DIPLOMA OF PRIMARY CARE DENTISTRY

-RCSI-

PART – 1

CLINICAL SKILLS

PART 6: <u>DENTAL MATERIALS</u>

✸ DENTAL MATERIALS:

Properties of dental materials:

1. Coefficient of thermal expansion:
- The extent to which a material expands upon heating.
- The fractional increase in length for each degree of temperature increases.
2. Creep:
   - The slow plastic deformation that occurs with the application of a static or dynamic force over time, after the material has set.
3. Elastic modulus:
   - A measure of the rigidity of a material, defined by the ratio of stress to strain (below elastic limit).
4. Fatigue:
   - When cyclic forces are applied, a crack may nucleate and increase by small increments each time the force is applied.
   - In time the crack will increase to a length at which the force results in # through the remaining material.
5. Hardness:
   - Resistance to penetration.
   - A number of hardness scales are in use (Vickers, Rockwell, Mohs').
   - Between these scales, hardness values are not interchangeable.
6. Resilience:
   - The energy absorbed by a material undergoing elastic deformation up to its elastic limit.
7. Stiffness:
   - An indication of how easy it is to bend a piece of material without causing permanent deformation or #.
   - It is dependent upon the elastic modulus, size, and shape of the specimen.
8. Strain:
   - Change in size of a material that occurs in response to a force.
   - It is the change in length divided by the original length.

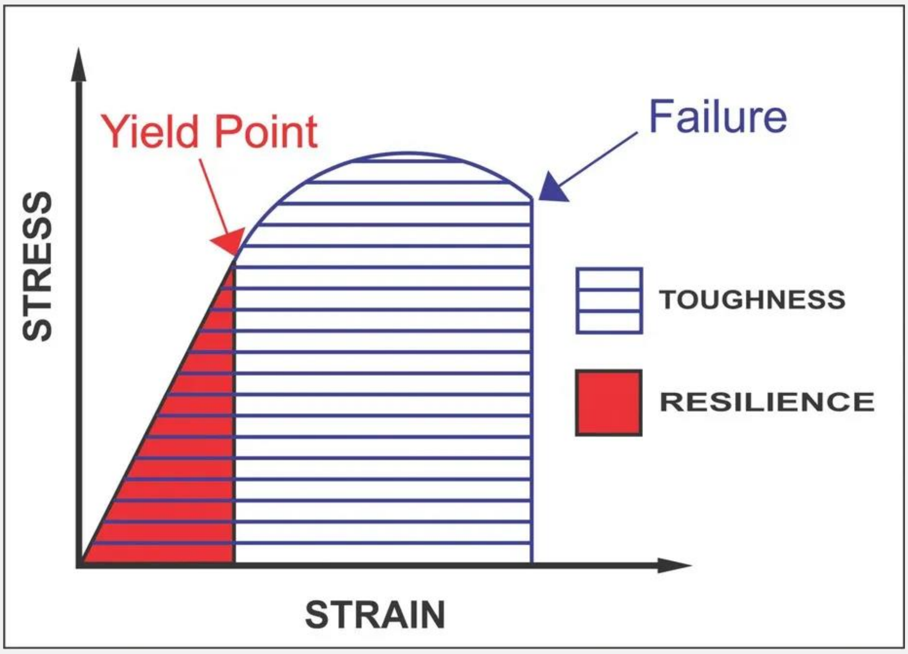
9. Stress:
   - Internal force per unit cross-sectional area acting on the material.
   - Can be classified according to the direction of the force: tensile (stretching), compressive, or shear.

10. Thermal conductivity:
   - Ability of a material to transmit heat.

11. Wear:
   - The abrasion (mechanical or chemical) resistance of a substance.

12. Wettability:
   - Ability of one material to flow across the surface of another, determined by the contact angle between the two materials and influenced by surface roughness and contamination.
   - The contact angle is the angle between solid/liquid and liquid/air interfaces measured through the liquid.

13. Yield strength (Or elastic limit):
   - The stress beyond which a material is permanently deformed when a force is applied.



Restoration of teeth:

1. **Amalgam:**
   - ω Dental amalgam is made by mixing together mercury (Hg) with a powdered silver–tin alloy (mercury around 50% by weight) to produce a soft mass that can be packed into a preparation before setting.
   - ω **Types of amalgam**: There are two ways of classifying amalgam:

a. Particle shape:

- Can be lathe-cut (irregular), spheroidal, or a mixture of the two.
- Spheroidal particles give a more fluid mix which is easy to condense, can be carved immediately, and take 3h to reach occlusal strength (compared to >6h for lathe-cut amalgams).
- Spheroidal amalgams are preferable for pinned restorations.

b. Particle composition:

- The first (conventional) alloys introduced had a low copper content (5%).
- The weakest (Sn–Hg or λ-2) phase of the set amalgam could be eliminated by increase the proportion of copper, so a variety of high copper (10–30%) amalgams have been introduced that react to eliminate it.
- These are more expensive, but superior in terms of corrosion resistance, creep, strength, and durability of marginal integrity.
- There are two types of high-copper alloy:
  - ℵ A single composition alloy of silver–tin–copper: the most resistant to tarnishing.
  - ℵ A blended (dispersion) mix of silver–tin and copper–silver alloys.

➲ **Types of amalgam currently available:**

Table 16.1 Composition of amalgams

	Average composition (%)			
	Silver	Tin	Copper	Zinc
Conventional	68	28	4	0–2
High copper	60	27	13	0

Handling characteristics:

⌘ Mixing or trituration:

- Pre-encapsulated by manufacturer, with automatic vibrator—preferred method.
- Using an amalgamator that dispenses Hg and alloy in correct proportions and mixes them.

⌘ Condensation:

- Carry out incrementally by hand instruments (lathe-cut or spheroidal).
- Preparations should be overfilled so that the Hg-rich surface layer is removed by carving.

⌘ Carving:

- With spherical alloys this can be commenced immediately; burnishing is recommended in an attempt to prevent marginal leakage.

⌘ Polishing:

- Polished amalgams look good, but whether polishing is necessary is still the subject of debate.
- NB: maximum strength takes 24h to develop, so it is advisable to recommend patients do not chew on the restored tooth for this time where possible.

Marginal leakage:

- While amalgam corrosion products will form a marginal seal in time, microleakage can be d by the use of either a conventional cavity varnish (Copalite®) or a bonding agent (Amalgambond® or Panavia-21™) in the interim.
- The latter (an anaerobic resin adhesive) also bonds to set amalgam.
- Alternatively, sealing over the completed restoration with a fissure sealant has been suggested, and this is a possible solution to the 'ditched', but caries-free amalgam.

Toxicity:

- Despite toxicity scares and the introduction of posterior composites, amalgam is still widely used, mainly because of its ease of handling.
- There should be no use of amalgam in the treatment of deciduous teeth, in children under 15yrs or pregnant or breastfeeding women, except when strictly deemed necessary by the practitioner on the grounds of specific medical needs of the patient.
- There is a link between allergy to constituents of dental amalgam and lichenoid eruptions in the oral cavity in certain individuals.

- The greatest actual risk appears to be related to the inhalation of Hg vapour and as such, the dental team as well as patients are theoretically at risk. Attention should be paid to the following:
  - ω Avoid spilling Hg if non-encapsulated system employed.
  - ω Waste amalgam should be stored appropriately to prevent mercury vapour release.
  - ω When removing old amalgams, safety glasses, masks, and high-volume aspiration are a wise precaution.
  - ω Amalgam separation devices should be in use as per Hazardous Waste Directive.

2. Composite resins—constituents and properties:

- The modern composite resin is a mixture of resin and particulate filler, the handling characteristics of which are determined largely by the size of the filler particles and method of cure.
- Constituents:
  - ℵ Resin: Most composite resins are based on either Bis-GMA (addition product of bisphenol A and glycidylmethacrylate) or urethane dimethacrylate plus a diluent monomer, triethylene glycol dimethacrylate (TEGMA).
  - ℵ Filler (quartz, fused silica, glasses such as aluminosilicate and borosilicate.) Confers the following benefits on the composite resin:
    - ω Compressive strength, abrasion resistance, modulus of elasticity, and # toughness
    - ω Thermal expansion and setting contraction.
    - ω Aesthetic qualities.

➲ Composite resins can be subdivided according to particle size:

- Macrofilled (Or conventional.):
  - ℵ Contains particles of radio-opaque barium or strontium glass 2.5–5µm in size, to give 75–80% by weight of filler.
  - ℵ Good mechanical properties, but hard to polish and soon roughens.
- Microfilled:
  - ℵ Contains colloidal silica particles 0.04µm in size and 30–60% by weight.
  - ℵ Retains a good surface polish, but is unsuitable for load-bearing situations, has poor wear resistance, and increase contraction shrinkage.
- Nanofilled:

ℵ By combining nanometric particles and nanoclusters in a conventional resin matrix, manufacturers claim to offer increase wear resistance as well as polishability and lustre.

- Hybrid:

ℵ Contains a mixture of conventional and microfine particles designed to optimize both mechanical and surface properties.

ℵ Contains 75–85% by weight of filler, of which the bulk is conventional (1–50μm).

ℵ Some manufacturers achieve up to 90% filler loadings by using blended sizes of filler particles.

- Packable (condensable):

ℵ Developed to simulate the 'condensation' of amalgam although no decrease in volume as compressed therefore not strictly condensed.

ℵ Resin and ceramic fillers are incorporated into a network of ceramic fibres. Claim to have increase wear resistance and less polymerization shrinkage.

➲ **Initiator/activator:**

- Chemically cured: benzoyl peroxide (or sulfinic acid) initiator + tertiary amine activator.
- Light cured: amine + diketone activated by blue light (460–70nm).

➲ **Other constituents**: these include pigments, stabilizers, and silane coupler to produce bond between particles and filler.

➲ **Composites may also be classified as:**

- Microfilled.
- Posterior composite.
- All-purpose.
- Flowable.
- Condensable/packable.

➲ **Important properties of composites:**

- Polymerization shrinkage of 1–4%.
- Thermal expansion is significantly greater than enamel or dentine, and without an acid-etch bond can result in marginal leakage.
- Elastic modulus should be high to resist occlusal forces.
- Modulus of hybrid type is greater than other composite resins, amalgam, or dentine. However, composite resins are still brittle and # if used in thin section.
- Wear resistance is greatest in hybrids.
- Radio-opacity is particularly useful, especially for posterior resin composites.
- Toxicity: resins have been found to be toxic in cell culture. Also, controversy surrounding the oestrogenicity of composite resins.

➲ **Method of polymerization:**

1. Chemical (self-cure):

- No additional equipment required, but mixing of two components introduces porosity and the working time is limited.

2. Light activation:

- Provides long working time, command set, and better colour stability, but requires a light source, has a limited depth of cure, and the temperature increase during setting can be as high as 40°C.

3. Dual-cure:

- Curing is initiated by a conventional light source, but continues chemically to help ensure polymerization throughout the restoration.

⇒ **Problems with composite resins:**

1. Difficult to obtain satisfactory contact points and occlusal stops. Modern placement techniques have made improvements in this regard, e.g. using sectional contoured matrix bands.
2. Post-operative sensitivity.
3. Polymerization shrinkage.
4. The C-factor (configuration) is the ratio of bonded to unbonded surfaces in a cavity. The higher the C-factor, the more likely the risk of effects of polymerization shrinkage (bond failure, cuspal deflection, post-operative sensitivity).
5. Depth of cure of light-cured materials is limited, this is a particular problem in posterior teeth.

Fissure sealants:

- Composite resins containing little or no filler, which are either self- or light cured.
- Clear or opaque types are available, the former having better flow characteristics (whether this is an advantage depends upon the position of the tooth).
- Success depends upon being able to achieve good moisture control for the acid-etch bond.

Flowable composite resins:

- Predominantly resin with a reduced percentage of filler particles, and consequently shrink considerably on curing.
- RMGIC is preferable in proximal preparations, which are below the cemento-enamel junction (bonded-base approach); however, they have a place in the marginal repair of restorations.
- Flowable technology has led to further developments in the ability to bulk fill with the addition of several new materials such as SDR® flow+ from Dentsply with a 4mm depth of cure.

Dentine-adhesive systems (dentine bonding agents):

- The advantages of bonding to dentine (preservation of tooth tissue) have fuelled considerable research effort.
- The problems that have had to be overcome include the high water and organic content of dentine; the presence of a 'smear layer' after dentine is cut; and the need for adequate strength immediately following placement, to withstand the polymerization contraction of composite resin.
- These difficulties have been approached in a number of ways, making the topic of dentine bonding confusing, a situation that has been exacerbated by the pace of new developments and by the claims of the manufacturers.
- Indications:
  - Marginal seal where preparation margin is in dentine or cementum, e.g. cervical (Class V), proximal (Class II) box.
  - Retention and seal of direct resin-composite restorations.
  - Retention and seal of indirect porcelain and composite inlays.
  - Dentine adhesives have also been used for repairing # teeth, cementing ceramic crowns and veneers, and as an endodontic sealer.

⇒ **The smear layer:**

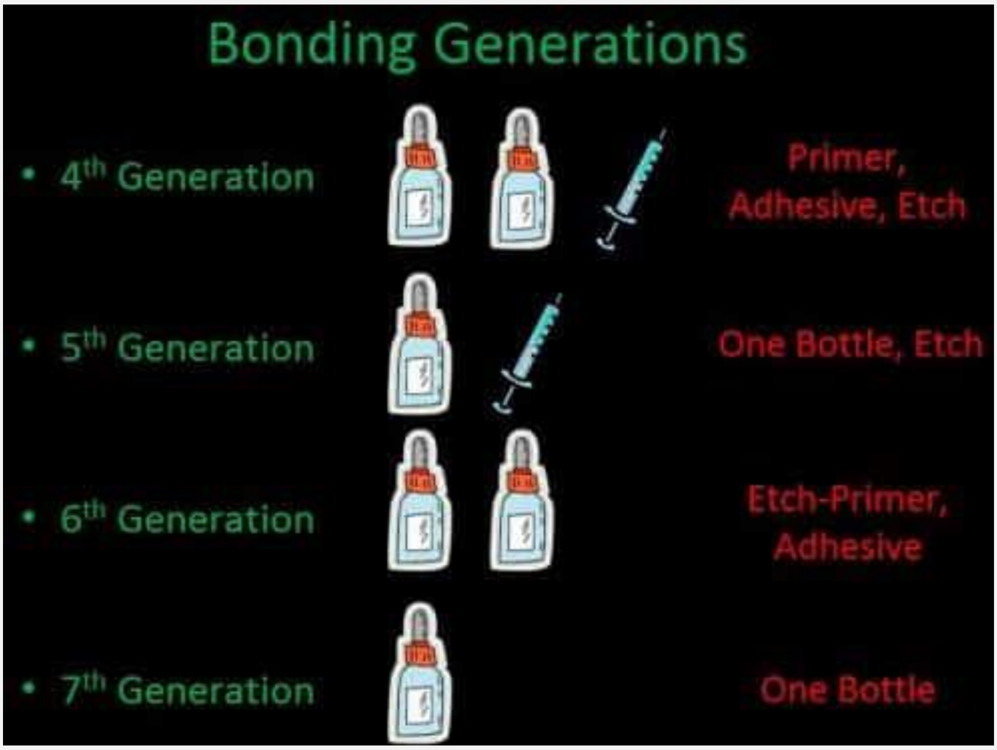
- This consists of an amorphous layer of organic and inorganic debris, produced by cutting dentine.
- It decreased sensitivity by occluding the dentine tubules and prevents loss of dentinal fluid.
- The smear layer is partially or completely removed &/or modified during dentine bonding.

Techniques:

1. Etch and rinse:
   - Three steps (acid etch, primer, and adhesive)—37% phosphoric acid usually used to remove the smear layer and demineralize the surface dentine.
   - A primer is then applied, often containing a solvent such as acetone to eliminate water in the dentine that is then filled by resin tags.
   - Another method is to use an aqueous primer solution. Benefit of ease of use as well as stronger acid etching of the enamel.
   - **Two steps (etchant and primer/adhesive).**

2. Self-etching:
   - ω Two steps:
     - A weaker acid is used to solubilize the smear layer and at the same time act as the difunctional primer (hydrophilic and hydrophobic ends).
     - Second stage is adhesive.
   - ω One step:
     - Self-etching one-step mix. The resin bonding agent is mixed in the same liquid as the etch and primer.
     - Often unidose presentation.
     - Self-etching, no mix 'one-bottle system'.

→ If enamel is present, it is usually better to undertake etch and rinse whereas at the other extreme when dentine only is present, e.g. a crown preparation, then the weaker acid of the self-etching technique may be preferable. Self-etching possibly leads to less post-operative sensitivity.



3. Glass ionomers:

- Setting reaction:
  - Alumino-silicate glass powder + polyalkenoic acid l calcium + aluminium polyalkenoates (base + polyacid l polysalt + water).
  - The set material consists of unreacted spheres of glass surrounded by a silicaeous gel, embedded in metal polyalkenoates. F
  - luoride is uptaken and released from the cement to give theoretical cariostatic properties.

- **Presentation:**
  - Powder + liquid.
  - Powder (with anhydrous acid) + water.
  - Encapsulated.

- Tartaric acid is added to lengthen working time.
- In some products, polymaleic acid replaces polyacrylic and Diamond Carve™ is hand-mixed glass polyphosphonate.
- 'High-viscosity' or reinforced GIs, e.g. GC Fuji IX GP™, are claimed to have improved earlier physical properties and resistance to dissolution.

- **Properties:**

1. Adhesion
2. Cariostatic
3. Thermal expansion
4. Strength Brittle material.
5. Radiolucent
6. Abrasion/erosion resistance
7. Biocompatibility

- **Applications:**

- GIs are unable to match the aesthetics and abrasion resistance of the composite resins, and brittleness limits their use to non-load-bearing situations.
- However, their adhesive and fluoride-releasing properties have resulted in a range of applications and matching formulations.

1. **Type I** Luting cements for crowns, bridges, and orthodontic bands.
2. **Type II** Restorative cements. There are two subtypes:
   a. Aesthetic
   b. Reinforced. Can also be used as a fissure sealant, for the restoration of 1° teeth and for repairing defective restorations.
3. **Type III** Fast-setting lining materials.
   - Defer placement of amalgam for at least 15min and composite for 4min.
   - In load-bearing situations or where lining is exposed to the oral environment (e.g. in sandwich technique), use of a type II reinforced cement or RMGIC is preferable.

4. **Type IV:**
   - Includes the light-cure and dual-cure GI (use of a light source optimizes the properties of the dual-cure materials, although they will self-polymerize without).
   - 3M Vitremer™ is an example of a so-called tri-cure GI where, in addition to the acid–base reaction and the photoinitiated free radical methacrylate cure there is also a further dark methacrylate cure that can occur in the absence of light.
   - Forms of true GI can also be used for fissure sealants, orthodontic cements, core build-ups, and for restoration of deciduous teeth.

Resin-modified glass ionomers:

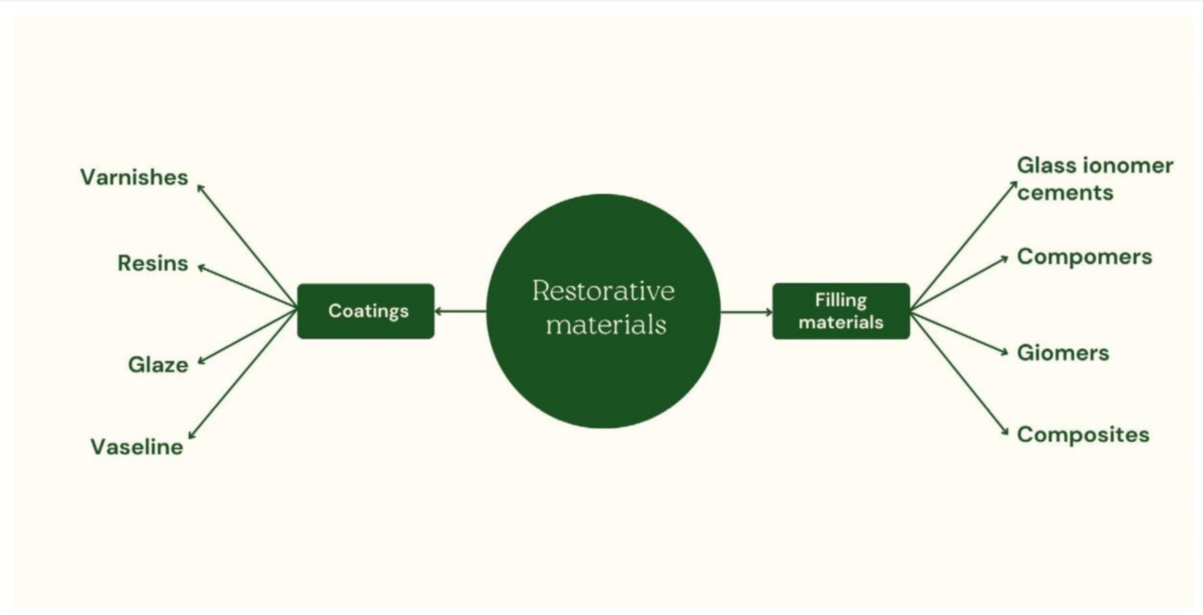
- These allow 'command' setting and help overcome the moisture sensitivity and low early mechanical strength associated with conventional GI.
- The acid–base reaction of GI is supplemented by the addition of 75% resin (hydroxyethyl methacrylate BisGMA).
- The initial set of the material is due to the formation of a polymerization matrix, which is strengthened by the acid–base reaction.
- They are easier to handle than conventional GIs and may be polished immediately after light-curing.
- Aesthetics approach those of resin-based materials, plus the advantage of fluoride release (although this is still of unproven clinical significance).
- These materials can be used in conjunction with composite resin for placement in deep proximal preparation where the deepest parts of the preparation are below the cemento-enamel junction.
- This type of open sandwich restoration fell into disrepute when restorations were placed with traditional GIC. Single-surface glass ionomer restorations have a relatively poor survival of<40% across 10yrs.
- Also widely used as lining materials and luting cements.

Compomer:

- Polyacid-modified composite resin. It combines the adhesive and fluoride-releasing properties of GI with the abrasion resistance of composite resin and is called, with a touch of originality, ‘compomer’.
- Composed of a single hydrophobic resin filled with acid-leachable glass particles. Bonded with a bi-functional primer and light-cured.
- It is claimed that the chemical reaction takes place through uptake of water from saliva leading to fluoride ions leaching out.
- Popular in general practice due to ease of technique and especially useful for restoration of deciduous teeth.

Giomers:

- This group of materials may be described as composite resins with active (GI) filler particles.
- The filler particles are based on pre-reacted surface or fully reacted GI filler particles (S-PRG) whereas the acid–base reaction process occurs after initial setting in acid-modified composites.
- Have been shown to be capable of sustained fluoride ion release in the absence of water (unlike GI and compomers that require water absorption before fluoride recharge can occur).
- Possibly useful for high-caries-risk individuals like Shofu Beautifil II™



Cements:

- Types of cement Based on zinc oxide eugenol (ZOE) Powder of pure zinc oxide is mixed (in a ratio of 3:1) with eugenol liquid to give zinc eugenolate and unreacted powder.
- Setting time is 24hours.
- This is the weakest cement, but the eugenol acts as an obtundent and analgesic, used as a sedative dressing.

1. **Zinc phosphate (DeTrey® Zinc.):**

- ω The powder consists of zinc and magnesium oxides, and the liquid 50% aqueous phosphoric acid.
- ω The working time is increased by adding the powder in small increments.
- ω Popular in the past because of its strength. Although low setting pH theoretically C/I its use for vital teeth, in practice this does not seem to be a problem.

2. **Zinc polycarboxylate (E.g. Poly-F Plus®, DurelonTM.)**

- ω The powder is a mixture of zinc and magnesium oxides and the liquid is 40% aqueous polyacrylic acid.
- ω Anhydrous acid formulations have been introduced, which are mixed with water or encapsulated.
- ω The powder should be added quickly to the liquid.
  Often used as temporary cement where increase adherence required.

3. **Calcium hydroxide**:

- ω Chemically curing types comprise two pastes which are mixed together in equal quantities.
- ω One paste contains the calcium hydroxide plus fillers in a non-reacting carrier, and the other polysalicylate fluid.
- ω The set material consists of an amorphous calcium disalicylate complex plus calcium hydroxide and has a pH of 11.
- ω In addition to being bacteriostatic, calcium hydroxide can induce mineralization of adjacent pulp.
- ω Light-cured formulations which are resin-based are available.
- ω Have decreased bactericidal properties but increase strength.

4. **RMGIC:** This is a popular luting cement used for indirect cast restorations and for cavity lining.

⇒ Strength: Phosphate > EBA or polycarboxylate > resin-bonded ZOE > accelerated ZOE > calcium hydroxide.

- **Choice of cement:**

a. Temporary restorations:

- Choice depends upon how long the dressing needs to last and whether any therapeutic qualities are required.
- Pure ZOE is useful for a tooth with a reversibly inflamed pulp, but resin-bonded ZOE is stronger.
- GI is preferable for semi-permanent dressings and endodontic provisionalization because it seals the preparation margins.

b. Luting cement:

- Zinc phosphate, GI, and polycarboxylate are all popular as luting cements.
- EBA cement is C/I because of increased solubility.
- Composite-based luting systems are often used in conjunction with dentine adhesive systems.
- Mandatory for cementing ceramic or porcelain inlays/onlays and ceramic veneers.
- Now available as one-step luting cements with no etching or bonding required.

c. Lining cement:

- Choice of lining depends upon the depth of the preparation and the material being used to restore it:
  - ℵ Amalgam—minimal: preparation sealer (Gluma® Desensitizer); moderate: RMGIC (Vitrebond™); deep: use a sub-lining of calcium hydroxide (direct or indirect pulp capping) and any of the cements listed. Typically, RMGIC is recommended as it seals as well as lines the preparation.
  - ℵ Composite resin: dentine adhesive system with direct or indirect pulp capping as indicated.

d. Pulp capping: Hard-setting calcium hydroxide or MTA.

e. Sedative dressing: ZOE &/or calcium hydroxide.

f. Bacteriostatic dressing: Calcium hydroxide plus GI (stepwise excavation)

Impression materials:

⇒ Classification:

Table 16.2 Classification of impression materials

	Elastic	
Non-elastic	Elastomers	Hydrocolloid
Compound	Silicone	Reversible
ZOE paste	Polysulfide	Irreversible
Wax	Polyether	

1. **Elastomers:**

ℵ Indicated when accuracy is paramount, like crown and bridge work, and implants.

a. Condensation-cured silicone: These materials are relatively cheap compared with other elastomers, but prone to some shrinkage and should be cast immediately.
b. Addition-cured silicones are preferred, this type of silicone is very stable, which means that impressions can be posted or stored prior to casting.
   - A perforated tray or rim lock tray is advisable as the adhesives supplied are not very effective.
   - Up to five viscosities are manufactured, allowing a range of impression techniques.
   - NB: powdered latex gloves (now rarely used) can retard setting of putty materials.
   - Can also be used for registering occlusion.

c. Polysulfide:
   - Messy to handle, but useful when a long working time is required.
   - Use with a special tray and, although stable, cast within 24h.
   - recommended except in complete denture cases.

d. Polyether (Impregum™)
   - Popular because it uses a single mix and a stock tray.
   - The set material is stiff, although newer products (Penta Soft™) have addressed this and removal can be stressful in cases with deep undercuts or advanced periodontitis.
   - Absorbs water, do not store with alginate impressions.
   - Can cause allergic reactions.
   - Routinely used for implant cases and crown and bridge work, multiple preps.

2. **Hydrocolloids.**

a. Reversible hydrocolloid:

- This is accurate, but liable to tear.
- Requires the purchase of a water bath and is not infection-control friendly.

b. Irreversible hydrocolloid (alginate):

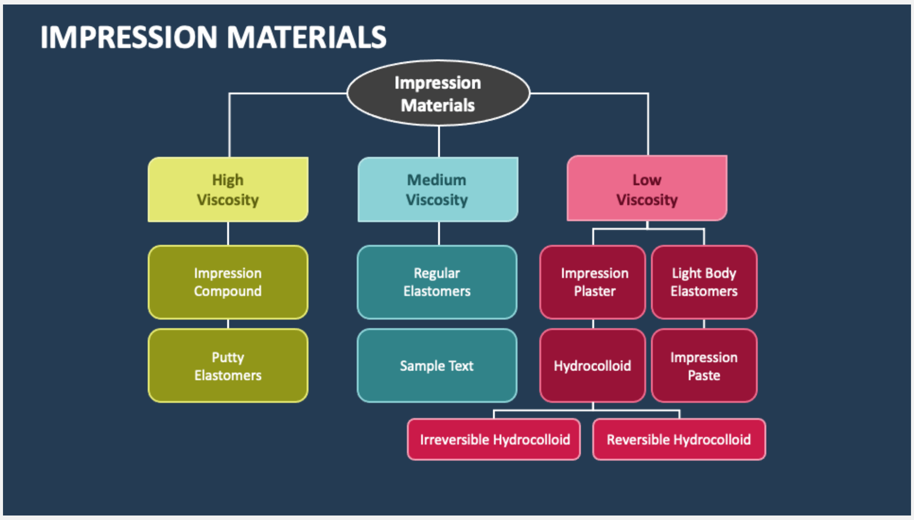
- Setting is a double decomposition reaction between sodium alginate and calcium sulfate.
- Popular because it is cheap and can be used with a stock tray.
- However, it is not sufficiently accurate for crown and bridge work.
- Impressions must be kept damp and cast within 24h.
- Alginate can retard the setting of gypsum and affect the surface of the model.

3. **Impression compound:**

- Available in either sheet form for recording preliminary impressions, or in stick form for modifying trays.
- The sheet material is softened in a waterbath with warm water (55–60°C) and used in a stock tray to record edentulous ridges.
- The viscosity of compound results in a well-extended impression, but limited detail.
- Admix impression material (mix of greenstick and impression compound) is useful for denture cases with severe resorption.

4. **Zinc oxide pastes:**

- Dispensed 1:1 and mixed to an even colour. Used for recording edentulous ridges in a special tray or the patient's existing dentures, but C/I for undercuts.
- Setting time is d by warmth and humidity.
- Fared worse in one particular RCT.



Dental ceramics:

- Ceramics are simple compounds of both metallic and non-metallic oxides.
- Dental porcelain has three basic requirements: function (durability, strength, and biocompatibility), form (ability to form complex shapes), and aesthetics (colour, translucency, and transmission of light).
- Dental ceramics exist in a spectrum from exclusively non-crystalline amorphous glasses through a combination of glass and crystalline mixtures to all-crystalline.
- In general, the 'glassier' the ceramic:
  - High translucence
  - High aesthetics
  - Decrease fracture resistance.

Properties:

- Firing shrinkage 30–40%, crown must be overbuilt.
- Chemically inert provided the surface layer is intact.
- Low thermal conductivity.
- Good aesthetic properties.
- Brittle. The main cause of failure is crack propagation which almost invariably emanates from the unglazed inner surface. This can be d by:
  - Fusion of the inner surface to metal, as in the platinum foil and metal-bonded techniques.
  - The use of a strengthened porcelain core.
- High resistance to wear.
- Glazed surface resists plaque accumulation.

Metal ceramic:

- The porcelains used for bonding to a metal substructure have additional leucite added to increase the coefficient of thermal expansion to almost match the alloys used.
- Porcelain that fuses below the melting point of the alloy is required. Bonding to the metal occurs by a combination of:
  - Mechanical retention.
  - Chemical bonding to the metal oxide layer on the surface of the alloy.

- The greater strength of porcelain bonded to metal crowns allows use in load-bearing areas and is due to:
  - The metal substructure supporting the porcelain.
  - Decrease crack propagation by bonding the inner surface of the porcelain to metal.
  - The outer surface of porcelain being under tension, thus decrease crack propagation.
  - Drawbacks are:decrease aesthetics, gingival staining, over-contouring cervically, and in some patients it may cause allergy.

➲ **<u>All-ceramic alternatives to metal ceramic restorations</u>**:

- Glass ceramic: glasses usually derived from silicon dioxide and with various amounts of aluminium form aluminosilicates or feldspaths.
- With addition of low levels of leucite, they are commonly labelled as feldspathic porcelains.
- With high-leucite variants, extra strength is attained.
- Can be powder-liquid, machined, or pressed.
- A specific popular variant has the usual aluminosilicate glass enhanced with lithium dioxide to give lithium disilicate glass in the form of IPS e.max®.
- The manufacturer claims increase flexural strength as well as increase optical properties via light transmission.
- A further category of dental ceramics is a crystalline system infiltrated with lanthanum glass known as VITA In-Ceram®.
- The final category is the polycrystalline form of dental ceramic: unable to be pressed, the zirconium oxide used in this technique must be oversized initially to compensate for firing shrinkage.
- This is either done by machining an oversized framework for firing (3M ESPE Lava™) or fabrication of an oversized die on which the framework is constructed for firing (Nobel Procera™).
- Porcelain repairs Can be carried out using composite and a silane coupling agent. A number of proprietary kits (Cojet™) are available.

CAD/CAM:

- CAD—computer-aided design.
- CAM—computer-aided manufacture.

Porcelain veneers:

- A thin shell of porcelain or castable ceramic ~0.5– 0.8mm thick.
- Their thin section limits their ability to hide underlying tooth discoloration.
- Amenable to CAD/CAM fabrication. Newer ceramics claim thicknesses of 0.3–0.4mm (e.g. Lumineers™) to be possible without increase fracture.

Porcelain inlays:

- Useful material for specific inlay/onlay treatment indications.
- Only limited long-term studies available.
- Also amenable to CAD/ CAM fabrication.

THE END