics (transition from the narrower implant to the broader artificial tooth).
IMPLANT ABUTMENT CONNECTION

It is one of the factors which help in proper functioning, stability and longevity of the implant. The abutment is secured to the implant with the help of a screw. During occlusal function considerable stress may be transferred to the screw and can lead to its early loosening or even fracture. Manufacturers have, therefore, incorporated certain design features to reduce the stress on the abutment screw.

Function of the implant abutment connection The implant/abutment interface determines

1- joint strength, lateral and rotational stability. It also

2-reduces stress on the abutment screw.

Types of implant abutment connections There are two ways the implant and abutment connect or interface. 1. External 2. Internal
External hex The original Brånemark protocol required several externally hexed implants to restore fully edentulous arches (Fig. 26.13).

Internal hex Its features were intended to distribute intraoral forces deeper within the implant to

1- protect the retention screw from excess loading, and
2- to reduce the potential of microleakage.
3- also provide superior strength for the implant/abutment connection.

Other internal connection designs have followed, frequently with variations in the numbers of hexes, connection length, angulation, etc. Some of the internal implant abutment connections are (Fig. 26.13)

3 point internal tripod — Replace select (Noble Biocare)
5 point internal pentagon — Tiologic (Dentaurum)
6 point internal hex — Frialit 2 (Friadent)
FIGURE 26.13 Various types of implant abutment connections.
Its high strength, fracture toughness, and its white color make zirconia an interesting material for the construction of implant abutments and superstructures especially in the anterior zone.

Indications for zirconia implant

1. Esthetic considerations

2. Sensitivity or allergy to titanium Zirconia implants (Fig. 26.17) should be considered in patients with known allergy to titanium.
ZIRCONIA ANATOMIC ROOT-FORM IMPLANTS

were introduced into dental implantology as an alternative to conventional cylindrical implants. Owing to its ability to be milled into the shape of the natural tooth root and be placed immediately following extraction,

its excellent biomechanical characteristics, biocompatibility, and bright tooth-like color, zirconia has the potential to become a substitute for titanium as dental implant material.

Immediate placement of implant similar in shape and size to the extracted root has its own advantages.

By adapting the root to the extraction socket instead of adapting the bone to a preformed standardized implant they reduced the bone and soft tissue trauma. Immediate custom-made root analogue implants were possible because of advances in material and CAD/CAM technology.
Advantages

1. Esthetic
2. Biocompatible
3. Immediate placement
4. No additional drilling or surgery required
5. No complications of implant surgery
6. Shorter waiting period
7. Fits into original socket
8. Immediate placement preserves bone and soft tissue (less resorption)
9. Preserves root eminences of the alveolar bone
10. Sinus lift not required
11. Bone graft not required
12. Little or no swelling or pain
13. Faster recovery time

Figures 26.18A AND B (A) Zirconia root form implants. (B) Periapical view.
The implant surface is critical to the proper biointegration of the implant. For this purpose various techniques have been used to modify the implant surfaces (Fig. 26.19) to improve its integration to the surrounding tissues. The techniques may be classified as

1. Ablative procedures
   Ablation is removal of material from the surface of an object by blasting, vaporization, or other erosive processes.
   - Grit blasting
   - Acid etching
   - Anodizing
   - Shot/ laser peening

2. Additive procedures
   It is a process of creating a layer by addition of material.
   - Plasma spraying
   - Electrophoretic deposition
   - Sputter deposition
   - Soluble gel coating
   - Soluble blast media
HYDROXYAPATITE COATED IMPLANTS

is a naturally occurring mineral form of calcium apatite. Bone is a specialized mineralized connective tissue consisting by weight of 33% organic matrix, permeated by HA, which makes up the remaining 67% of bone. For this reason, HA is being investigated as a possible material for coatings or composites.

Rationale The use of hydroxyapatite implants have been reported to stimulate bone healing, resulting in an improvement in the rate and strength of initial implant integration.

Hence, the dense HA layer on the top of titanium substrate is mainly for biointegration to bone tissue and enhanced implant stability. Thus, it is believed that the use of HA coatings on metallic implants would speed rehabilitation of patients by decreasing the time from implant insertion to final reconstruction.
DENTAL INVESTMENTS AND REFRACTORY MATERIALS
Investment داخل

• An investment can be described as a ceramic material which is suitable for forming a mold into which molten metal or alloy is cast. The procedure for forming the mold is described as ‘investing’. These materials can withstand high temperatures. For this reason, they are also known as refractory materials.

• A refractory is a nonmetallic material that can withstand high temperatures without degrading, softening, or losing its strength.
• 1. The investment mold must expand to compensate for the alloy shrinkage, which occurs during the cooling of the molten alloy.

• 2. The powder should have a fine particle size to give a smooth surface to the casting.

• 3. The manipulation should be easy. It should have a suitable setting time.

• 4. The material should have a smooth consistency when mixed.

• 5. The set material should be porous enough to permit air in the mold cavity to escape easily during casting.

• 6. At higher temperatures, the investment must not decompose to give off gases that may corrode the surface of the alloy.
CLASSIFICATION OF REFRACTORY MATERIALS IN DENTISTRY

A. Classification based on application

- Type 1: for the construction of inlays, crowns and other fixed restorations
- Type 2: for the construction of complete or partial dentures or other removable appliances
- Type 3: for the construction of casts used in brazing procedures

B. Sub-classification based on method of burn out

- Class 1: recommended for burn-out by a slow- or step-heating method
- Class 2: recommended for burn-out by a quick-heating method
C. Classification based on type of binder used:

There are three types of investment materials based on the binder used. They all contain silica as the refractory material. The type of binder used is different.

1. Gypsum bonded investments - They are used for casting gold alloys. They can withstand temperature up to 700 °C.

2. Phosphate bonded investments - For metal ceramic and cobalt-chromium alloys. They can withstand higher temperatures.

3. Ethyl silica bonded investments - They are an alternative to the phosphate bonded investments, for high temperature casting. They are principally used in the casting of base metal alloy partial dentures.
GYPSUM BONDED INVESTMENTS

• For casting of inlays, fixed partial dentures, removable partial denture frameworks using gold alloys and other low-fusing alloys

• Functions of Constituents

• A - Alpha hemihydrate

• 1 - It binds and holds the silica particles together.

• 2 - Permits pouring of the mix into the mold.

• 3 - It imparts strength to the mold.

• 4 - Contributes to mold expansion (by setting expansion).
• B- Silica quartz or cristobalite

• 1- Acts as a refractory during heating.

• 2- Regulates thermal expansion.

• 3- Increases setting expansion of stone.

• 4- Silica in the investment eliminates contraction of gypsum and changes it to an expansion during heating.
PROPERTIES OF GYPSUM INVESTMENTS

• **Thermal Behavior** of Gypsum When gypsum is heated to a high temperature, it shrinks and fractures. It contaminates the casting with the sulfides of silver and copper. So the gypsum bonded investments should not be heated above 700 °C.

• **Thermal Behavior of Silica** When heated, quartz or cristobalite changes its crystalline form. This occurs at a transition temperature, characteristic of the particular form of silica. When heated, inverts from a ‘low’ form known as alpha to a ‘high’ form called as **beta**

• The beta forms are stable only above the transition temperature, with a resulting increase in volume and a rapid increase in linear expansion.
EXPANSION

Expansion aids in enlarging the mold to compensate for the casting shrinkage of the gold alloys. Three types of expansions may be seen:

1. Normal setting expansion
2. Hygroscopic setting expansion
3. Thermal expansion
• **Normal setting expansion** A mixture of silica and dental stone results in a setting expansion which is greater than when the gypsum product is used alone.

• **Hygroscopic setting expansion** (HSE) When gypsum products are allowed to set in contact with water, the amount of expansion exhibited is much greater than the normal setting expansion. The increased amount of expansion is because water helps the outward growth of crystals. This expansion is known as hygroscopic setting expansion. The investment should be immersed in water before initial set is complete.
Factors affecting hygroscopic setting expansion

1. Composition The finer the particle size of the silica, the greater is the HSE. Higher the silica content, greater is the expansion.
2. W-P ratio The higher the W-P ratio of the original investment water mixture, the less is the HSE.
3. Temperature Higher the temperature of the immersion water, greater is the expansion.
4. Effect of time of immersion before the initial set results in greater expansion.
5. Spatulation Shorter the mixing time, the less is the HSE.
Thermal expansion

• In case of gypsum investments, thermal expansion (TE) is achieved by placing the mold in a furnace at a temperature not greater than 700 °C. The amount of thermal expansion required depends on which method is used for casting shrinkage compensation. If hygroscopic expansion technique is used, then TE of 0.5 to 0.6% is sufficient. But if the compensation is by TE together with normal setting expansion, then the TE should be 1 to 2%.

• Factors affecting thermal expansion

1. TE is related to the amount and type of silica used.

2. Effect of the W-P ratio more the water, less the TE.

3. Effect of chemical modifiers eliminates the contraction caused by gypsum.
Phosphate bonded investments

For casting high fusing alloys, e.g. high fusing noble metal alloys, metal ceramic alloys and base metal alloys like nickel-chromium and cobalt-chromium

Composition

Powder

A- Ammonium diacid phosphate

It gives strength at room temperature.

It is soluble in water and provides phosphate ions.

It reacts with silica at high temperatures to increase strength at casting temperatures.

B- Silica in the form of quartz or cristobalite (80%) functions as refractory.

C- Magnesium oxide Reacts with phosphate ions.

Liquid The phosphate bonded investments are mixed with a special liquid supplied by the manufacturer. This liquid is a form of silica sol in water, which gives higher thermal expansion.
Properties

• Expansion

• As mentioned earlier, expansion of the mold is desirable to compensate for casting shrinkage. Phosphate investments get their expansion from three sources.

  1. Wax pattern expansion The heat during setting allows a significant expansion of the wax pattern.

  2. Setting expansion

  3. Thermal expansion

• Strength

• Wet strength is important for handling the set material prior to casting.

• Dry strength is the strength of the investment under high temperatures. The investment should have sufficient strength to withstand the casting force of the molten alloy at high temperatures.
• Flow Investments appear to have low flow when mixed. However, they flow readily and envelope the pattern when poured into the mold under vibration. Therefore, use of a vibrator is recommended.

• Surface smoothness Early phosphate investments produced rough castings when compared to gypsum based investments. Current investments have improved and now approach surface smoothness comparable to that of gypsum bonded investments.
Investments for ceramics

- Two types are available

1. Those used as refractory dies or casts to construct all-porcelain restorations like porcelain veneers and porcelain jacket crowns. Two varieties are seen based on expansion.

- Medium expansion—Currently used with medium expanding porcelains

- High expansion—The second type is used with high expansion porcelains

2. The second type is used with heat pressed ceramics. It is not used as a die, rather, it is used to surround the wax pattern for the heat pressing process.

- Properties These are fine-grained phosphate investment with a working time of 2–5 minutes. Unlike regular refractory materials, these can withstand repeated firings at furnace temperatures of up to 1200 °C without disintegrating.
Investments for titanium castings

- Conventional silica (SiO\textsubscript{2}) based dental casting investments are used for the casting of pure titanium using casting machines specifically developed for this metal. Highly reactive molten titanium reduces SiO\textsubscript{2} and titanium is, in turn, oxidized. For this reason possible alternatives to SiO\textsubscript{2} have been studied in the past decade and MgO (magnesia) and Al\textsubscript{2}O\textsubscript{3} (alumina) are the most common in current commercial investments released for titanium casting.
Brazing (SOLDERING) INVESTMENT

• In the process of assembling the parts of a restoration by soldering, such as clasps on a removable partial denture, it is necessary to surround the parts with a suitable ceramic or investment.
- **Uses**: داخِل
- 1. Joining segments of fixed partial dentures (Fig 20.11).
- 2. Fixing clasps on cast RPDs.

- **Types**: Based on the type of binder used brazing investments are of two types.
  - 1. Gypsum-bonded (for low melting alloys)
  - 2. Phosphate-bonded (for high melting alloys).

- **Properties**
  - Soldering investments are designed to have lower setting (0.2%) and thermal expansions (0.6-1%) than casting investments, a feature that is desirable so that the assembled parts do not shift position.
  - Soldering investments do not have as fine a particle size as the casting investment, since the smoothness of the mass is less important.
CAUSES OF DEFECTIVE CASTINGS

• DISTORTION: Any marked distortion of the casting is probably related to a distortion of the wax pattern. The setting and hygroscopic expansions of the investment may produce a non-uniform expansion of the walls of the pattern.

• SURFACE ROUGHNESS, IRREGULARITIES, AND DISCOLORATION:

  • Surface roughness is defined as relatively finely spaced surface imperfections whose height, width, and direction establish the predominant surface pattern.

  • Surface irregularities are isolated imperfections, such as nodules, that are not characteristic of the entire surface area. is probably related to the particle size of the investment and its ability to reproduce the wax pattern in microscopic details.
Surface roughness

Surface irregularities

Defects
• **AIR VOIDS** Small nodules on a casting are caused by air bubbles that become attached to the pattern during or subsequent to the investing procedure. Such nodules can sometimes be removed if they are not in a critical area. However, for nodules on margins or on internal surfaces, removal of these irregularities might alter the fit of the cast.
• **POROSITY ذائخلأ**
  
  • A. Localized shrinkage porosity is generally caused by premature termination of the flow of molten metal during solidification.
  
  • B. Microporosity also occurs from rapid solidification shrinkage
  
  • C. Suck-back porosity: often occurs at an occlusoaxial line angle or incisoaxial line angle that is not well rounded. The entering metal impinges onto the mold surface at this point and creates a higher localized mold temperature in this region, known as a hot spot. A hot spot may retain a localized pool of molten metal after other areas of the casting have solidified. This, in turn, creates a shrinkage void or suck back porosity
Localized shrinkage porosity

Suck-back porosity
DENTAL MATERIAL

م.م. اريج مفيد
DENTAL MATERIALS: A science that deals with the study of materials used in dentistry, which includes chemical properties, physical properties, manipulation and their applications in dental practice.

The science of dental materials involves a study of the composition and properties of materials and the way in which they interact with the environment in which they are placed. The selection of materials for any given application can thus be undertaken with confidence and sound judgement.
the ideal restorative material would

- be biocompatible
- bond permanently to tooth structure or bone
- match the natural appearance of tooth structure and other visible tissues
- exhibit properties similar to those of tooth enamel, dentin, and other tissues
- be capable of initiating tissue repair or the regeneration of missing or damaged tissues.
Preventive dental materials | Dental restoratives | Auxiliary dental materials
---|---|---
include pit and fissure sealants; sealing agents that prevent leakage; materials used primarily for their antibacterial effects; and liners, bases, cements, and restorative materials | Restorative materials may be used for temporary, short-term purposes or for longer-term applications. Restorative materials may further be classified as direct restorative materials whether they are used intraorally or indirect restorative materials, to fabricate restorations extraorally. | are substances used in the process of fabricating dental prostheses and appliances but that do not become part of these devices
Structure of Matter and Principles of Adhesion

FIGURE 1: Electron cloud model of an atom. The neutrons (blue spheres) and protons (spheres with “+”) occupy a dense central region called the nucleus. The orange cloud formation illustrates the trace of electrons (spheres with “−”) as they move around the nucleus.
INTERATOMIC BONDS

- The electronic structure of an atom is relatively stable if it has eight electrons in its outer valence shell. Other atoms must lose, acquire, or share electrons with yet other atoms to achieve a stable configuration—that is, eight electrons in the outer shell.

- **PRIMARY BONDS**: The formation of primary bonds depends on the atomic structures and their tendency to assume a stable configuration.
Ionic Bond: is the transfer of the valence electron between atoms results in the stable compound.

Covalent Bonds: In many chemical compounds, two valence electrons are shared by adjacent atoms. By virtue of sharing electrons, the two atoms are held together by covalent bonds to form a molecule that is sufficiently stable.
**Metallic bond:** The free valence electrons can move about in the metal space lattice (A space lattice can be defined as any arrangement of atoms in space in which every atom is situated similarly to every other atom). To form what is sometimes described as an electron “cloud” or “gas.” The electrostatic attraction between the electron cloud and the positive ions in the lattice provides the force that bonds the metal atoms together as a solid.
SECONDARY BONDS In contrast with primary bonds, secondary bonds do not share electrons. Instead, charge variations among atomic groups of the molecule induce dipole forces that attract adjacent molecules or parts of a large molecule.
van der Waals Forces of attraction are:
- weak intermolecular interactions observed in condensed phases like solid and liquid.
- arise from dipole attractions. A neutral molecule that has a partial positive charge at one end and a partial negative charge at the other, it is a polar molecule.
- In the case of nonpolar molecules, random movement of electrons within the molecule creates fluctuating dipoles
- Hydrogen Bond is a special case of dipole attraction of polar compounds. Polarity of this nature is important in accounting for the intermolecular reactions in many organic compounds—for example, the sorption of water by synthetic dental resins
CRYSTALLINE STRUCTURE: The type of space lattice is defined by the length of each of three unit cell edges (called the axes) and the angles between the edges. The simplest and most regular lattice is a cubic, as shown it is characterized by axes that are all of equal length and meet at 90-degree angles.
NONCRYSTALLINE STRUCTURE Glass is a typical non-crystalline solid because its atoms tend to be arranged in non-repeating units (Figure 4). Because of the complexity of the physical configuration of polymer chains, the molecules of resins are not favored to arrange in orderly repeating patterns. Therefore, polymeric-based materials used in dentistry are usually noncrystalline.
DIFFUSION

It is defined as the amount of a substance that diffuses across a given unit area (e.g., 1 cm²) through a unit thickness of the substance (e.g., 1 cm) in one unit of time (e.g., 1 s).
Factors affect diffusion

- Diffusion rates increase as
  - temperature,
  - the chemical potential gradient,
  - concentration gradient, or lattice imperfections increase.

- in a noncrystalline material Diffusion may occur at a more rapid rate and often may be evident at room or body temperature.

- The diffusion rate will decrease with an
  - increase in atom size and interatomic (or intermolecular) bonding.

- The diffusion coefficients of elements in most crystalline solids at room temperature are very low.
ADHESION AND BONDING

- When the molecules of one substrate adhere or are attracted to molecules of the other substrate, the force of attraction is called **adhesion** when unlike molecules are attracted and **cohesion** when the molecules involved are of the same kind.
A surface is defined as the outmost layer of an object.

Surface energy is phenomenon of attraction between atoms by the potential energy. Inside the lattice, all the atoms are equally attracted to each other. The interatomic distance for atom “A” has a balanced array of neighbors surrounding it and the energy is minimal.

At the surface of the lattice, atom “B” is not equally attracted in all directions and the energy is greater. This energy quantifies the work needed to disrupt intermolecular bonds resulting a new surface. Thus, it is called the surface energy.
Comparing an atom under the surface (A) with one on the surface (B) reveals that a bond balance exists around the interior atom (A), while the surface atom (B) is free to develop bonds to atoms or molecules approaching the surface.
WETTING

- wetting is the ability of the liquid to flow easily over the entire surface and adhere to the solid
- It is obvious that gas and liquid can adapt to a solid surface by flowing into surface irregularities. If a drop of water is introduced between the same two glass plates before they are pressed together, considerable difficulty is encountered in separating the two plates.

The cleanliness of the surface is of particular importance. Impurities on the solid surface often yield a surface of lower energy than the clean surface and prevents any wetting by the adhesive.
CONTACT ANGLE OF WETTING

- The tangent line and the solid surface constitute an angle that defines the shape of the liquid; this is called the contact angle. If the force of attraction between molecules of the adhesive and molecules of the substrate is stronger than the attraction between molecules of the adhesive, the liquid adhesive will spread much more broadly over the solid surface and result in a smaller contact angle (Figure 7, A). Thus, a small contact angle indicates that the adhesive forces at the interface are stronger than the cohesive forces holding the molecules of the adhesive together.

- Complete wetting occurs at a contact angle of 0° and no wetting occurs at an angle of 180°. Thus, the smaller the contact angles between an adhesive and an adherend, the better the ability of the adhesive to flow into and fill in irregularities within the surface of the adherend.

- The contact angle is a useful indicator of spreadability or wettability.
FIGURE 7 Contact angles of distilled water on three surfaces and relationship among interfacial energy. A, Water spreads freely on a flame-cleaned glass slide (good wetting). The profile depicted here is considered having 0° contact angle. B, Water on an acrylic surface. C, Water on a Teflon surface (poor wetting). D, Relationships between the interfacial energies at vapor/liquid (γVL), liquid/solid (γLS), and solid/ vapor (γSV) interfaces with respect to contact angle at equilibrium; the relationship is also known as Young’s equation.
Physical and Chemical Properties of Solids
Physical properties are based on the laws of mechanics, optics, thermodynamics, electricity, magnetism, radiation.

Hue, value, and chroma relate to color and laws of optics, which is the science that deals with the phenomena of light, vision, and sight.

Thermal conductivity, diffusivity, and expansion are physical properties based on the laws of thermodynamics.

Chemical properties are based on the ways in which substances interact, combine, and change, as governed by their outer orbital electrons.

The outer electrons are responsible for binding atoms together in molecules and for the electrical, thermal, optical, and magnetic properties of solids.
RHEOLOGY: is the study of the deformation and flow characteristics of matter, whether liquid or solid. Viscosity is the resistance of a fluid to flow, most liquids, when placed in motion, resist imposed forces that cause them to move. This resistance to fluid flow (viscosity) is controlled by internal frictional forces within the liquid.
STRESS RELAXATION: After a substance has been permanently deformed (plastic deformation), there are trapped internal stresses.

The displaced atoms are not in equilibrium positions and are therefore unstable. The result is a change in the shape or contour of the solid as the atoms or molecules change positions.

The rate of relaxation increases with an increase in temperature.

Considerable attention is given to this phenomenon because such dimensional changes by relaxation may result in an inaccurate fit of dental appliances.
Creep and Flow: Creep is defined as the time dependent plastic strain of a material under a static load or constant stress.

The term flow, rather than creep, has generally been used in dentistry to describe the rheology of amorphous materials such as waxes. The flow of wax is a measure of its potential to deform under a small static load.
NATURE OF LIGHT AND THE ROLE OF HUMAN VISION

Light is electromagnetic radiation that can be detected by the human eye. The eye is sensitive to wavelengths from approximately 400 nm (violet) to 700 nm (dark red).

For an object to be visible, it must reflect or transmit light incident on it from an external source.
Electromagnetic radiation in the visible region interacts with an object through reflection from its surface, absorption, refraction, or transmission (i.e., by passing through unchanged.) These phenomena determine the opacity, translucency, or transparency of an object.

- Opacity of a material is related to the amount of light it can absorb and/or scatter. The opposite of opacity is translucency. For example, if 1-mm thicknesses of each of two materials absorb 20% and 50%, respectively, of the light passing through them, the former is less opaque or more translucent than the latter.

- Transparent materials are at the far end of the translucency scale, absorb no light, and transmit 100% of the light that passes through them. Enamel. When light strikes enamel, some is reflected, some refracted, some absorbed, and some transmitted.
THREE DIMENSIONS OF COLOR: color perception is described by three objective variables: hue, value, and chroma.

- **Hue**: The dominant color of an object, for example red, green, or blue. This refers to the dominant wavelengths present in the spectral distribution.

- **Value**: Value is also known as the gray scale. It is the vertical, or Z-axis, of Figure 3-5. Value increases toward the high end (lighter) and decreases toward the low end (darker). Value is also expressed by the “lightness” factor,

- **Chroma**: Chroma is the degree of saturation of a particular hue. For example, red can vary from “scarlet” to light pink, where scarlet has a high saturation and pink has a low saturation. The yellow color of a lemon is a more saturated, “vivid,” color than that of a banana, which is a less saturated, “dull” yellow. Chroma varies radially, perpendicular to the value/L*
• RADIOPACITY:

The amount of x-ray energy absorbed by an object depends on the density and thickness of the material and the energy of the radiation.

• Generally, the higher the atomic number of the component atoms, the greater the x-ray absorbance and the larger the contrast produced.

• Thermal conductivity ($\kappa$) داخل

is the physical property that governs 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 a cross section of 1 cm$^2$ having a temperature difference of 1 K (1 °C) and is measured under steady-state conditions in which the temperature gradient does not change.

• Materials that have a high thermal conductivity are called conductors, whereas materials of low thermal conductivity are called insulators
THERMAL DIFFUSIVITY

- is a 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: $h = \frac{\kappa}{\text{cp} \times \rho}$ where $h$ is thermal diffusivity, $\kappa$ is thermal conductivity, $\text{cp}$ is heat capacity at constant pressure, and $\rho$ is the temperature dependent density in grams per cm$^3$

- Enamel and dentin are effective thermal insulators. The thermal conductivities and thermal diffusivities of cementing materials (glass ionomer, zinc phosphate, and composite) compare favorably with these tissues
Thermal conductivity

\[ \text{Temperature Difference} \quad \Delta T = T_1 - T_2 \quad (\text{K}) \]

THERMAL DIFFUSIVITY
which is defined as the change in length per unit of the original length of a material when its temperature is raised 1 °C (1 K): $\alpha = \Delta L / L \times \Delta T$ where $L$ is the original length, $\Delta L$ is the change in length and $\Delta T$ is the temperature change.

This parameter is extremely important in dental applications as broad ranging as producing cast restorations that fit and maintaining the seal at a restoration margin.
Corrosion is an electrochemical process and is dependent on the ability to conduct electrical current, either by means of free electrons in metals or via ions in solution. Corrosion and its influence on durability and appearance are the major ways in which electrochemistry affects oral well-being.
TARNISH AND CORROSION

- Tarnish is a surface discoloration on a metal or a slight loss or alteration of the surface finish or luster.
- In the oral environment, tarnish often occurs from the formation of deposits on the surface of a restoration, such as oxides, sulfides, or chlorides. However,
- it is often an early indication and precurser of corrosion.
Corrosion is a process whereby deterioration of a metal is caused by reaction with its environment. In due course, corrosion can cause severe and catastrophic disintegration of metals.

Even if highly localized, corrosion may cause mechanical failure of a structure even though the actual volume of material lost is quite small.
FUNDAMENTAL BASIS OF CORROSION

- Corrosion occurs because most commonly used metals and alloys are not in their lowest energy state. Thus, pure metals spontaneously convert to a highly reacted, oxidized state by reacting with, for example, oxygen, sulfur, or chlorine in order to revert to their lowest energy state. This, in essence, is the process of corrosion.

- Corrosion of a metal is either a chemical or an electrochemical process.
Chemical corrosion is the direct combination of metallic and nonmetallic elements to yield a chemical compound through oxidation reactions.

Electrochemical corrosion, also known as galvanic corrosion, requires the presence of water or some other fluid electrolyte and a pathway for the transport of electrons (i.e., an electrical current). It is also referred to as wet corrosion, since it requires a fluid electrolyte.
When a metal is in contact with a fluid electrolyte, the chemical potential causes enough ions to dissolve to form a saturated solution and produce an equal number of free electrons. The loss of electrons by a metal is known as oxidation and is the initial electrochemical event in the corrosion process.
Galvanic Cell

Anode: $\text{Zn}^{2+} + 2 \, \text{e}^- \rightarrow \text{Zn}: E^0 = -0.76 \, \text{V}$  (Oxidation)

Cathode: $\text{Cu}^{2+} + 2 \, \text{e}^- \rightarrow \text{Cu}: E^0 = +0.34 \, \text{V}$  (Reduction)

Overall or net cell reaction is: $\text{Cu}^{2+} + \text{Zn} \rightleftharpoons \text{Cu} + \text{Zn}^{2+}$  (Redox reaction)
Iron hydroxide forms and precipitates

The hydroxide quickly oxidizes to form rust

Electrochemical cell action driven by the energy of oxidation continues the corrosion process.

Cathode action reduces oxygen from air, forming hydroxide ions.

Anode action causes pitting of the iron.
An important type of electrochemical reaction occurs when combinations of dissimilar metals are in direct physical contact.

Because both restorations are wet with saliva, an electrical circuit exists with a difference in potential between the dissimilar restorations (Figure 5).

When the two restorations are brought into contact, there is a sudden short-circuit through the two alloys. This can result in a sharp pain, called galvanic shock.
It is defined as the amount of a substance that diffuses across a given unit area (e.g., 1 cm$^2$) through a unit thickness of the substance (e.g., 1 cm) in one unit of time (e.g., 1 s).
Factors affect diffusion

- Diffusion rates increase as:
  - temperature,
  - the chemical potential gradient,
  - concentration gradient, or lattice imperfections increase.
- in a noncrystalline material Diffusion may occur at a more rapid rate and often may be evident at room or body temperature.
- The diffusion rate will decrease with an:
  - increase in atom size and interatomic (or intermolecular) bonding.
  - The diffusion coefficients of elements in most crystalline solids at room temperature are very low.
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Elastomeric Impression Materials
The term ‘elastomer’ is derived from the words elastic polymers. Thus elastomers are essentially polymers with elastic or rubber-like properties.

**TYPES**

According to their chemistry

Chemically, there are four kinds of elastomers.

1. Polysulfide
2. Condensation polymerizing silicones
3. Addition polymerizing silicones
4. Polyether

Classification based on viscosity Each type may be further divided into four viscosity classes based on consistencies determined immediately after completion of mixing.

- **Type 0**—Putty consistency (very heavy)
- **Type 1**—Heavy-bodied consistency (tray consistency)
- **Type 2**—Medium-bodied consistency (regular bodied)
- **Type 3**—Light-bodied (syringe consistency)
USES OF ELASTOMERIC IMPRESSION MATERIALS

1. In fixed partial dentures for impressions of prepared teeth.
2. Impressions of dentulous mouths for removable partial dentures.
3. Impressions of edentulous mouths for complete dentures.
4. Polyether is used for border molding of edentulous custom trays.
5. For bite registration (figure 16-14).
6. Silicone duplicating material is used for making refractory casts during cast partial denture construction (figure 16-17).
7. For detecting errors in the internal surface of crowns and fixed partial dentures. (Fig. 16.16A)
FIGURE 16.14 Bite registration procedure using bite registration silicone.

FIGURE 16.15 Bite registration silicone.

FIGURES 16.16A AND B (A) Addition silicone for locating high spots, interferences, fulcrum points and pressure spots on the fitting surfaces of restorations and prostheses (fit checking). (B) Crown with fit checker. The high spots show as areas of metal exposure.

FIGURES 16.17A AND B (A) Duplicating silicone (base and catalyst) including flasks. (B) Duplicating silicone being poured into the mould former.
GENERAL PROPERTIES OF ELASTOMERIC Material

1. Excellent reproduction of surface details. The low viscosity is capable of producing very fine details.

2. They are generally hydrophobic (except polyether which is hydrophilic), so the oral tissues in the area of impression should be absolutely dry for better flow of the impression material.

3. Elastic properties of elastomers is good with near complete elastic recovery. Repeated pouring of impression is possible (though not recommended when high accuracy is critical).

4. In general dimensional changes and inaccuracies occur due to:
   - Curing shrinkage.
   - Thermal contraction when transferred from mouth to room temperature.
   - Removing impression before complete setting can cause serious distortion.
   - Uniform thickness of material gives more accurate impression as the shrinkage is uniform.
   - Good adhesion of impression to the tray (using adhesives) minimizes dimensional changes as the shrinkage is directed towards the tray.
5. The tear strength of these materials are excellent, thus making it more resistant to tearing even when the impression is in thin sections.

6. Radiopacity Radiopacity of impression materials is important for radiographic identification of excess material which may be accidentally swallowed, aspirated or left in gingival tissues. Presently, only the polysulfide materials exhibit significant radiopacity due to their lead dioxide content.

7. Retention to tray: Elastomeric materials do not adhere well to the impression tray. They may be retained by – Mechanically by using perforated trays (only in case of putty). – Tray adhesives These are tacky liquids that are applied with a brush. Each elastomer type has a specific adhesive which is not interchangeable.

8. The shelf life is about two years. The silicones have a slightly lower shelf life. Storage under cool conditions increases shelf life.
POLYSULFIDE

• This was the first elastomeric impression material to be introduced (1950). It is also known as Mercaptan. Interestingly, they were first developed as an industrial sealant for gaps between sectional concrete structures.
• As they are supplied as a two-paste system in collapsible tubes. The base paste is white colored. The accelerator may be brown or gray. Available in three viscosities
  • Light bodied
  • Medium bodied
  • Heavy bodied
PROPERTY

• 1. Unpleasant odor and color.
• 2. These materials are extremely viscous and sticky. Mixing is difficult. However, they exhibit pseudoplasticity,
• 3. It has a long setting time of 12.5 minutes (at 37 °C). In colder climates setting can take as longer. This adds to the patient’s discomfort. Heat and moisture accelerate the setting time (sets faster in the mouth).
• 4. Excellent reproduction of surface detail.
• 5. Dimensional stability The curing shrinkage is high (0.45%) and continues even after setting. It has the highest permanent deformation (3–5%) among the elastomers.
• 6. It is hydrophobic so the mouth should be dried thoroughly before making an impression.
These materials were developed to overcome some of the disadvantages of polysulfide materials, such as their objectionable odor, the staining of clothing by the lead dioxide, the amount of effort required to mix the base with the accelerator, the rather long setting times, the moderately high shrinkage on setting.

**TYPES**

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

1. Condensation silicones
2. Addition silicones
CONSENSATION SILICONE

• This was the earlier of the two silicone impression materials. It is also referred to as conventional silicones.
• SUPPLIED AS two pastes in unequal sized collapsible tubes. The base paste comes in a larger tube while the catalyst paste is supplied in a much smaller tube (Fig. 16.4B).
• Putty The putty is supplied in a single large plastic jar (Fig. 16.4A). The catalyst may be in paste form.
PROPERTIES

• 1. Pleasant color and odor. Although nontoxic, direct skin contact should be avoided to prevent any allergic reactions.
• 2. Setting time is 6–9 minutes. Mixing time is 45 seconds.
• 3. Excellent reproduction of surface details.
• 4. Dimensional stability is comparatively less because of the high curing shrinkage (0.4–0.6%), To avoid this the cast should be poured immediately.
• 5. Tear strength is lower than the polysulfides.
• 6. It is stiffer and harder than polysulfide. The hardness increases with time. The spacing in the tray is increased to 3 mm to compensate for the stiffness.
• 7. It is hydrophobic. The field should be well-dried before making an impression. Care should also be taken while pouring the cast to avoid air entrapment.
ADDITION SILICONES (POLYVINYL SILOXANE)

• These materials were introduced subsequent to the introduction of the condensation silicones. Currently, the addition silicones are very popular and is perhaps the most widely used elastomeric impression material worldwide.

• **SUPPLIED AS**
  1. Tubes The base and catalyst pastes come in equal sized tubes. The different viscosities usually come in different colors like orange, blue, green, etc.
  2. Cartridge form with static mixing tips For use with a dispensing gun.
  3. Putty jars Two equal sized plastic jars—containing the base and catalyst.
  4. A larger electric driven autodispenser and mixing device is also available (Pentamix— ESPE). This machine stores larger quantities. At the press of the button, it dispenses and mixes the material.
• Available in four viscosities (Fig. 16.2)
• Light bodied
• Medium bodied
• 1. Pleasant odor and color.
• 2. This may also cause allergic reaction so direct skin contact should be avoided.
• 3. Excellent reproduction of surface details. Polyvinyl siloxanes are currently considered to reproduce the greatest detail of all the impression materials. (light bodied) impression material
• 4. Setting time ranges from 5 to 9 minutes. Mixing time is 45 seconds. Working time may be extended by chilling the tubes.
• 5. It has the best dimensional stability among the elastomers.
• 6. It is extremely hydrophobic, so similar care should be taken while making the impression and pouring the wet stone.
• 7. It has low flexibility and is harder than polysulfides. Extra spacing (3 mm) should be provided in the impression tray. Care should also be taken while removing the stone cast from the impression to avoid any breakage.
POLYETHER RUBBER IMPRESSION MATERIAL

• It has good mechanical properties and dimensional stability. Its disadvantage was that the working time was short and the material was very stiff. It is also expensive.

• AVAILABLE AS base and accelerator in collapsible tubes, cartridges for static mixing and dynamic mechanical mixing devices. The accelerator tube is usually smaller (Fig. 16.5).
PROPERTIES

• 1. Pleasant odor and taste.
• 2. The sulfonic ester can cause skin reactions. Thorough mixing is recommended before making an impression and direct skin contact should be avoided.
• 3. Setting time is around 6–8 minutes. Mixing should be done quickly that is 30 seconds. Heat decreases the setting time.
• 4. Dimensional stability is very good. However, polyethers absorb water and can change dimension. Therefore, prolonged storage in water or in humid climates is not recommended.
• 5. It is extremely stiff (flexibility 3%). It is harder than polysulfides and increases with time. Removing it from undercuts can be difficult, so additional spacing (4 mm) is recommended. Care should also be taken while removing the cast from the impression to avoid any breakage.
• 6. It is hydrophilic, so moisture in the impression field is not so critical. It has the best compatibility with stone among the elastomers.
• 7. It has excellent detail reproduction (20 microns).
• 8. Material interactions Composite based provisional crown materials have been observed to have an inhibitory effect on the setting of polyvinyl siloxane materials.
• There are many methods of mixing and using elastomeric impression materials depending on whether it is supplied in tube, cartridge or putty form.
• **HAND MIXING** - Pastes in tubes Hand or manual spatulation and is primarily used elastomers supplied in tubes
• **Kneading** - putty Kneading is primarily employed for very heavy or putty consistency elastomers.
• **Rotary table-assisted mixing** (Fig. 16.7). The spatula is used to scoop and flatten the pastes alternately and continuously as the table rotates until a uniform mix is obtained.
• **Static OR EXTRUSION Mixing** has grown in popularity over the years, primarily because of its high accuracy and convenience. (Figs. 16.6A to D).
• **Dynamic Mechanical Mixing** Another device is an electrically operated dynamic mechanical mixer (Figs. 16.8A and B). On pressing a button, the material is mixed and extruded through the tip, directly into the impression tray.
FIGURE 16.6 (A) Static mixing tip showing internal helical mixers. The used tip show set material inside the tip. (B) Internal helix demonstrating flow division. (C) Accessory tips for direct delivery to impression site. (D) Static mixing device.

FIGURE 16.7 Rotary mixing device.

FIGURES 16.8A AND B Two representative dynamic mechanical mixing devices.
IMPRESSION techniques

• Impressions may be made in custom or stock trays. Elastomers do not adhere well to the tray. An adhesive (Fig. 16.9A) should be applied to the tray and allowed to dry before making impressions. The adhesive cements provided with the various elastomers are no interchangeable. A slightly roughened tray surface will increase the adhesion. For putty impressions, a perforated stock tray is used.
Classification of elastomeric impression techniques Based on the viscosity used
• 1. Single viscosity technique
• 2. Dual viscosity techniques
  • a. Dual viscosity technique using light body-heavy bodied
  • b. Putty-wash technique
• Based on the number of stages used
  • 1. One stage technique—Both viscosities are dispensed and allowed to set simultaneously.
  • -One-stage single viscosity (MONOPHASE) Technique
  • -One-stage dual viscosity (dual-PHASE) Technique
  • 2. Two stage technique)—This is usually employed with putty. In this technique a preliminary impression is made first with the ultra-heavy or putty viscosity. This is relined later by the lighter viscosity called as wash impression.
  • (Two-stage putty Reline)
  • One-stage putty RELINE (one-stage PUTTY-WASH technique)
Figures 16.10A to J Two-stage Putty-wash technique. (A) Equal quantities of base and catalyst is dispensed. (B) Mixing by kneading until uniform color is achieved. (C) A plastic sheet spacer is placed to provide space for the final impression material. (D) Making the preliminary impression. (E) The completed preliminary impression. (F) The final impression material dispensed in to the preliminary impression. (G) Simultaneously some material is loaded in to the syringe. (H) The syringe material is injected around the prepared tooth/teeth. (I) The loaded tray is seated in the mouth. (J) The completed impression.
Impression Errors

► Air entrapment

► Voids occur from a variety of causes.

► 1. Air entrapment due to faulty loading of the tray. Material should be loaded in a continuous motion from one end of the tray to the other pushing the material ahead as it is ejected from the static mixing device. The tip should be in close proximity to the surface of the tray. Lifting the tip away from the tray and moving it from place to place in a discontinuous motion can result in air entrapment.

► 2. Air entrapment from faulty placement of material around the prepared tooth. When placing the material on the prepared tooth using a syringe or a static mixing tip, the material should be extruded in close proximity to the sulcus and prepared tooth in a continuous motion around the prepared tooth starting from the sulcus and finish line through to the occlusal surface.

► Fluid entrapment and fluid trails can occur due to

► Failure to adequately remove water or control saliva in impression field.

► Failure to control bleeding and exudate. (Figs. 16.11A and B).
Seating voids or trails are usually seen when using a ‘single stage putty-wash technique’. The putty tends to displace the light bodied resulting in voids or ‘seating trails’ (Figs. 16.12A and B). The void caused by the penetration of the cusp fails to get filled by the wash material because of the displacement. Seating trails correspond to the direction of seating. For this reason the single stage putty reline technique is not advocated for procedures requiring a high degree of accuracy. The two-stage technique is superior in this regard.
FIGURES 16.11A AND B (A) Gingival bleeding following teeth preparation. (B) Impression errors (fluid trails and loss of detail) caused by active bleeding and inadequate fluid control.

FIGURES 16.12A AND B (A) Seating trails (arrows) corresponding to the palatal cusps of the maxillary molars result in a significant loss of detail in the impression and the corresponding area of the cast (B).
Elastomeric Impression Materials
The term ‘elastomer’ is derived from the words elastic polymers. Thus elastomers are essentially polymers with elastic or rubber-like properties.

**TYPES**

**According to their chemistry**

Chemically, there are four kinds of elastomers.

1. Polysulfide
2. Condensation polymerizing silicones
3. Addition polymerizing silicones
4. Polyether

**Classification based on viscosity** Each type may be further divided into four viscosity classes based on consistencies determined immediately after completion of mixing.

- **Type 0**—Putty consistency (very heavy)
- **Type 1**—Heavy-bodied consistency (tray consistency)
- **Type 2**—Medium-bodied consistency (regular bodied)
- **Type 3**—Light-bodied (syringe consistency)
USES OF ELASTOMERIC IMPRESSION MATERIALS

1. In fixed partial dentures for impressions of prepared teeth.
2. Impressions of dentulous mouths for removable partial dentures.
3. Impressions of edentulous mouths for complete dentures.
4. Polyether is used for border molding of edentulous custom trays.
5. For bite registration (figure 16-14).
6. Silicone duplicating material is used for making refractory casts during cast partial denture construction (figure 16-17).
7. For detecting errors in the internal surface of crowns and fixed partial dentures. (Fig. 16.16A)
**FIGURE 16.14** Bite registration procedure using bite registration silicone.

**FIGURE 16.15** Bite registration silicone.

**FIGURES 16.16A AND B** (A) Addition silicone for locating high spots, interferences, fulcrum points and pressure spots on the fitting surfaces of restorations and prostheses (fit checking). (B) Crown with fit checker. The high spots show as areas of metal exposure.

**FIGURES 16.17A AND B** (A) Duplicating silicone (base and catalyst) including flasks. (B) Duplicating silicone being poured into the mould former.
GENERAL PROPERTIES OF ELASTOMERIC Material

1. Excellent reproduction of surface details. The low viscosity is capable of producing very fine details.

2. They are generally hydrophobic (except polyether which is hydrophilic), so the oral tissues in the area of impression should be absolutely dry for better flow of the impression material.

3. Elastic properties of elastomers is good with near complete elastic recovery. Repeated pouring of impression is possible (though not recommended when high accuracy is critical).

4. In general dimensional changes and inaccuracies occur due to:
   - Curing shrinkage.
   - Thermal contraction when transferred from mouth to room temperature.
   - Removing impression before complete setting can cause serious distortion.
   - Uniform thickness of material gives more accurate impression as the shrinkage is uniform.
   - Good adhesion of impression to the tray (using adhesives) minimizes dimensional changes as the shrinkage is directed towards the tray.
5. The tear strength of these materials are excellent, thus making it more resistant to tearing even when the impression is in thin sections.

6. Radiopacity Radiopacity of impression materials is important for radiographic identification of excess material which may be accidentally swallowed, aspirated or left in gingival tissues. Presently, only the polysulfide materials exhibit significant radiopacity due to their lead dioxide content.

7. Retention to tray: Elastomeric materials do not adhere well to the impression tray. They may be retained by – Mechanically by using perforated trays (only in case of putty). – Tray adhesives These are tacky liquids that are applied with a brush. Each elastomer type has a specific adhesive which is not interchangeable.

8. The shelf life is about two years. The silicones have a slightly lower shelf life. Storage under cool conditions increases shelf life.
POLYSULFIDE

• This was the first elastomeric impression material to be introduced (1950). It is also known as Mercaptan. Interestingly, they were first developed as an industrial sealant for gaps between sectional concrete structures.

• **AS They are supplied** as a two-paste system in collapsible tubes. The base paste is white colored. The accelerator may be brown or gray. Available in three viscosities:
  - Light bodied
  - Medium bodied
  - Heavy bodied
PROPERTIES

• 1. Unpleasant odor and color.
• 2. These materials are extremely viscous and sticky. Mixing is difficult. However, they exhibit pseudoplasticity,
• 3. It has a long setting time of 12.5 minutes (at 37 °C). In colder climates setting can take as longer. This adds to the patient’s discomfort. Heat and moisture accelerate the setting time (sets faster in the mouth).
• 4. Excellent reproduction of surface detail.
• 5. Dimensional stability The curing shrinkage is high (0.45%) and continues even after setting. It has the highest permanent deformation (3–5%) among the elastomers.
• 6. It is hydrophobic so the mouth should be dried thoroughly before making an impression.
These materials were developed to overcome some of the disadvantages of polysulfide materials, such as their objectionable odor, the staining of clothing by the lead dioxide, the amount of effort required to mix the base with the accelerator, the rather long setting times, the moderately high shrinkage on setting.

**TYPES**

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

1. Condensation silicones
2. Addition silicones
• This was the earlier of the two silicone impression materials. It is also referred to as conventional silicons.

• **SUPPLIED AS** two pastes in unequal sized collapsible tubes. The base paste comes in a larger tube while the catalyst paste is supplied in a much smaller tube (Fig. 16.4B).

• Putty The putty is supplied in a single large plastic jar (Fig. 16.4A). The catalyst may be in paste form.
• 1. Pleasant color and odor. Although nontoxic, direct skin contact should be avoided to prevent any allergic reactions.
• 2. Setting time is 6–9 minutes. Mixing time is 45 seconds.
• 3. Excellent reproduction of surface details.
• 4. Dimensional stability is comparatively less because of the high curing shrinkage (0.4–0.6%), To avoid this the cast should be poured immediately.
• 5. Tear strength is lower than the polysulfides.
• 6. It is stiffer and harder than polysulfide. The hardness increases with time. The spacing in the tray is increased to 3 mm to compensate for the stiffness.
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1. Single viscosity technique
2. Dual viscosity techniques
   a. Dual viscosity technique using light body-heavy bodied
   b. Putty-wash technique

Based on the number of stages used

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GYPSUM PRODUCTS

م.م اريج مفيد
• Dental plaster (plaster of Paris)—The beta form of calcium sulfate hemihydrate (CaSO₄•1/2H₂O).
• Dental stone—The alpha form of calcium sulfate hemihydrate (CaSO₄•1/2H₂O).
• Die—A reproduction of a prepared tooth made from a gypsum product, a metal, or a refractory material.
• Gypsum—Calcium sulfate dihydrate (CaSO₄•2H₂O).
• Gypsum-based investment—A refractory material consisting of silica and gypsum as a binder used to produce a mold for the metal casting process.
• Model—A positive likeness of an object.
• Normal setting expansion—The expansion that occurs when gypsum or a gypsum-bonded investment sets in ambient air.
PRODUCTION OF GYPSUM PRODUCTS

• The principal constituent of gypsum-based products is calcium sulfate hemihydrate [(CaSO\(_4\))\(\frac{1}{2}\)\(\cdot\)H\(_2\)O].

• Because of differences in crystal size, surface area, and degree of lattice perfection, the resulting powders are often referred to as α-hemihydrate for dental stone and β-hemihydrate for plaster of Paris.

<table>
<thead>
<tr>
<th>β-hemihydrate crystals</th>
<th>α-hemihydrate crystals</th>
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<tbody>
<tr>
<td>sponginess</td>
<td>denser</td>
</tr>
<tr>
<td>irregular shape</td>
<td>a prismatic shape</td>
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<td>require more water to</td>
<td>require less water to</td>
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<tr>
<td>wet the powder particles</td>
<td>wet the powder particles</td>
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Figure 1: 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.
THEORIES OF SETTING

1. Colloidal theory
2. Hydration theory
3. Dissolution–precipitation theory

- **Colloidal theory:** The theory proposes that when mixed with water, plaster enters into a colloidal state through a sol-gel mechanism. In the sol state, hemihydrate combines with water (hydrates) to form dihydrate. As the water is consumed, the mass turns to a ‘solid gel’.

- **Hydration theory:** The hydration theory suggests that rehydrated plaster particles join together through hydrogen bonding to the sulfate groups to form the set material.

- **Dissolution–precipitation theory (Crystalline theory):** This theory is more widely accepted. According to the theory, the plaster dissolves and reacts to form gypsum crystals which interlock to form the set solid. Hemihydrate is four times more soluble than dihydrate.
the setting reactions occur as follows:

1. When the hemihydrate is mixed with water, a suspension is formed that is fluid and workable.

2. The hemihydrate dissolves until it forms a saturated solution of Ca\(^{2+}\) and (SO\(_4\))\(^{2-}\).

3. This saturated hemihydrate solution is supersaturated with respect to the solubility of the dihydrate; precipitation of dihydrate occurs.

4. As the dihydrate precipitates, the hemihydrate continues to dissolve. The crystals already present until no further dihydrate can precipitate out of solution.
• The time elapsing from the beginning of mixing until the material hardens is called **setting time**.

• **Mixing time:** It is the time from the addition the powder to the water until mixing is complete. A mixing time of 1 minute is usually sufficient.

• **Working time:** It is the time available to work with the mix for the intended purpose. At the end of the working period the material thickens and is no longer workable. The freshly mixed mass is semifluid in consistency and quite free flowing. A working time of 3 minutes is usually sufficient.

• **Initial setting time:** As the reaction proceeds, more hemihydrate 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 be carved but not moulded. This is known as initial setting time.

• **Final setting time:** The time at which the material can be separated from the impression without distortion or fracture.
Mixing time

Working time
MEASUREMENT OF SETTING TIME:

1. **Loss of gloss method**: As reaction proceeds the gloss disappears from the surface of 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 exothermic.

3. **Penetration tests**: By using penetrometers. The time elapsing from the start of mixing till the needle does not penetrate to the bottom of the plaster is the setting time. Types of penetrometers: Vicat needle, Gillmore needles.
CONTROL OF THE SETTING TIME

1. **Solubility of the hemihydrate** If the solubility of the hemihydrate is increased, accelerates the rate of dihydrate crystal deposition.

2. **Number of nuclei of crystallization** The greater the number of nuclei of crystallization, the faster the dihydrate crystals will form and the sooner the mass will harden.

3. **Rate of crystal growth**

4. **The amounts of water and hemihydrate** The use of a higher W/P ratio decreases the number of nuclei per unit volume. Consequently, the setting time is prolonged.
• 5. speed of manipulation the longer and the more rapidly the gypsum product is mixed, the shorter is the setting time.

• 6. water temperature Little change in setting time occurs between 0 °C and 50 °C

• 7. Chemical modifiers

• Several inorganic salts play dual roles in the setting kinetics of dihydrate, which are accelerators at low concentration and retarders at higher concentration. For example, borax,
PROPERTIES:

- Setting expansion is of two types
  1. Normal setting expansion
  2. Hygroscopic setting expansion

Normal Setting Expansion (0.05 to 0.5%) All gypsum products show a linear expansion during setting, due to the outward thrust of the growing crystals during setting. Crystals growing from the nuclei not only intermesh but also intercept each other during growth.

CONTROL OF SETTING EXPANSION

1. Mechanical mixing reduces setting expansion when compared to hand mixed stone.
2. Increase in W/P ratio reduces the setting expansion.
3. Modifiers generally reduce the setting expansion.
• **Strength** The strength increases rapidly as the material hardens after the initial setting. Factors affecting strength:
  
  - **The free water content (excess water)** The greater the amount of free water in the set stone, the less the strength.
  - **Wet strength** It is the strength when excess free water (more than is necessary for reaction) is present in the set gypsum.
  - **Dry strength** It is the strength of gypsum when the excess free water is lost due to evaporation. It is two or more times greater than the wet strength.
  - **Temperature Gypsum** is stable only below about 40 °C. Drying at higher temperatures be carefully controlled. Loss of water of crystallization occurs rapidly at 100 °C or higher and causes shrinkage and a reduction in strength.
  - **W/P ratio** The more the water, the greater the porosity and less the strength.
  - **Spatulation** Within limits, strength increases with increased spatulation.
  - **Addition of accelerators and retarders** Lowers strength.
  - **Time at which cast can be used** The cast cannot be used as soon as it reaches its final setting (as defined by the Vicat and Gillmore tests). This is because the cast has not reached its full strength.
**Hardness and Abrasion Resistance.** Hardness is related to the compressive strength. The higher the compressive strength of the hardening mass, the higher the surface hardness. Commercial hardening solutions are available to increase the surface hardness of stone.

**Flow:** The flow of freshly mixed gypsum depends on the amount of water used (W/P ratio). The greater the amount of water used, the greater would be the flow. However, a correctly proportioned mix has sufficient flow. Vibrating the mix greatly improves the flow. The flow reduces as it approaches its initial set.

**Reproduction of Detail:** Gypsum products reproduce detail accurately. Cast material has to duplicate all the detail recorded by the impression. Factors which affect detail reproduction include compatibility with the impression material, trapped air bubbles in the mix and surface contaminants like saliva.
Porous cast

Reproduction of Detail
TYPES OF GYPSUM PRODUCTS

- IMPRESSION PLASTER (TYPE I)

- MODEL PLASTER (TYPE II): used principally to fill a flask used in denture construction when setting expansion is not critical and the strength is adequate.

- DENTAL STONE (TYPE III) are preferred for casts used to process dentures because the stone has enough strength for this purpose and the denture is easier to remove after processing.

- DENTAL STONE, HIGH STRENGTH (TYPE IV) This material is also called die stone. A hard surface is necessary for a die stone because the tooth preparation is covered with wax and carved flush with the margins of the die.

- DENTAL STONE, HIGH STRENGTH, HIGH EXPANSION (TYPE V) The rationale for increasing setting expansion is that certain newer alloys, such as base metal, have a greater casting shrinkage. Thus, higher expansion is required in the stone die to aid in compensating for the alloy solidification shrinkage.
SPECIALIZED GYPSUM PRODUCTS

- DENTAL CASTING INVESTMENTS
- Orthodontic stone
- Mounting plaster Plaster
- Fast setting Stone
MANIPULATION OF GYPSUM PRODUCTS

• CARE OF GYPSUM PRODUCTS: it is important that all gypsum products be stored in a dry atmosphere. The best means of storage is to seal the product in a moisture-proof metal container.

• PROPORTIONING: The water and powder should be measured by using an accurate graduated cylinder for the water volume and a weighing balance for the weight of powder.

• MIXING AND POURING
  • HAND MIXING
  • MECHANICAL MIXER

• CARE OF THE CAST: cast dimensions will be relatively constant under ordinary conditions of room temperature and humidity.

• INFECTION CONTROL Disinfection solutions can be used that do not adversely affect the quality of the gypsum cast.
FIGURE 18.5 Stone/plaster dispenser.

FIGURE 18.6 Stone/plaster vibrator.

FIGURE 18.7 A vibrator improves the flow and reduces voids thereby improving strength and accuracy.
Impression Materials

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Impression Materials

- **Rigid Impression Materials**
  - Impression compound and Zoe Paste
  - Zinc Oxide Eugenol Impression Paste

- **Elastic Impression Materials**
  - Agar
  - Alginate

- **Elastomeric Impression Materials**
  - Polysulfides
  - Silicone Impression Materials
    - Condensation Silicone
    - Addition Silicones – Polyether Rubber Impression
A dental impression is a negative record of the tissues of the mouth. It is used to reproduce the form of the teeth and surrounding tissues.

The negative reproduction of the tissues given by the impression material is filled up with dental stone or other model materials to get a positive cast. The positive reproduction of a single tooth is described as a ‘die’, and when several teeth or a whole arch is reproduced, it is called a ‘cast’ or ‘model’.

ADVANTAGES OF USING A CAST OR MODEL

1. Models provide a three-dimensional view of the oral structures, thus aiding in diagnosis and treatment planning.

2. Many restorations or appliances are best constructed on casts. It may be inconvenient to both dentist and patient if these have to be made directly in the patient’s mouth.

3. Models can be used to educate the patient.

4. They serve as treatment records.

5. By using casts, technical work can be passed on to technicians, saving valuable clinical time.
1. Should be nontoxic and nonirritant to dentist and patient.
2. Acceptable to the patient. 
   a. Have a pleasant taste, odor, consistency and color. 
   b. Should set quickly once placed in the mouth.
3. Should be accurate.
   a. Accurate surface detail.
   b. Elastic properties with freedom from permanent deformation after strain.
   c. Dimensionally stable.

4. Have adequate shelf life for storage and distribution.
5. Be economical.
6. Have adequate strength so that it will not break or tear while removing from the mouth.

6. Handling properties.
   a. Sufficient working time.
   b. Set quickly in mouth (saves chairside time).
   c. Be easy to use with the minimum equipment.
   d. Satisfactory consistency and texture.
CLASSIFICATION OF IMPRESSION MATERIALS

• According to mode of setting and elasticity
  • Thermoset (irreversible)
  • Thermoplastic (reversible)
  • rigid and elastic.

• According to tissue displacement
  • Depending on whether tissues are displaced while making impressions a material may be
    • 1. Mucostatic: Mucostatic materials produce minimal displacement of the tissue during impression, e.g. plaster, zinc oxide eugenol, low viscosity alginates, low viscosity elastomeric materials, etc.
    • 2. Mucocompressive (Mucodisplacive): Mucocompressive materials are more viscous and displace the tissues while recording them, e.g. compound, high viscosity alginates, high viscosity elastomers, etc.
• According to their uses in dentistry

• **Impression materials used for complete denture prosthesis:** Impression plaster, impression compound and impression paste set to a hard rigid mass, and hence cannot be removed from undercuts without the impression being fractured or distorted. Therefore these materials are best suited for edentulous mouth.

• **Impression materials used for dentulous mouths:** On the other hand alginates and rubber base impressions are sufficiently elastic to be withdrawn from undercut areas. Such elastic impression materials are suitable for impressions for fabrication of removable and fixed partial denture prostheses, where the impressions of the ridge and teeth are required.
Rigid Impression Materials

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

**IMPRESSSION COMPOUND**

- Impression compound is one of the oldest of the dental impression materials. It can be described as a rigid, reversible impression material which sets by physical change. On applying heat, it softens and on cooling it hardens. It is mainly used for making impressions of edentulous ridges.
• CLASSIFICATION
  • Type I - Impression compound
  • Type II - Tray compound: is used to prepare a tray for making an impression. A second material is then carried in it in order to make an impression of oral tissues. The use of dental tray compound decreased with the increased substitution of acrylic tray materials.
  • SUPPLIED AS sheets, sticks, cakes and cones in a variety of colors
• APPLICATIONS
• 1. For making a preliminary impression in an edentulous mouth (mouth without teeth).
• 2. For impressions of full crown preparations where gingival tissues must be displaced.
• 3. Peripheral tracing or border molding. Type I
• 4. To check undercuts in inlay preparation.
• 5. To make a special tray. Type II

• Single tooth impression In conservative dentistry, an impression is made of a single tooth in which a cavity is prepared. The compound is softened and carried in a copper band. The filled band is pressed over the tooth and the compound flows into the prepared cavity. It is referred to as a tube impression.

• Complete denture impression In complete denture fabrication, it is common to make two sets of impressions—the preliminary and the final impression. The preliminary impression is made in a stock tray. A study cast made from this is used to construct a custom tray or special tray. The custom tray is used to make the final impression. The technique of making a preliminary and final impression greatly improves the accuracy of the complete denture.
PROPERTIES OF IMPRESSION COMPOUND

• FUSION TEMPERATURE When impression compound is heated in a hot water bath the material starts to soften at approximately 39 °C. However at this stage, it is still not plastic or soft enough for making an impression. This temperature at which the material looses its hardness or brittleness on heating or forms a rigid mass upon cooling is referred to as fusion temperature. On continued heating above 43.5 °C, the material continues to soften and flow to a plastic mass that can be manipulated.

• FLOW Good flow is desirable during impression making. The softened material should flow into all the details of the tissue contour. Once the compound hardens, it should have minimum flow, otherwise it will get distorted.
• THERMAL PROPERTIES

• Thermal conductivity Impression compound has very low thermal conductivity, i.e. they are poor conductors of heat. Significance

• 1. During softening of the material, the outside will soften first and the inside last. So to ensure uniform softening the material should be kept immersed for a sufficient period in a water bath. Kneading of the material ensures further uniform softening.

• 2. The low thermal conductivity affects the cooling rate. The layer adjacent to the oral tissues cools faster than the inside. Removal of the impression at this stage can cause serious distortion. Thus it is important to wait for the compound to cool thoroughly before removing it from the mouth.

• Coefficient of thermal expansion (CTE) The CTE of compound is comparatively high due to the presence of resins and waxes. The linear contraction from mouth temperature to room temperature is 0.3%. Errors from thermal distortion can be reduced

• 1. By obtaining an impression and then passing the impression over a flame until the surface is softened and then obtaining a second impression. During the second impression, the shrinkage is relatively lower, since only the surface layer has been softened.

• 2. Another way of reducing the thermal contraction is by spraying cold water on the metal tray just before it is inserted in the mouth. Thus the material adjacent to the tray will be hardened, while the surface layer is still soft. In both techniques, the impression is likely to be stressed considerably and so the stone cast should be constructed at the earliest.
• **Dimensional stability** Since the release of strains is unavoidable, the safest way to prevent distortion is to pour the cast immediately or at least within the hour. Another cause of warpage is removal of the impression too early from the mouth before complete hardening.

• **Detail reproduction** Surface detail reproduction is comparatively less because of its high viscosity and low flow. Because of the viscosity, pressure has to be used during impression, which compresses or distorts the tissues. Thus the tissues are recorded in a distorted state.
MANIPULATION

**FIGURE 14.2** Manipulation of stick compound for border molding of a custom tray.

**FIGURE 14.3** A thermostatically controlled water bath. This water bath maintains a steady softening temperature and is ideal for softening impression compound.

**FIGURE 14.4** A slightly oversized stock metal tray.
ADVANTAGES AND DISADVANTAGES

• ADVANTAGES
• 1. The material can be reused a number of times (for the same patient only) in case of errors.
• 2. Inaccurate portions can be remade without having to remake the entire impression.
• 3. Accuracy can be improved by flaming the surface.
• 4. The material has sufficient body to support itself especially in the peripheral portions. It does not collapse completely if unsupported by the tray.

• DISADVANTAGES
• 1. Records less detail because of its high viscosity.
• 2. Compresses soft tissues during impression.
• 3. Distortion due to its poor dimensional stability.
• 4. Difficult to remove if there are severe undercuts.
• 5. There is always the possibility of overextension especially in the peripheries.
ZINC OXIDE EUGENOL IMPRESSION PASTE

- **CLASSIFICATION**
- Type I or Hard
- Type II or Soft

- **AVAILABLE AS**: In paste form in two tubes (Fig. 14.8)
- Base paste (white in color)
- Accelerator or reactor or catalyst paste (red in color)
**FIGURE 14.7** Impressions of the upper (right) and lower (left) edentulous arches made with zinc oxide eugenol impression paste in custom trays.

**FIGURE 14.8** DPI (India) and SS white (USA) are examples of two commercially available zinc oxide eugenol impression pastes (Courtesy: KDC, Kannur).
SETTING TIME

- **Working time** There should be sufficient time for mixing, loading onto the tray and seating the impression into the mouth.
- **Setting time** Once the material is in place, it should set fast.
- **Why should an impression material set quickly in the mouth?**
  - Any material which takes a long time to set in the mouth. Would obviously be uncomfortable to the patient.
  - Movement is bound to occur, resulting in stresses and errors in the impression.
  - Result in a wastage of time for the dentist.
- **Initial setting time** is the period from the beginning of the mixing until the material ceases to pull away or string out when its surface is touched with a metal rod. The impressions should be seated in the mouth before the initial set.
- **The final set** occurs when a needle of specified dimension fails to penetrate the surface of the specimen more than 0.2 mm under a load of 50 gm.
• **Factors controlling setting time**

• 1. Particle size of zinc oxide powder: If the particle size is small, the setting time is less.

• 2. By varying the lengths of the two pastes (not recommended).

• 3. Setting time can be decreased by adding zinc acetate or a drop of water or acetic acid (acetic acid is a more effective than water. It increases speed of formation of the zinc hydroxide).

• 4. Longer the mixing time, shorter is the setting time.

• 5. High atmospheric temperature and humidity accelerate setting.

• 6. Setting can be delayed by cooling the mixing slab, spatula or adding small amounts of retarder or oils or waxes.
FIGURE 14.9 Proper dispensing is an important aspect of the manipulation of materials supplied in tubes. For zinc oxide eugenol both the ropes should be of equal length and width in order to ensure correct proportioning. One way of obtaining this is by ensuring the extruded paste has a uniform width and length.

FIGURES 14.10A AND B Manipulation of zinc oxide eugenol paste. (A) Equal lengths of base and reactor pastes are dispensed. (B) Mixing is done with a stainless steel spatula using circular motions until a streak free mix is obtained (Manufacturers usually provide such materials in contrasting colors to aid in visually ascertaining completion of mix).

FIGURES 14.14A AND B (A) Bite registration paste. (B) Bite registration paste used for making a faccebow transfer.
• **Consistency and flow** These are clinically important properties. A paste of thick consistency can compress the tissues. A thin free flowing material copies the tissues without distorting them. These materials have a very good flow.

• **Detail reproduction** It registers surface details quite accurately due to the good flow. Rigidity and strength The impression should resist distortion and fracture when removed from the mouth after setting.

• **Dimensional stability** The dimensional stability is quite satisfactory. A negligible shrinkage (less than 0.1%) may occur during hardening.
ADVANTAGES AND DISADVANTAGES

• ADVANTAGES
  • 1. It has enough working time to complete border molding.
  • 2. It can be checked in the mouth repeatedly without deforming.
  • 3. It registers accurate surface details.
  • 4. It is dimensionally stable.
  • 5. Does not require separating media since it does not stick to the cast material.
  • 6. Minor defects can be corrected locally without discarding a good impression.

• DISADVANTAGES
  • 1. It requires a special tray for impression making.
  • 2. It is sticky in nature and adheres to tissues.
  • 3. Eugenol can cause burning sensation and tissue irritation.
  • 4. It cannot be used for making impression of teeth and undercut areas as it is inelastic in nature.
Elastic Impression Materials

- TYPES OF ELASTIC IMPRESSION MATERIALS
- Two systems are used
  - 1. Hydrocolloids
  - 2. Elastomeric materials
- Hydrocolloids They consist of gelatin particles suspended in water (Lyosol). Since water is the dispersion medium it is known as hydrocolloid.
- Gels, Sols, Gelation Colloids with a liquid as the dispersion medium can exist in two different forms known as ‘sol’ and ‘gel’.
  - A sol has the appearance and many characteristics of a viscous liquid.
  - A gel is a jelly like elastic semisolid and is produced from a sol by a process called gelation by the formation of fibrils or chains of the dispersed phase which become interlocked.
- Gelation may be brought about in one of the two ways
  - 1. Lowering the temperature, e.g. agar.
  - 2. By a chemical reaction, e.g. alginate
Reversible hydrocolloids—AGAR

• Agar hydrocolloid was the first successful elastic impression material to be used in dentistry. It is an organic hydrophilic colloid (polysaccharide) extracted from a type of seaweed. Although it is an excellent impression material and yields accurate impressions, presently it has been largely replaced by alginate hydrocolloid and rubber impression materials.
• **Uses**
  1. Widely used at present for cast duplication (e.g. during the fabrication of cast metal removable partial dentures, etc.).
  2. For full mouth impressions without deep undercuts.
  3. It was used extensively for FPD impressions prior to elastomers.
  4. As a tissue conditioner.

• **SUPPLIED AS**
  • Gel in collapsible tubes (for impressions).
  • As cartridges or gel sticks (syringe material, Fig. 15.2).
  • In bulk containers (for duplication, Figs. 15.3A and B).
FIGURE 15.2 Agar impression syringe and syringe material.

FIGURES 15.3A AND B (A) Agar duplication gel samples. (B) Bulk packing.
• Gelation or setting of agar

• Agar changes from the sol to the gel state (and vice versa) by a physical process. The process of converting gel to sol is known as liquefaction which occurs at a temperature between 70 and 100 °C. On cooling agar reverses to the gel state and the process is called gelation. Gelation occurs at or near mouth temperature which is necessary to avoid injury to oral tissues.
PROPERTIES OF AGAR HYDROCOLLOIDS

• Gelation, liquefaction and hysteresis  Gelation (solidification) occurs at 37 °C approximately, whereas liquefaction (melting) occurs at a higher temperature, i.e. 60–70 °C higher than the gelation temperature. This temperature lag between liquefaction and gelation is known as hysteresis.

• Syneresis and imbibition  (dimensional stability) Since hydrocolloids use water as the dispersion medium, they are prone for dimensional change due to either loss or gain of water. If left in a dry atmosphere, water is lost by syneresis and evaporation, and if it is immersed in water, it absorbs water by a process known as imbibition.

• Accuracy and dimensional change  Some contraction takes place during gelation. If the material is retained well in the tray, the material contracts towards the tray resulting in larger dies. Agar impressions are highly accurate at the time of removal from the mouth, but shrink when stored in air or 100% relative humidity and expand when stored in water. However, prompt pouring of plaster or stone models is recommended.
• **Flow** The material is sufficiently fluid to record the fine details if correctly manipulated.

• **Gel strength** The gel can withstand great stresses particularly shear stress, without flow, provided the stress is applied rapidly. Thus, the impression should be removed as rapidly as possible in order to avoid distortion.

• Factors affecting strength

  • 1. The composition—agar concentration, borate and filler content, etc.
  • 2. The temperature—the lower the temperature the greater the strength.
LAMINATE TECHNIQUE (AGAR–ALGINATE COMBINATION TECHNIQUE) After injecting the syringe agar on to the area to be recorded, an impression tray containing a mix of chilled alginate that will bond with the agar is positioned over it. The alginate gels by a chemical reaction, whereas the agar gels through contact with the cool alginate (Fig. 15.6),

- Advantages
  1. The syringe agar gives better details than alginate.
  2. Less air bubbles.
  3. It sets faster than the regular agar technique.
CAST DUPLICATION as a duplicating material primarily because. When liquefied it flows readily (like a fluid) over the cast to be duplicated. This makes it an ideal mould material. Large quantities can be prepared relatively easily. It is economical, because it can be reused. In the construction of cast removable partial dentures (RPD) the relieved and blocked master cast is duplicated in investment material. This is known as a refractory cast.
Advantages and Disadvantages of Agar Hydrocolloid

**Advantages**
1. Accurate dies can be prepared, if the material is properly handled.
2. Good elastic properties help reproduce most undercut areas.
3. It has good recovery from distortion.
4. Hydrophilic, moist mouth not a problem. It also gives a good model surface.
5. It is palatable and well tolerated by the patient.
6. It is economical when compared to synthetic elastic materials.

**Disadvantages**
1. Does not flow well when compared to newly available materials.
2. It cannot be electroplated.
3. During insertion or gelation the patient may experience thermal discomfort.
4. Tears relatively easily. Greater gingival retraction is required for providing adequate thickness of the material.
5. Only one model can be poured.
6. Has to be poured immediately. Cannot be stored for too long.
IRREVERSIBLE HYDROCOLLOID—ALGINATE

• The word alginate comes from ‘alginic acid’ which is a mucous extract yielded by species of brown seaweed.

• Alginate was developed as a substitute for agar when it became scarce due to World War II (Japan was a prime source of agar).

• Currently alginate is more popular than agar for dental impressions, because it is simpler to use. Alginate is perhaps the most widely used impression material in the world.
SETTING REACTION

• When alginate powder is mixed with water a sol is formed which later sets to a gel by a chemical reaction. The final gel

• Gel structure The final gel consists of a brush heap of calcium alginate fibril network enclosing unreacted sodium alginate sol, excess water, filler particles and reaction byproducts. It is a cross-linked structure (i.e. each fiber is tied to each other at certain points).
FIGURES 15.12A AND B (A) Alginate is mixed by stropping or swiping the material against the sides of the bowl.
(B) The loaded tray.
Properties of Alginate Hydrocolloid

- **Taste and Odor** Alginate has a pleasant taste and smell. Over the years, manufacturers have added a variety of colors, odors, and tastes to make it as pleasant as possible to the patient. Flavors include strawberry, orange, mint, vanilla, etc.

- **Elasticity and Elastic Recovery** Alginate hydrocolloids are highly elastic (but less when compared to agar) and about 98.2% elastic recovery occurs. Thus, permanent deformation is more for alginate (about 1.8%). Permanent deformation is less if the set impression is removed from the mouth quickly.

- **Reproduction of Tissue Detail** Detail reproduction is also lower when compared to agar hydrocolloid.

- **Adhesion** Alginate does not adhere well to the tray. Good adhesion is important for the accuracy of the impression. Retention to the tray is achieved by mechanical locking features in the tray or by applying an adhesive.
• **Strength**

  Tear strength This is an important property for alginates.

  Factors affecting strength are

  - Water/powder ratio Too much or too little water reduces gel strength.
  - Mixing time Over and under mixing both reduce strength.
  - Time of removal of impression Strength increases if the time of removal is delayed for few minutes after setting.

• **Syneresis and Imbibition** Like agar–agar alginate also exhibits the properties of syneresis and imbibition. When placed in contact with water alginates absorb water and swell. Continued immersion in water results in the total disintegration of the alginate.

• **Dimensional Stability** Set alginates have poor dimensional stability due to evaporation, syneresis and imbibition. Therefore, the cast should be poured immediately. If storage is unavoidable, keeping in a humid atmosphere of 100% relative humidity (humidor) results in the least dimensional change. Alginates can also be stored in sealed plastic bags.
Advantages and disadvantages of alginate

• Advantages
  • 1. It is easy to mix and manipulate.
  • 2. Minimum requirement of equipment.
  • 3. Flexibility of the set impression.
  • 4. Accuracy if properly handled.
  • 5. Low cost.
  • 6. Comfortable to the patient.
  • 7. It is hygienic, as fresh material must be used for each impression.
  • 8. It gives a good surface detail even in presence of saliva.

• Disadvantages
  • 1. Cannot be electroplated so metal dies are not possible.
  • 2. It cannot be corrected.
  • 3. Distortion may occur without it being obvious if the material is not held steady while it is setting.
  • 4. Poor dimensional stability—it cannot be stored for long time.
  • 5. Poor tear strength.
MECHANICAL PROPERTIES

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MECHANICAL PROPERTIES

Mechanical properties are defined by the laws of mechanics—that is, the physical science dealing with forces that act on bodies and the resultant motion, deformation, or stresses that those bodies experience.

An important factor in the design of a dental prosthesis is strength. In a general sense, strength is the ability of the prosthesis to resist induced stress without fracture or permanent deformation (plastic strain).
The strength of a material is defined as the average level of stress at which it exhibits a certain degree of initial plastic deformation (yield strength) or at which fracture occurs (ultimate strength).
the stress induced near the surface decreases with distance from the loading point and increases as the supporting surface is approached. This pattern is called a stress distribution.

The stress produced within the solid material is equal to the applied force divided by the area over which it acts.

there are several types of stresses that develop according to the nature of the applied forces and the object’s shape. These include tensile stress, shear stress, and compressive stress
Stress is the force per unit area acting on millions of atoms or molecules in a given plane of a material.

Elastic stresses in materials do not cause permanent (irreversible) deformation. On the other hand, stresses greater than the proportional limit cause permanent deformation and, if high enough, may cause fracture.

Strain, or the change in length per unit length, is the relative deformation of an object subjected to a stress. Strain may be either elastic, plastic, elastic and plastic, or viscoelastic.

Elastic strain is reversible. The object fully recovers its original shape when the force is removed.

Plastic strain represents a permanent deformation of the material; it does not decrease when the force is removed.

Viscoelastic materials only the elastic portion is recovered when the stress is reduced.
Unloading and Reloading

plastic strain (permanent)  elastic strain (recovered)

Loading and unloading
No energy loss

Loading and unloading
The area inside the curve, hysteresis loop is energy loss

Purely elastic material

Viscoelastic material
**TENSILE STRESS:** A tensile stress is always accompanied by tensile strain, that is, a stress caused by a load that tends to stretch or elongate a body. If a slight amount of bending (flexure) occurs during tensile loading, the resulting stress distribution will consist of tension, compression, and shear components. However, a tensile stress can be generated when structures are flexed.
**COMPRESSIVE STRESS:** When a body is placed under a load that tends to compress or shorten it, the internal resistance to such a load is called a compressive stress. A compressive stress is associated with a compressive strain.

**SHEAR STRESS:** This type of stress tends to resist the sliding or twisting of one portion of a body over another. Shear stress can also be produced by a twisting or torsional action on a material.

In the mouth, shear failure is unlikely to occur for:

1. Many of the brittle materials in restored tooth surfaces generally have rough, curved surfaces.
2. To produce shear failure, the applied force must be located immediately adjacent to the interface, as shown in Figure B.
3. Because the tensile strength of brittle materials is usually well below their shear strength values, tensile failure is more likely to occur.
**FLEXURAL (BENDING) STRESS:** Flexural strength (bending strength or modulus of rupture)—Force per unit area at the instant of fracture in a test specimen subjected to flexural loading.
ELASTIC MODULUS (YOUNG’S MODULUS OR MODULUS OF ELASTICITY):

- Elastic modulus describes the relative stiffness or rigidity of a material, which is measured by the slope of the elastic region of the stress strain graph.

- The proportional limit corresponds to the location of stress at the end of the linear region.

- Yield strength refers to an indication of maximum stress that can be developed in a material without causing plastic deformation. It is the stress at which a material exhibits a specified permanent deformation and is a practical approximation of the elastic limit.
STRESS STRAIN CURVE

- Elastic region
- Plastic region
- Ultimate strength
- Fracture

- Maximum allowable stress
- Proportional limit
- Yield strength

- Young’s modulus: $\frac{\sigma_l}{\varepsilon_l}$

- Elastic limit

- Stress $(\sigma)$ vs. Strain $(\varepsilon)$
This figure represents a plot of true stress versus strain because the force has been divided by the changing cross-sectional area as the wire was being stretched. The straight-line region represents reversible elastic deformation, because the stress remains below the proportional limit and the curved region represents irreversible plastic deformation, which is not recovered when the wire fractures.

If the tensile stress below the proportional limit or the compressive stress (below the proportional limit) is divided by its corresponding strain value, that is, tensile stress/tensile strain or compressive stress/compressive strain, a constant of proportionality will be obtained that is known as the elastic modulus, modulus of elasticity, or Young’s modulus.
STRENGTH PROPERTIES

- Strength is equal to the degree of stress necessary to cause either fracture (ultimate strength) or a specified amount of plastic deformation (yield strength).

1. Proportional limit, the point above which the curve deviates from a straight line the stress above which stress is no longer proportional to strain.
2. Elastic limit: The elastic limit of a material is defined as the greatest stress to which the material can be subjected such that it returns to its original dimensions when the force is released the maximum stress a material can withstand before it becomes plastically deformed.
3. Yield strength or proof stress: Yield strength often is a property that represents the stress value at which a small amount (0.1% or 0.2%) of plastic strain has occurred is referred to as the percent offset.
4. Ultimate tensile strength, shear strength, compressive strength, and flexural strength, each of which is a measure of stress required to fracture a material.

- The true stress is calculated as the force divided by the actual cross-sectional area at each measured strain value.
FLEXIBILITY: The maximum flexibility is defined as the flexural strain that occurs when the material is stressed to its proportional limit.

For materials used to fabricate dental appliances and restorations, a high value for the elastic limit (the stress above which a material will not recover to its original state when the force is released) is a necessary requirement because the structure is expected to return to its original shape after it has been stressed and the force is removed (elastic recovery).
**RESILIENCE:** the term resilience is associated with springiness, but it means precisely the amount of energy absorbed within a unit volume of a structure when it is stressed to its proportional limit. The material with the larger elastic area has the higher resilience. Shown in Figure 4-6 is a stress-strain diagram illustrating the concepts of resilience and toughness.

**TOUGHNESS:** is defined as the amount of elastic and plastic deformation energy required to fracture a material. Fracture toughness is a measure of the energy required to propagate critical flaws in the structure. Toughness is measured as the total area under the stress-strain graph (such as shown in Figure) from zero stress to the fracture stress. Toughness increases with increases in strength and ductility.
IMPACT STRENGTH This property may be defined as the energy required to fracture a material under an impact force. The term impact is used to describe the reaction of a stationary object to a collision with a moving object. A moving object possesses a known amount of kinetic energy. If the struck object is not permanently deformed.
Materials that are very brittle have a tensile strength markedly lower than their corresponding compressive strength because of their inability to plastically deform and reduce the tensile stress at flaw tips. This is true of all brittle dental materials, such as amalgams, composites, cements, ceramics, and some base metal alloys.
DUCTILITY AND MALLEABILITY:

- Ductility represents the ability of a material to sustain a large permanent deformation under a tensile load up to the point of fracture.
- Malleability is the ability of a material to sustain considerable permanent deformation without rupture under compression.
Malleability and Ductility

- Malleable - Most metals can be hammered or rolled into shape.
- Ductile - Most metals can be pulled into long wire.

Ductility is the relative ability of a material to be stretched plastically at room temperature without fracturing.
HARDNESS:

- Among the properties that are related to the hardness of a material are compressive strength, proportional limit, and ductility. There are several types of surface hardness tests. Most are based on the ability of the surface of a material to resist penetration by a diamond point or steel ball under a specified load.

- The Brinell hardness number is related to the proportional limit and the ultimate tensile strength of dental gold alloys. The Brinell hardness test is one of the oldest tests employed for determining the hardness of metals. In this test, a hardened steel ball is pressed under a specified load into the polished surface of a material, the load is divided by the area of the projected surface of the indentation, and the quotient is referred to as the Brinell hardness number, usually abbreviated as HB or BHN.
Physical and Chemical Properties of Solids
• **Physical properties** are based on the laws of mechanics, optics, thermodynamics, electricity, magnetism, radiation.

• Hue, value, and chroma relate to color and laws of optics, which is the science that deals with the phenomena of light, vision, and sight.

• Thermal conductivity, diffusivity, and expansion are physical properties based on the laws of thermodynamics.

• **Chemical properties** are based on the ways in which substances interact, combine, and change, as governed by their outer orbital electrons.

• The outer electrons are responsible for binding atoms together in molecules and for the electrical, thermal, optical, and magnetic properties of solids.
**RHEOLOGY**: is the study of the deformation and flow characteristics of matter, whether liquid or solid. Viscosity is the resistance of a fluid to flow, most liquids, when placed in motion, resist imposed forces that cause them to move. This resistance to fluid flow (viscosity) is controlled by internal frictional forces within the liquid.
STRESS RELAXATION: After a substance has been permanently deformed (plastic deformation), there are trapped internal stresses.

The displaced atoms are not in equilibrium positions and are therefore unstable. The result is a change in the shape or contour of the solid as the atoms or molecules change positions.

The rate of relaxation increases with an increase in temperature.

Considerable attention is given to this phenomenon because such dimensional changes by relaxation may result in an inaccurate fit of dental appliances.
CREEP AND FLOW: Creep is defined as the time dependent plastic strain of a material under a static load or constant stress.

The term flow, rather than creep, has generally been used in dentistry to describe the rheology of amorphous materials such as waxes. The flow of wax is a measure of its potential to deform under a small static load.
NATURE OF LIGHT AND THE ROLE OF HUMAN VISION

Light is electromagnetic radiation that can be detected by the human eye. The eye is sensitive to wavelengths from approximately 400 nm (violet) to 700 nm (dark red).

For an object to be visible, it must reflect or transmit light incident on it from an external source.
Electromagnetic radiation in the visible region interacts with an object through reflection from its surface, absorption, refraction, or transmission (i.e., by passing through unchanged.) These phenomena determine the opacity, translucency, or transparency of an object.

- Opacity of a material is related to the amount of light it can absorb and/or scatter. The opposite of opacity is translucency. For example, if 1-mm thicknesses of each of two materials absorb 20% and 50%, respectively, of the light passing through them, the former is less opaque or more translucent than the latter.

- Transparent materials are at the far end of the translucency scale, absorb no light, and transmit 100% of the light that passes through them. Enamel. When light strikes enamel, some is reflected, some refracted, some absorbed, and some transmitted.
THREE DIMENSIONS OF COLOR: color perception is described by three objective variables: hue, value, and chroma.

- **Hue**: The dominant color of an object, for example red, green, or blue. This refers to the dominant wavelengths present in the spectral distribution.

- **Value**: Value is also known as the gray scale. It is the vertical, or Z-axis, of Figure 3-5. Value increases toward the high end (lighter) and decreases toward the low end (darker). Value is also expressed by the “lightness” factor,

- **Chroma**: Chroma is the degree of saturation of a particular hue. For example, red can vary from “scarlet” to light pink, where scarlet has a high saturation and pink has a low saturation. The yellow color of a lemon is a more saturated, “vivid,” color than that of a banana, which is a less saturated, “dull” yellow. Chroma varies radially, perpendicular to the value/L*
RADIOPACITY:

The amount of x-ray energy absorbed by an object depends on the density and thickness of the material and the energy of the radiation.

Generally, the higher the atomic number of the component atoms, the greater the x-ray absorbance and the larger the contrast produced.

Thermal conductivity ($\kappa$) is the physical property that governs 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 a cross section of 1 cm$^2$ having a temperature difference of 1 K (1 °C) and is measured under steady-state conditions in which the temperature gradient does not change.

Materials that have a high thermal conductivity are called conductors, whereas materials of low thermal conductivity are called insulators.
THERMAL DIFFUSIVITY

is a 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: $h = \frac{\kappa}{c_p \times \rho}$ where $h$ is thermal diffusivity, $\kappa$ is thermal conductivity, $c_p$ is heat capacity at constant pressure, and $\rho$ is the temperature dependent density in grams per cm$^3$

Enamel and dentin are effective thermal insulators. The thermal conductivities and thermal diffusivities of cementing materials (glass ionomer, zinc phosphate, and composite) compare favorably with these tissues.
Thermal conductivity

THERMAL DIFFUSIVITY
which is defined as the change in length per unit of the original length of a material when its temperature is raised 1 °C (1 K): \( \alpha = \frac{\Delta L}{L \times \Delta T} \) where \( L \) is the original length, \( \Delta L \) is the change in length and \( \Delta T \) is the temperature change.

This parameter is extremely important in dental applications as broad ranging as producing cast restorations that fit and maintaining the seal at a restoration margin.
ELECTROCHEMICAL PROPERTIES

- **Corrosion** is an electrochemical process and is dependent on the ability to conduct electrical current, either by means of free electrons in metals or via ions in solution. Corrosion and its influence on durability and appearance are the major ways in which electrochemistry affects oral well-being.
TARNISH AND CORROSION

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

In the oral environment, tarnish often occurs from the formation of deposits on the surface of a restoration, such as oxides, sulfides, or chlorides. However,

it is often an early indication and precursor of corrosion.
Corrosion is a process whereby deterioration of a metal is caused by reaction with its environment. In due course, corrosion can cause severe and catastrophic disintegration of metals.

Even if highly localized, corrosion may cause mechanical failure of a structure even though the actual volume of material lost is quite small.
FUNDAMENTAL BASIS OF CORROSION

- Corrosion occurs because most commonly used metals and alloys are not in their lowest energy state. Thus, pure metals spontaneously convert to a highly reacted, oxidized state by reacting with, for example, oxygen, sulfur, or chlorine in order to revert to their lowest energy state. This, in essence, is the process of corrosion.

- Corrosion of a metal is either a chemical or an electrochemical process.
Chemical corrosion is the direct combination of metallic and nonmetallic elements to yield a chemical compound through oxidation reactions.

Electrochemical corrosion, also known as galvanic corrosion, requires the presence of water or some other fluid electrolyte and a pathway for the transport of electrons (i.e., an electrical current). It is also referred to as wet corrosion, since it requires a fluid electrolyte.
ELECTROCHEMICAL MECHANISM OF CORROSION

- When a metal is in contact with a fluid electrolyte, the chemical potential causes enough ions to dissolve to form a saturated solution and produce an equal number of free electrons. The loss of electrons by a metal is known as oxidation and is the initial electrochemical event in the corrosion process.
Galvanic Cell

Anode: \( \text{Zn}^{2+} + 2 \text{e}^- \rightleftharpoons \text{Zn}: E^0 = -0.76 \text{ V} \) (Oxidation)

Cathode: \( \text{Cu}^{2+} + 2 \text{e}^- \rightleftharpoons \text{Cu}: E^0 = +0.34 \text{ V} \) (Reduction)

Overall or net cell reaction is: \( \text{Cu}^{2+} + \text{Zn} \rightleftharpoons \text{Cu} + \text{Zn}^{2+} \) (Redox reaction)
Iron hydroxide forms and precipitates

The hydroxide quickly oxidizes to form rust

Water droplet

Electrochemical cell action driven by the energy of oxidation continues the corrosion process.

Cathode action reduces oxygen from air, forming hydroxide ions.

Anode action causes pitting of the iron.
- **galvanic shock**

- An important type of electrochemical reaction occurs when combinations of dissimilar metals are in direct physical contact.

- Because both restorations are wet with saliva, an electrical circuit exists with a difference in potential between the dissimilar restorations (Figure 5).

- When the two restorations are brought into contact, there is a sudden short-circuit through the two alloys. This can result in a sharp pain, called.
DENTURE RELINERS
Because ridge contours change during denture service, it is sometimes necessary to alter tissue surfaces of prostheses to ensure proper fit. In other instances, tissue surfaces must be replaced by relining or rebasing existing dentures.

The application of elastomer polymers in the prevention and treatment of chronic tissue irritation from dentures is an excellent alternative to the use of hard polymer resins and it is useful for preserving the health of the remaining denture-supporting tissues.
Uses of denture reliners

- Denture reliners find several uses in the specialty of prosthodontics.
- 1- They are used to improve fit of ill fitting dentures,
- 2-to prevent traumatic damage to the mucosa, as a cushion between denture bearing mucosa and denture,
- 3-to retain over denture bar attachments, to retain extra oral prosthesis,
- 4-to distribute occlusal forces, to increase serviceable life of prosthesis,
- 5-to replace the fitting surface of conventional hard dentures,
- 6-to relieve mucosal pain under hard dentures, improves the rhythm of chewing strokes
RELINING RESIN DENTURE BASES

- Relining involves replacement of the tissue surface of an existing denture, تعريف داخل

- an impression of the soft tissues is made using the existing denture as an impression tray. A gypsum cast is generated in the impression, and the resultant assembly is invested in a brass denture flask. Subsequently, the flask is opened and prepared for the introduction of resin.

- the impression material is removed from the denture. The tissue surface is cleaned to enhance bonding between the existing denture base and the reline material. Next, an appropriate resin is introduced and shaped using a compression molding technique.
For relining, a low polymerization temperature is desirable to minimize distortion of the remaining denture base. Hence, a chemically activated resin is usually chosen. The selected material is mixed according to the manufacturer’s recommendations, placed into the mold, compressed, and permitted to polymerize. Finally, the denture is recovered, finished, and polished.

Relining can also be accomplished using resins that are activated by heat, light, or microwave energy. In all of these instances, significant heat can be generated and distortion of the existing denture base will be more likely.
REBASING RESIN DENTURES

- rebasing involves replacement of the entire denture base except for the denture teeth.
- The steps required in denture rebasing are similar to those described for relining.
- An accurate impression of the soft tissues is made using the existing denture as a custom tray. Subsequently, a gypsum cast is fabricated in the impression. The cast and denture are mounted in a device designed to maintain the correct vertical and horizontal relationships between the stone cast and surfaces of the prosthetic teeth.
- The denture is removed and the teeth are separated from the existing denture base. The teeth are repositioned in their respective indices and held in their original relationships to the cast while they are waxed to a new baseplate.
- At this point, the denture base is waxed to the desired form.
- Following elimination of the wax and removal of the baseplate, resin is introduced into the mold cavity. The material subsequently is processed.
DENTURE RELINERS

- Classification:
- I. Based on curing:
  - Self cure- eg., soften, viscogel
  - Heat cure- eg., supersoft, molloplast
- II. Based on composition:
  - Silicone elastomers
  - Soft acrylic compounds
- III. Based on durability
  - Temporary/Short term liners
  - Definitive/long term liners
- IV. Based on consistency
  - Hard denture liners
  - Soft denture liners
- Based on the availability
  - Home reliners
  - Tissue conditioners
Desirable properties of lining materials

• 1-Long term viscoelastic behaviour which is stable,
• 2-low water sorption,
• 3-improved colour stability, resistance to staining,
• 4-tear resistance,
• 5-good bond strength to denture base,
• 6-dimensional stability,
• 7-resistance to fungal and bacterial growth,
• 8-high magnitude of energy dissipation, good resiliency,
• 9-heat resistance, low glass transition temperature.
HEAT CURED ACRYLIC RESIN (HARD LINER) New resin is cured against the old denture by compression molding technique.

A low curing temperature is necessary for the relining process to avoid distortion of the denture.

Disadvantages

1- There is a tendency for it to warp toward the relined side due to

2- Diffusion of the monomer from the reliner before curing, and

3- Processing shrinkage of the liner. For this reason the rebasing is preferred to relining
**CHAIRSIDE RELINERS (HARD SHORT-TERM LINER)**

*These materials are used for relining resin dentures directly in the mouth (Fig. 29.40). Some of them generate enough heat to injure oral tissues.*

*Generally the specifications are far less demanding for these materials than for the regular denture base resins.*

*On the whole their properties are inferior to laboratory processed acrylic resins.*

1. They have higher porosity and water sorption.
2. They often contain low molecular weight polymers, plasticizers or solvents to increase their fluidity while seating the denture.
3. They tend to discolor, become foul smelling and may even separate from the denture base.

*Thus, these materials have many disadvantages and are therefore considered as short-term materials.*
FIGURE 29.40  Hard setting chairside denture liner.

FIGURE 29.41  Soft denture liner.
SOFT OR RESILIENT DENTURE LINERS

1. Short-term soft liners (also known as tissue conditioners)
2. Long-term soft liners

LONG-TERM SOFT LINERS The purpose of the ‘permanent’ soft liner (Fig. 29.41) is to protect the soft tissue by acting as a cushion.

They are used when there is
1. irritation of the mucosa,
2. in areas of severe undercut and
3. congenital or acquired defects of palate.
Classification

1. Based on depth of penetration
   - Type A—soft
   - Type B—extra soft

2. Based on their method of processing they are further divided into
   - Mouth cured or chairside soft liners – does not last beyond a few weeks.
   - Processed soft liners – lasts up to a year.

Types

Several soft lining materials are available commercially
- Plasticized acrylic resin
- Plasticized vinyl resins
- Silicone rubbers
- Polyphosphazene
• **PLASTICIZED ACRYLIC RESIN**: This is most commonly used. It may be self-cured or heat-cured. The heat-cured resin may be supplied in a sheet form or powder-liquid form. The glass transition (softening) temperature of the cured resin will be below mouth temperature.

• Disadvantages: They lose plasticizers and harden with use.

• **VINYL RESINS**: The plasticized poly (vinyl chloride) and poly (vinyl acetate) resins, like the plasticized acrylic resins, lose plasticizer and harden during use.

• **SILICONE RUBBERS**: These materials retain their elastic properties but may lose adhesion to the denture base. It is heat polymerized against acrylic resin using compression molding technique.

• For adhesion between silicones and the denture base, a rubber poly (methylmethacrylate) graft polymer solution cement may be used.
TISSUE CONDITIONERS (SHORT-TERM SOFT LINER)

- Tissue conditioners are soft elastomers used to treat irritated mucosa. Their useful function is very short, generally a matter of a few days. They are replaced every 3-5 days.
- They lose alcohol over time resulting in a weight loss of 5–9%. These materials show both viscous and viscoelastic behavior which help in both adaptation to tissue and cushioning of masticatory forces.

Uses

1. Ill-fitting dentures can cause inflammation and distortion of the oral tissues. Relining an ill-fitting denture with tissue conditioner allows the tissues to return to ‘normal’ at which point a new denture can be made.
2. As an impression material (this material is used in a special impression technique known as functional impression).

Manipulation The denture base is relieved on the tissue surface. Powder and liquid are mixed together to form a gel and it is placed on the tissue surface of the denture and inserted in the mouth. The gel flows readily to fill the space between the denture base and the oral tissue.

The properties that make tissue conditioners effective are

1. Viscous properties, which allow excellent adaptation to the irritated denture-bearing mucosa over a period of several days and brings it back to health.
2. Elastic behavior which cushions the tissues from the forces of mastication and bruxism.
<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denture surface before relining</td>
<td>Grind the borders. Relieve those areas that need to be relined</td>
</tr>
<tr>
<td>Grind the borders. Relieve those areas that need to be relined</td>
<td>Apply coating agent as bonding (optional)</td>
</tr>
<tr>
<td>Apply coating agent as bonding (optional)</td>
<td>Mix powder &amp; liquid</td>
</tr>
<tr>
<td>Mix powder &amp; liquid</td>
<td>Apply material on the denture</td>
</tr>
<tr>
<td>Seat denture and remain in situ for 5 minutes</td>
<td>Remove from the mouth after 5 minutes</td>
</tr>
<tr>
<td>Remove from the mouth after 5 minutes</td>
<td>Trim excess with a sharp instrument</td>
</tr>
<tr>
<td>Trim excess with a sharp instrument</td>
<td>After cleaning apply the coating agent</td>
</tr>
<tr>
<td>After cleaning apply the coating agent</td>
<td>Finished denture</td>
</tr>
</tbody>
</table>
Properties of liners

- Anti fungal can be incorporated into tissue conditioners. There are several advantages of tissue conditioners incorporated antifungal such as
  - reduced treatment cost,
  - Simultaneous treatment of both injured tissues and Candida infection possible,
  - reduced frequency of application of antifungal. At the same time
  - mechanical properties like increased tensile strength, reduces hardness and modulus of elasticity
- Less change of color and improved resistance to staining were seen with the fluorinated soft lining materials. More colour change is seen in Hydrophobic and pigmented liners. Leaching of plasticizers creates space which incorporates staining pigments which is accentuated by rough surfaces,
Factors that affect the bond between acrylic and liner are:

1- Geometry of bond surface whether roughened or clinically etched, use of bonding agents,
2- Inherent bond strength,
3- Tear strength and thickness of lining materials.

One of the main disadvantages of silicone is its lack of ability to bond to the acrylic denture base without an adhesive.

Even if it succeeds to bond, the bond is seen to be week and less durable. On the other hand acrylic products have better bonding ability to the denture bases.

of reducing agent makes heat-polymerized resins superior in color stability
• **stress relaxation and softness** varied under cyclic loading conditions. Softness value increased on loaded or stored period and the stress relaxation increased as increase in thickness of the lining materials from 1mm to 3 mm.

• Superior resistances to flow and the higher elasticity is a result of cross-linked polymer structure. Curing temperature, powder/liquid ratio is responsible for thickness of the layer.

• **Water sorption:** by lining material leads to change in dimension and stress concentration at liner- denture base interface as a result leading to reduction of bond strength.

• Heat cured silicone has better bond to filler and greater cross linking leading to the production of a denser material which are devoid of micro pockets of water.

• Plasticized acrylics have a better capacity to adhere to denture base but rapid plasticizer leaching from them leads to surface deterioration.
Problems associated with soft liners

1. Inadequate bonding to denture, especially silicone liners.
2. Some silicone liners and the hydrophilic acrylics undergo a high volume change (up to 40%) with gain and loss of water.
3. The heat cured soft acrylics bond well to the hard denture base but loose their softness as plasticizer is leached from the liner.
4. It reduces the denture base strength, not only because of reduced base thickness but also by solvent action of the silicone adhesive and the monomer.
5. Trimming, cutting, adjusting and polishing of a soft liner is difficult. The silicone surface is abrasive and irritating to the oral mucosa when compared to that of hard acrylic resin.
6. Characteristic disagreeable taste and odor and they cannot be cleaned as effectively.
7. The debris that accumulate in pores in the silicone liner can promote fungal growth (Candida albicans).
SPECIALIZED POLY (METHYL METHACRYLATE) MATERIAL
NEW ERA IN DENTURE BASE RESINS

1. Reinforced resins
   a. High impact resins
   b. Fiber-reinforced
2. Hypoallergenic resins
3. Resins with modified chemical structure
4. Thermoplastic resins
5. Enigma gum toning in denture bases
HIGH IMPACT RESINS Rubber reinforced

They are so-called because of greater impact strength & fatigue properties, hence indicated for patients who drop their dentures repeatedly e.g. parkinsonism, senility. Available as powder-liquid system & processing is same as heat cure resins.

A) FIBER REINFORCED RESINS

a) METAL FIBER REINFORCED
b) CARBON / GRAPHITE FIBER REINFORCED: are placed during packing. Carbon-graphite fibers provide greatest reinforcement of denture base resins in terms of flexural strength & bending properties when placed longitudinally (perpendicular to applied forces).

c) ARAMID FIBER REINFORCED

d) GLASS FIBRES (HAVE BEST AESTHETICS): Continuous fibers provide superior reinforcement over chopped fibres but placing continuous fibers at weak parts of denture is difficult & there is formation of voids inside fiber polymer matrix system.
B) HYPOALLERGENIC RESINS
C) RESINS WITH MODIFIED CHEMICAL STRUCTURE: Addition of
1- hydroxy-apatite fillers increases fracture toughness.
2- Addition of Al2O3 fillers increases the flexural strength & thermal diffusivity that could lead to more patient satisfaction.
3- 2% quaternary ammonium compound polymerised with a denture acrylic resin displays antiseptic properties & these dentures may be used for geriatric patients to improve their oral health.
D) ENIGMA GUM TONING:
1) Custom shade matching of natural gingival tissue using ‘Enigma’ colour tones.
2) Available in Ivory, Light Pink, Natural Pink, Dark Pink & Light Brown. Different colors are mixed to get the desired gum tone.
**E) THERMOPLASTIC RESINS** | Thermoplastic resins have many advantages over the conventional powder-liquid systems.

1- They provide excellent esthetics with tooth or tissue colored materials and are very comfortable for the patient.

2- These are very stable, have high fatigue endurance, high creep resistance, excellent wear characteristics & solvent resistance.

3- They are non-porous so no growth of bacteria.

4- They are unbreakable, flexible & light weight. Thermoplastic resins are a safe alternative to conventional resins because of very little or no monomer content. These include

I.) **THERMOPLASTIC NYLON:** Thermoplastic nylon was introduced to dentistry in 1950’s. It uses Rapid Injection System (currently known as The Flexite Company - USA)
II. THERMOPLASTIC ACETAL: Acetal was first proposed as an unbreakable thermoplastic resin removable partial denture material in 1971. Rapid injection system developed the first tooth coloured clasps.

III.) THERMOPLASTIC ACRYLIC: Thermoplastic acrylic has poor impact resistance, but has adequate tensile and flexural strength. Thermoplastic acrylic is available in both tooth and gingival colors, and has both translucency and vitality, providing excellent esthetics.
RESIN TEETH The composition of resin teeth is essentially poly (methyl methacrylate) copolymerized with a cross-linking agent.

A greater amount of the cross-linking agent is used in resin teeth in order to reduce the tendency of the teeth to craze upon contact with the monomer-polymer dough during construction.

Various pigments are utilized to produce a natural esthetic appearance. The bond between the resin teeth and denture base resin is chemical in nature unlike porcelain teeth which requires mechanical locking.
<table>
<thead>
<tr>
<th>Resin</th>
<th>Porcelain</th>
</tr>
</thead>
<tbody>
<tr>
<td>High fracture toughness</td>
<td>Brittle, may chip</td>
</tr>
<tr>
<td>Crazing if not cross-linked</td>
<td>Susceptible to crazing by thermal shock</td>
</tr>
<tr>
<td>Clinically significant wear</td>
<td>Insignificant wear</td>
</tr>
<tr>
<td>Easily ground and polished</td>
<td>Grinding difficult</td>
</tr>
<tr>
<td>Silent on contact</td>
<td>Clicking sound on impact</td>
</tr>
<tr>
<td>Dimensional change with water sorption</td>
<td>Dimensionally stable</td>
</tr>
</tbody>
</table>

Comparison of resin and porcelain denture teeth
PROPERTIES OF METHYL METHACRYLATE DENTURE RESINS

METHYL METHACRYLATE MONOMER
It is a clear, transparent, volatile liquid at room temperature. It has a characteristic sweetish odor.

POLY (METHYL METHACRYLATE)
1- Taste and odor: Completely polymerized acrylic resin is tasteless and odorless. On the other hand poorly made dentures with a high amount of porosity can absorb food and bacteria, resulting in an unpleasant taste and odor.

2- Esthetics
It is a clear transparent resin which can be pigmented (colored) easily to duplicate oral tissue. It is compatible with dyed synthetic fibers. Thus esthetics is acceptable.
Strength These materials are typically low in strength. However they have adequate compressive and tensile strength for complete or partial denture applications.
Self cured resins generally have lower strength values.
The strength is affected by
1. Composition of the resin
2. Technique of processing
3. Degree of polymerization
4. Water sorption
5. Subsequent environment of the denture.
Fatigue strength refers to the ability of the denture to withstand large number of small cyclic loading such as during mastication over a period of time. Most current dental plastics have sufficient fatigue strength.

4- Hardness and wear resistance Acrylic resins are materials having low hardness. They can be easily scratched and abraded.

5- Creep Denture resins exhibit creep. When a load is applied an initial deflection is observed. If the load is sustained additional deformation is observed over time. The additional deformation is called creep. Chemically activated resins have higher creep rates.

6- Dimensional stability A well-processed acrylic resin denture has good dimensional stability. The processing shrinkage is balanced by the expansion due to water sorption.
Polymerization shrinkage Acrylic resins shrink during processing due to
a- Thermal shrinkage on cooling
b- Polymerization shrinkage During polymerization, this results in shrinkage in the volume of monomer-polymer dough. However, in spite of the high shrinkage, the fit of the denture is not affected because the shrinkage is uniformly distributed over all surfaces of the denture.

Thermal properties Stability to heat Poly (methyl methacrylate) is chemically stable to heat up to a point. It softens at 125 °C. However, above this temperature, i.e. between 125 °C and 200 °C it begins to depolymerize. Thermal conductivity They are poor conductors of heat and electricity. This is undesirable because patients wearing acrylic complete dentures often complain that they cannot feel the temperature of food or liquids they ingest, thus reducing the pleasure.
9- Color stability Heat-cured acrylic resins have good color stability. The color stability of self-cure resins is slightly lower (yellows very slightly).

10- Biocompatibility Completely polymerized acrylic resins are biocompatible. True allergic reactions to acrylic resins are rarely seen in the oral cavity. The residual monomer (approximately in a well-processed denture) is the usual component singled out as an irritant.
Porosity presents many problems:

1. It makes the appearance of denture base unsightly.
2. Proper cleaning of the denture is not possible, so the denture hygiene and thus, the oral hygiene suffers.
3. It weakens the denture base and the pores are areas of stress concentration.

Porosity may be:

A. Internal porosity
B. External porosity
Internal porosity appears as voids or bubbles within the mass of the polymerized acrylic. It is usually not present on the surface of the denture. It is confined to the thick portions of the denture base and it may not occur uniform. Cause Internal porosity is due to the vaporization of monomer when the temperature of the resin increases above the boiling point of monomer (100.8 °C).

Avoided by Dentures with excessive thickness should be cured using a long, low temperature curing cycle.
External porosity It can occur due to two reasons

1- Lack of homogeneity If the dough is not homogenous at the time of polymerization, the portions containing more monomer will shrink more. Avoided by Using proper powder/liquid ratio and mixing it well. The mix is more homogenous in the dough stage, so packing should be done in the dough stage.

2- Lack of adequate pressure during polymerization or inadequate amount of dough in the mold during final closure causes bubbles
CRAZING Crazing is formation of surface cracks on the denture base resin. Crazing weakens the resin and reduces the esthetic qualities. The cracks formed can cause fracture.

- Crazing is due to:
  1. Mechanical stresses
  2. Attack by a solvent
  3. Incorporation of water In poly (methyl methacrylate) crazing occurs when tensile stresses are present. Water incorporation during processing will form stresses due to evaporation of water after processing, causing crazing.

- Avoided by:
  1. Using cross linked acrylics
  2. Tin foil separating medium
  3. Metal molds
FIGURE 29.34 Surface and subsurface porosity from lack of insufficient pressure during curing.

FIGURE 29.35 Representation of crazing in resins.

FIGURE 29.36 Denture warpage has resulted in a space between the palatal surface and the cast. Obviously this would affect the fit.
DENTURE WARPAGE Denture warpage is the deformity or change of shape of the denture which can affect the fit of the denture. It is caused by:

1- a release of stresses incorporated during processing. May be a result of the uneven or rapid cooling.

2- Packing of the resin during the rubbery stage can also induce stresses. These stresses are released subsequently.

3- During polishing, a rise in temperature can cause warpage.

4- Immersion of the denture in hot water can cause warpage.

5- Re-curing of the denture after addition of relining material, etc.
Dentures should be stored in water when not in use, since dimensional changes can occur on drying.

Acrylic dentures should not be cleaned in hot water, since processing stresses can be released and can result in distortion.

Abrasive dentifrices (regular toothpastes) should not be used, since the plastic is soft and can be easily scratched and abraded. The tissue surface should be brushed carefully with a soft brush since any material removed alters the fit of the denture.
DENTURE CLEANSERS A wide variety of agents are used by patients for cleaning artificial dentures. They include dentifrices, proprietary denture cleansers, soap and water, salt and soda, household cleansers. Dentures are cleaned by either
1. Immersion in an agent or
2. By brushing with the cleanser. The most common commercial denture cleansers are the immersion type, which are available as a powder or tablet.
SYNTHETIC POLYMERS
DENTAL POLYMERS

Resins are compositions of either monomers or macromolecules blended with other components to provide a material with a useful set of properties.

Macromolecule—A large high-molecular-weight compound usually consisting of repeating units in a chain like configuration

Monomer—Chemical compound that is capable of reacting to form a polymer. Polymer molecules may be prepared from a mixture of different types of monomers and they are called copolymers.

Polymer—Chemical compound consisting of a large organic molecule (“macromolecule”) formed by the union of many smaller repeating units (mers) The mer ending represents the simplest repeating chemical structural unit from which the polymer is composed.
Based on their thermal behavior, they can be divided either into thermoplastic resins or thermosetting resins.

<table>
<thead>
<tr>
<th>thermoplastic resins</th>
<th>thermosetting resins</th>
</tr>
</thead>
<tbody>
<tr>
<td>repeatedly softened and molded under heat and pressure</td>
<td>They set when heated. These cannot be softened by reheating like the thermoplastic resins</td>
</tr>
<tr>
<td>fusible and are usually soluble in organic solvents.</td>
<td>infusible and insoluble</td>
</tr>
<tr>
<td>The setting reaction is reversible because of the relatively weak bonds among the molecular chains.</td>
<td>become permanently hard (irreversible)</td>
</tr>
<tr>
<td>without any chemical change</td>
<td>undergo a chemical change during the setting reaction</td>
</tr>
<tr>
<td>better flexural and impact properties</td>
<td>superior abrasion resistance and dimensional stability</td>
</tr>
<tr>
<td>Without crosslinking</td>
<td>are crosslinked</td>
</tr>
</tbody>
</table>
DENTAL USES OF POLYMERIC MATERIALS AND RESINS

• Prosthodontics: denture bases and teeth, soft liners, custom trays, impression materials, core buildup materials, and maxillofacial prostheses

• Operative Dentistry: dentin bonding agents, cavity fillings, resin and glass-ionomer cements, pit and fissure sealants

• Orthodontics: brackets, bracket bonding resins and cements, and spacers

• Endodontics: gutta-percha points, root canal sealants, and rubber dams

• Equipment: mixing bowls and spatulas, mouth guards
IDEAL REQUIREMENTS OF DENTAL RESINS

1. Be tasteless, odorless, nontoxic and nonirritant to the oral tissues. A resin should be completely insoluble in saliva or in any other fluids taken into the mouth.

2. Sufficient strength and resilience to resist the forces developed by biting, chewing, and impact and sufficient toughness.

3. Fracture and fatigue resistance to maintain form and function for many years.

4. The material should also be dimensionally stable under all conditions of service, including thermal changes and variations in loading.

5. When used as a denture base for maxillary dentures, a resin should also have a low density to ensure a light weight, and it should have good thermal conductivity to maintain the patient’s ability to detect temperature changes.
Polymerization

Condensation polymerization (step growth): condensation reaction involves two molecules reacting together to form a third, larger molecule for such a reaction to result in the formation of a polymer, usually, produce a low-molecular-weight by-product, such as water or an alcohol, to be “condensed out”—hence the term condensation polymerization.
Condensation Polymerisation

hexanedioic acid + ethane diol → a polyester + water

ester link
Addition polymerization: An addition reaction simply involves the joining together of two molecules to form a third, larger molecule. No change in chemical composition and no by-products are formed.

Starting from an active center, one molecule at a time is added and a chain rapidly builds up. This occurs in four stages:

**Induction or initiation period:** is the time during which the molecules of the initiator become energized or activated and start to transfer the energy to the monomer. There are three induction systems for dental resins.

- **Heat activation**
- **Chemical activation** This system consists of at least two reactants, when mixed they undergo chemical reaction and liberate free radicals,
- **Light activation** In this system, photons of light energy activate the initiator to generate free radicals.
**Propagation**: the process continues rapidly and is accompanied by evolution of heat. Theoretically, the chain reactions should continue with evolution of heat until all the monomer has been changed to polymer.

**Chain transfer**: The chain termination can also result from chain transfer. Here the active state is transferred from an activated radical to an inactive molecule.

**Termination**: It is possible for the propagation reaction to continue until the supply of monomer molecules is exhausted.
Initiator Molecule

Activation → Free Radicals → Monomer

Initiation

Propagation

Polymer

Termination
ACRYLIC RESINS

Pure poly methyl methacrylate is a colorless transparent solid.

To facilitate its use in dental applications, the polymer can be tinted to provide almost any color, shade, and degree of translucency.

Its color, optical characteristics, and dimensional properties remain stable under normal intraoral conditions.
TYPES

Based on the method used for its activation:

- Heat activated resins
- Chemically activated resins
- Light activated resins

HEAT ACTIVATED DENTURE BASE ACRYLIC RESINS:

Heat activated polymethyl methacrylate resins are the most widely used resins for the fabrication of complete dentures.

Available as Powder and liquid. The powder may be transparent or tooth colored or pink colored (to simulate the gums, some even contain red fibers to duplicate blood vessels).

The liquid (monomer) is supplied in tightly sealed dark colored bottles (to prevent premature polymerization by light or ultraviolet radiation on storage).
POLYMERIZATION REACTION

Polymerization is achieved by application of heat and pressure. The simplified reaction is

\[
\text{Powder} + \text{Liquid} + \text{Heat} \quad \overset{}{\longrightarrow} \quad \text{Polymer} + \text{Heat}
\]

(Polymer) (Monomer) (External) \quad \text{(Reaction)}

TECHNICAL CONSIDERATIONS

1. Compression molding technique (usually heat activated resins).
2. Injection molding technique (heat activated resins).
3. Fluid resin technique (chemically activated resins).
4. Visible light curing technique (VLC resins).
COMPRESSION MOLDING
TECHNIQUE

1. Preparation of a Waxed Denture Pattern

2. Preparation of the split mold:
Steps 3 Application of separating medium

Steps 4 Mixing of powder and liquid: Polymer—monomer proportion = 3:1 by volume or 2:1 by weight.
If too much monomer is used (Lower polymer/monomer ratio)داخل
1. There will be greater curing or polymerization shrinkage.
2. More time is needed to reach the packing consistency.
3. Porosity can occur in the denture.

If too little monomer is used (Higher polymer/monomer ratio)
- Not all the polymer beads will be wetted by monomer and
- the cured acrylic will be granular.
- Dough will be difficult to manage and it may not fuse into a continuous unit of plastic during processing.
**PHYSICAL STAGES OF POLYMERIZATION REACTION**

**Stage I:** Wet sand stage The polymer gradually settles into the monomer forming a fluid, incoherent mass.

**Stage II:** Sticky stage The mass is sticky and stringy when touched or pulled apart.

**Stage III:** Dough or gel stage As the monomer diffuses into the polymer, it becomes smooth and dough like. It does not adhere to the walls of the jar. The mass is plastic and can be packed into the mold at this stage.

**Stage IV:** Rubbery stage The mass is rubberlike, non-plastic and cannot be molded.

**Stage V:** Stiff stage The mass is totally unworkable and is discarded.
WORKING TIME: The working time is the time elapsing between stage II and the beginning of stage IV, at least 5 minutes. The working time is affected by temperature. In warm weather when the working time is insufficient, the mixing jar is chilled to prolong the working time.

PACKING

TRIAL CLOSURE:

CURING CYCLE 1. Long cycle a. 74 °C for 8 hours b. 74 °C for 8 hours, then boil for 1 hour

2. Short cycle - 74 °C for 2 hours, then boil for 1 hour of the thinner portions (short cycle).

COOLING

DEFLASKING

FINISHING AND POLISHING
INJECTION MOLDING TECHNIQUE

FIGURE 29.20 Injection molded denture resin technique. The picture shows the dentures invested in a special flask. The lower denture utilizes a Y-shaped sprue as shown by the operator.

FIGURES 29.21A TO C Injection molded denture resin technique (A) Mixing monomer and polymer. (B) Assembled flask in clamp. (C) Curing water bath.

There is no difference in accuracy or physical properties as compared to compression molding technique.

Advantages

1. Dimensional accuracy (low shrinkage).
2. No increase in vertical dimension.
3. Homogeneous denture base.
4. Low free monomer content.
5. Good impact strength.

Disadvantages

1. Higher cost of equipment.
2. Mold design problems.
3. Less craze resistance.
4. Special flask is required.
CHEMICALLY ACTIVATED DENTURE BASE ACRYLIC RESINS داخل

The chemically activated acrylic resins polymerize at room temperature. They are also known as ‘self-curing’, ‘cold-cure’ or ‘auto-polymerizing’ resins.

In cold cured acrylic resins, the chemical initiator benzoyl peroxide is activated by another chemical (dimethyl-para toluidine which is present in the monomer), instead of heat as in heat cure resins.
USES

1. For making temporary crowns and FDPs.
2. Construction of special trays.
3. For denture repair, relining and rebasing.
4. For making removable orthodontic appliances.
5. For adding a post-dam to an adjusted upper denture.
6. For making temporary and permanent denture bases.
ADVANTAGES AND DISADVANTAGES

1. Better initial fit, which is because the curing is carried out at room temperature. Thus there is less thermal contraction.

2. Color stability is inferior to that of heat cure resin.

3. Slightly inferior properties because the degree of polymerization of self curing acrylics is less than that of heat cured ones.

4. For repairing dentures, self curing resins are preferable to heat cured resins as heat curing causes warpage.
MANIPULATION OF AUTOPOLYMERIZING RESINS

Sprinkle on technique

Adapting technique
Fluid resin technique (pour-type acrylic resins)
LIGHT ACTIVATED DENTURE BASE RESINS:

A: VLC Triad pink sheet for dentures
B: Pink denture base sheets
C: Light curing chamber (Dentsply)
D: Light curing device Blu Lux
   (Courtesy Yohan and Lippy, The Dental Center, Chennai)
Waxes in Dentistry

Waxes in Dentistry
Dental wax

- A low-molecular-weight ester of fatty acids derived from natural or synthetic components, such as petroleum derivatives, that soften to a plastic state at a relatively low temperature.
- A mixture of two or more waxes and additives used as an aid for the production of gypsum casts, production of nonmetallic denture bases, registering of jaw relations, and laboratory work.
## CLASSIFICATION OF DENTAL WAXES

- According to Origin
  - Mineral
  - Plant
  - Insect
  - Animal
- According to Use

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DESIRABLE PROPERTIES OF WAX

1. The wax should be uniform when softened. It should be compounded with ingredients that blend with each other so that there are no granules on the surface.

2. The color should contrast with die materials or prepared teeth. Since it is necessary to carve the wax margins against the die surface.

3. The wax should not fragment into flakes or similar surface particles when it is molded after softening.

4. The wax must not be pulled away by the carving instrument or chip as it is carved or such precision cannot be achieved.

5. When wax melts and is vaporized at 500 °C, it should not leave a solid residue that amounts to more than 0.10% of the original weight of the specimen.
GENERAL PROPERTIES

• **Thermal Expansion:** Waxes expand when subjected to a rise in temperature and contract as the temperature is decreased. Temperature changes in wax patterns after removal from the mouth can produce inaccuracies in the finished restoration.

• **Mechanical Properties:** The elastic modulus, proportional limit and compressive strength of waxes are low compared to other dental materials. These properties are strongly dependent on the temperature. As temperature decreases, the properties improve.

• **Flow:** is an important property, especially in inlay waxes. When melted, the wax should flow readily into all the parts of the die. Flow is dependent on 1. Temperature of the wax 2. Force applied 3. The length of time the force is applied. Flow increases as the melting point of the wax is approached.
• **Residual Stress** Regardless of the method used to make a wax pattern, residual stresses will exist in the completed pattern. The stress may be compressive or tensile in nature. The motion of the molecules is restricted. This restriction results in residual stress (hidden stresses) in the specimen. When the specimen is heated, release of the residual stress is added to the normal thermal expansion, and the total expansion is greater than normal.

• **Ductility** Like flow, the ductility increases as the temperature of the wax is increased. In general, waxes with low melting points have greater ductility than those with high melting points
PATTERN WAXES

• Many dental restorations or prostheses are first made with pattern waxes. The wax is later replaced with the permanent material, e.g. cast gold alloys.

• All pattern waxes have two major qualities which cause serious problems in their use—thermal change in dimension and tendency to warp or distort on standing, e.g. inlay casting wax, RPD casting wax and baseplate wax.

• Types
  • 1. Casting waxes
    • – Inlay
    • – Removable partial denture
    • – Milling wax
  • 2. Baseplate wax (used in the construction of complete and partial denture).
INLAY CASTING WAX

• The inlay casting wax is among the oldest waxes in dentistry.
• Uses The pattern for inlays, crowns and FPDs is first made in wax, and then replaced by metal during casting.
• Direct and indirect techniques If the pattern is made directly in the tooth (in the mouth), it is said to be prepared by direct technique. If it is prepared on a replica of the tooth (die), it is called indirect technique.
• Ideal Requirements of Inlay Casting Waxes
  • 1. When softened, the wax should be uniform, there should be no graininess or hard spots in the plastic material.
  • 2. The color should contrast with the die. A definite color contrast helps in identifying and finishing of margins.
3. The wax should not flake or crumble when the wax is softened.

4. The wax should not chip, flake or tear during carving.

5. During burnout (500 °C), it should vaporize completely without residue.
• Classification* According to ISO 15854:2005, inlay casting waxes are classified as
  - Class 1 Soft—Extraoral or laboratory use
  - Class 2 Hard—Intraoral use
• Supplied As Blue, green or purple sticks or cakes. Also available as small pellets and cones. The waxes are also available in preformed shapes. Commercial Names Harvard, Kerr, etc
Properties of Inlay Wax

- **Flow Requirements** At 45 °C – Both Class 1 and Class 2 should have a flow between 70 to 90%. At 37 °C – Class 2 should not flow more than 1% when heated to around 45 °C. This temperature is tolerated by the patient. The wax cools down and hardens at 37 °C (mouth temperature), allowing the operator to carve and shape it in the mouth.

- **Thermal conductivity** of these waxes is low. It takes time to heat the wax uniformly and to cool it to body or room temperature.

- **Coefficient of thermal expansion** Inlay wax has a high CTE. Its thermal changes are higher than any other dental material. Importance This property is more significant in direct technique because contraction of the pattern can occur when it is taken from mouth to room temperature.

- **Factors affecting** If the wax is allowed to cool under pressure, its thermal properties are changed. When reheated, the linear CTE is increased. The temperature of the die and the method used to apply pressure on the wax as it solidifies also influences the CTE.
• **Wax distortion**: Distortion is due to any method of manipulation that creates inhomogeneity of wax involving the intermolecular distance.

• Wax distortion is the most serious problem in inlay wax. It is due to release of stresses in the pattern caused due to
  1. Contraction on cooling
  2. Occluded gas bubbles
  3. Change of shape of the wax during molding
  4. From manipulation—carving, pooling, removal, etc.

• **Thus the amount of residual stress is dependent on**
  - The method of forming the pattern
  - Its handling, and
  - Length of time and temperature of storage of the wax pattern
• distortion under control of the operator cannot be totally eliminated.
• **Distortion of the wax can occur**
  1-If wax is not at uniform temperature when inserted in the cavity,
  2-If wax is not held under uniform pressure during cooling.
  3-If fresh wax is melted and added in an area of deficiency, the added wax will introduce stresses during cooling.
  4-During carving, some molecules of wax will be disturbed and stresses will result.
• **To avoid** 1. Minimal carving and change in temperature.
  3. Store it in a refrigerator if necessary. It cannot be totally eliminated. It can only be reduced to a point which is not of clinical importance
Manipulation of Inlay Wax

- **Direct wax technique**—A process whereby a wax pattern is prepared in the mouth directly on prepared teeth.

- **Indirect technique** Inlay pattern is prepared over a lubricated die.
  - Dipping method In case of full crowns, the die can be dipped repeatedly, into hot liquid wax. The wax is allowed to cool, carved, and removed from the die.
  - Softening in warm water This technique is not recommended because
    - Soluble constituents may leach out and the properties of wax will change
    - Water gets into the wax causing splattering on the flame, interference with the softening of the wax surface and distortion of the pattern on thermal changes.
  - Addition method The wax is melted and added in layers using a spatula or a brush.
    - Polishing is done by rubbing with a silk cloth.

- Note 1. Invest all wax patterns as soon as possible to avoid distortion.
- 2. Waxes oxidize on heating. Prolonged heating causes it to evaporate. There will also be darkening. To avoid this, use the lowest temperature needed for melting.
RPD CASTING WAX

- The partial denture casting waxes are quite unlike the inlay casting waxes in appearance and handling properties.
- Uses To make patterns of the metallic framework and sprues of removable partial dentures.
- Supplied As It is available in different forms. \( \text{Sheets} \) 0.40 and 0.32 mm thickness
- Preformed shapes
  - Round (10 cm), half round and half pear-shaped rods
  - Reticular, grid or mesh form
  - Clasp shapes
- Bulk wax as blocks or in containers \( \text{Rolls} \) or coils of various diameters ranging for 2 to 5 mm for forming sprues.
• Properties: These waxes are **داخل**
  
• tacky and highly ductile as they must adapt easily and stick onto the refractory cast.

• Since the wax comes in preformed shapes, it is quite easy to assemble.

• The wax forms are sticky and pliable and can be adapted easily onto the cast.
MILLING WAX

- Milling or machinable wax is wax that can be shaped by milling or machining using CAD/ CAM or dental drills.
- Machinable wax is an extremely hard wax with high melting temperature.
- The wax pattern formed after machining is invested and cast like regular casting waxes.
- Available as Machinable wax is available as Blocks, Cylinders, Discs, Cakes in containers.
- Properties It is harder and has a higher melting temperature than most other waxes.

**FIGURES 19.4A TO C** Machinable wax. (A) CAD/CAM milling. (B) Milling wax in cake form. (C) Milling with handpiece.
BASEPLATE WAX

- It is sometimes referred to as modeling or Type 2 wax.
- They are classified under pattern waxes because they are used to create the form of dentures and appliances made of acrylic and like materials.
- Ideally, these waxes should be
  - easy to carve,
  - should not chip and break at try-in and
  - should boil out without leaving any oily residue.
• **Uses** These waxes are used for the following:
  1. To make occlusion rims
  2. To form the contour of the denture after teeth are set.
  3. To make patterns for orthodontic appliances and other prostheses which are to be constructed of plastics.

• **Classification** (ISO 15854:2005)
  - Type I Soft — for building veneers
  - Type II Hard — to use in mouths in normal climates
  - Type III Extra-hard — for use in tropical climates
PROCESSING WAXES

- **Uses** Used to build up vertical walls around the impression, in order to pour the stone and make a cast. The procedure is known as boxing.

- **Advantages of Beading and Boxing**
  1. Preserves the extensions and landmarks.
  2. Controls the thickness of the borders.
  3. Controls the form and thickness of the base of the cast.
  4. Conserves the artificial stone.

![Boxed impression ready for pouring stone.](image)
STICKY WAX

- **Composition** It consists mainly of yellow beeswax, rosin, and natural resins such as gum dammar.

- **Properties** It is sticky when melted and adheres closely to the surfaces to which it is applied. At room temperature, it is firm, free from tackiness, and brittle.

- **Uses** Used for joining (assembling) metal parts before soldering and for joining fragments of broken dentures before repair procedure.
Shellac was once extensively used in dentistry to fabricate temporary denture bases and custom trays. It is also used for bite registration.

• Heating over flame above 100 °C results in polymerization with release of water (characterized by bubbling). This results in a marked increase in its viscosity (becomes stiffer).

• Manipulation Being a thermoplastic material, it is manipulated by softening with heat to adapt, cut and shape it.

• Drawbacks Again being a thermoplastic material, it is affected by heat and is, therefore, potentially unstable and subject to distortion. It is now largely replaced by resins which are more stable.
**IMPRESSION WAXES**

- Waxes were used widely in the past for making dental impressions. Waxes are highly unstable and susceptible to distortion and are, therefore, not particularly suited for conventional impressions.

- **Uses** It is used as a wax veneer over an original impression to contact and register the details of the soft tissues.

- 1. To make functional impression of free end saddles (Class I and II removable partial dentures).

- 2. To record the posterior palatal seal in dentures.

- 3. Functional impression for obturators.
BITE REGISTRATION WAX

• **Uses** It is used to record the relationship between the upper and lower teeth. This is necessary in order to mount the casts correctly in the articulator.

• **Supplied As** U-shaped rods or wafers.

• **Procedure** The wax is softened in warm water. The soft wax is then placed between the teeth and the patient is asked to bite. After the wax hardens, it is then taken out and placed in chilled water.

• It is replaced back in the mouth and the patient asked to occlude for a final check. The casts of the patient is placed in the indentations formed by the teeth in the wax. It is then mounted with plaster on the articulator. Mounting should not be delayed as wax distortion can lead to inaccurate results.
WROUGHT METALS AND ALLOYS
Wrought metal—A metal that has been plastically deformed to alter the shape of the structure and certain mechanical properties, such as strength, hardness, and ductility.

Cold working—The process of plastically deforming metal at room temperature.

Annealing—The process of controlled heating and cooling that is designed to produce desired properties in a metal. Typically, the annealing process is intended to soften metals, to increase their ductility, stabilize shape, and increase machinability.
All alloys are initially formed by casting. When a cast metal is subject to any deformation, it is considered a wrought metal. Wrought alloys have a fibrous structure which result from the cold working applied during the drawing operation to shape the wire.

Dislocations:

- Face-centered cubic (fcc) structures have the greatest number of slip system. Therefore, metals with a fcc structure like gold, copper, nickel, palladium, silver, platinum, etc. are highly ductile and easy to draw.
- Body-centered cubic (bcc) metal have intermediate levels of ductility.
- Hexagonal close-packed structures (hcp) have the least amount of slip systems and therefore are relatively brittle, e.g. zinc.
Crystalline structure

Crystal lattice examples

- Cubic body centered (bcc): Fe, V, Nb, Cr
- Cubic face centered (fcc): Al, Ni, Ag, Cu, Au
- Hexagonal: Ti, Zn, Mg, Cd

Unit cells

- BCC
- FCC
- HCP

Allotropic characteristics?
Another type of permanent deformation is known as twinning. The deformation occurs along either side of a plane in such a way that it mirrors each other. Twinning is favored over dislocation in metals that have relatively few slip systems.
Fracture Continuation of cold working in a heavily deformed metal eventually leads to fracture. The fracture initiates from microcracks that occur at points where there is an accumulation of dislocations or at boundaries between different microstructural phases.

Alloys can undergo brittle or ductile fracture depending on a variety of factors, such as composition, microstructure and strain rate. When a ductile alloy fractures under tension, there is a reduction in the diameter of the metal (necking down) at the fracture site prior to fracture.
Annealing

- Annealing takes place in three stages
- The time and temperature for annealing is dependent on the melting temperature of the alloy. A commonly observed rule is to use a temperature that is approximately half the melting point of the metal or alloy on the absolute scale (K).
### Recovery

- In the recovery stage, there is a slight decrease in tensile strength with no change in ductility. The most important beneficial changes occur during the recovery phase. The purpose of annealing heat treatment is to relieve these stresses. Maximum stress relief occurs during the recovery stage.

### Recrystallization

- On further heating, changes in the microstructure begin to take place. The deformed grains begin to recrystallize forming new stress free grains. The metal essentially regains its old soft and ductile condition. The metal loses its properties of resilience rendering it useless for its intended purpose. Thus recrystallization must be avoided.

### Grain growth

- In this phase the recrystallized grains continue to grow with larger grains consuming smaller grains. Ceases until a coarse grain structure is formed. There is no significant difference in ductility and tensile strength from that observed in the previous stage.

**Significance** It is clear from the above that annealing should be done only until the recovery stage.
Deformed structure → Grain Nucleation → Recrystallization → Grain Growth
FIGURE 17-12 Tensile strength and ductility of a metal as a function of the percentage of cold work and annealing time. Tensile strength increases and ductility decreases during cold working. These properties change only slightly during recovery. During recrystallization, tensile strength decreases and ductility increases rapidly. Only slight changes occur during grain growth. (Adapted from Richman MH: Introduction to the Science of Metals. Waltham, MA, Blaisdell, 1967.)
Uses of wrought alloys

- Partial Denture Clasp
- Endodontic Files
- Surgical Instruments
- Orthodontic Wires
- Pre-Fabricated Crowns
- Orthodontic Brackets
Orthodontic wires

- Classification: Wires are classified on the basis of their elastic behavior.
- Type 1 wires: Wires displaying linear elastic behavior during unloading at temperatures up to 50 °C.
- Type 2 wires: Wires displaying nonlinear elastic behavior during unloading at temperatures up to 50 °C.
General properties of orthodontic wires

- The following properties are important in orthodontic treatment.

- **Force generated** The force generated by the wire on the tooth is dependent on its composition and design. For a given design, the force generated is proportional to the wire’s stiffness.

- **Elastic deflection** and working range Biologically, low constant forces are less damaging. This is best achieved by a large elastic deflection because it produces a more constant force and has a greater ‘working range’.

- **Maximum elastic deflection** = \( \frac{\text{Proportional limit (PL)}}{\text{Modulus of elasticity (MOE)}} \)
- **Springiness**: It is a measure of how far a wire can be deflected without causing permanent deformation.
- **Stiffness**: Amount of force required to produce a specific deformation.
- **Resilience**: It is the energy storage capacity of the wires which is a combination of strength and springiness.
- **Formability**: It represents the amount of permanent bending; the wire will tolerate before it breaks.
Steel is an iron-based alloy which contains less than 1.2% carbon. When chromium (12 to 30%) is added to steel, the alloy is called as stainless steel.

Passivation Stainless steels are resistant to tarnish and corrosion, because of the passivating effect of the chromium. A thin, transparent but tough and impervious oxide layer forms on the surface of the alloy when it is exposed to air, which protects it against tarnish and corrosion. It loses its protection if the oxide layer is ruptured by mechanical or chemical factors.
Oxygen in the air
Chromium oxide layer
Stainless steel
Chromium oxide layer protects stainless steel
Chromium oxide layer damaged by machining
Chromium oxide layer deformed automatically
TYPES There are three types of stainless steel based on the lattice arrangement of iron.

1. Ferritic

2. Martensitic

3. Austenitic

4. Duplex

5. Precipitation Hardening

1. Ferritic stainless steels: Pure iron at room temperature has body-centered cubic (BCC) structure and is referred to as ferrite, which is stable up to 912 °C.

Properties and Use The ferric alloys have good corrosion resistance, but less strength and hardness. So they find little application in dentistry.
MARTENSITIC STAINLESS STEELS Corrosion resistance of the martensitic stainless steel is less than that of the other types. Because of their high strength and hardness, martensitic stainless steels are used for surgical and cutting instruments.
Austenitic Stainless Steels

- The addition of nickel to the iron-chromium-carbon composition stabilizes the austenite phase on cooling. Type 18-8 stainless steel, which contains 18% chromium and 8% nickel by weight, is the most commonly used alloy for orthodontic stainless steel wires and bands. Austenitic stainless steel is preferable to ferritic stainless steel for dental applications because it has the following properties:

  - **Advantages**
    - Greater ductility and ability to undergo more cold work without fracturing
    - Substantial strengthening during cold working
    - Greater ease of welding
    - Ability to overcome sensitization
    - Less critical grain growth
    - Comparative ease of forming
Properties

- **Sensitization** The 18-8 stainless steel may lose its resistance to corrosion if it is heated between 400 and 900 °C (temperature used during soldering and welding).

- **Stabilization** (methods to minimize sensitization) By stabilization, i.e., some element is introduced that precipitates as a carbide in preference to chromium. Titanium is commonly used. Titanium at six times the carbon content, inhibits the precipitation of chromium carbide at soldering temperatures. These are known as stabilized stainless steels.

- **Annealed and partially annealed wires** When stainless steel wires are fully annealed, they become soft and highly formable. When it is partially annealed, the yield strength is increased and formability decreased. Stainless steel is available in different grades depending on their yield strength. Both the fully annealed and partially annealed wires are used as orthodontic wires.
Braided and Twisted Wires

Very small diameter stainless steel wires (about 0.15 mm) can be braided or twisted together to form either round or rectangular shaped (about 0.4 to 0.6 mm in cross-section) wires. These wires are available as straight lengths or as formed archwires. These braided or twisted wires are able to sustain large elastic deflections in bending, and apply low forces for a given deflection when compared with solid stainless steel wire.
Commercially pure titanium (CP Ti) exists in a stable hcp crystal structure at temperatures below 882 °C and a stable bcc structure above that temperature. These structures are referred to as α-titanium and β-titanium, respectively. The addition of molybdenum stabilizes the bcc β-titanium structure at room temperature and yields an alloy of lower elastic modulus and higher ductility. This means that β-titanium can easily be drawn into wires for orthodontic applications. One commercial alloy has the trade name of TMA (titanium-molybdenum alloy).

MECHANICAL PROPERTIES

The springback (YS/E) for β-titanium wires is much greater than that for the stainless steel. The β-titanium wires can be highly cold-worked and, the wires have high formability, which is comparable to that of austenitic stainless steel, and can be readily bent into various orthodontic configurations.
Welding Titanium alloys are highly reactive with oxygen at high temperature. To prevent the potential reaction of titanium alloys with the oxygen in ambient air during the metal joining process, these procedures are often performed in a vacuum environment. The β-titanium wires are the only orthodontic wire alloy type that demonstrates true weldability, and clinically satisfactory joints can be made by electrical resistance welding.

Corrosion Resistance titanium and its alloys generally have excellent corrosion resistance and environmental stability.