The Science of Dental Materials: It studies of mechanical, physical, biological and chemical properties of materials used in dentistry with emphasis on material in correlation with both clinical and non-clinical aspects.

Study of dental material enables the dentist to understand the behavior of these materials and how to use them to their best advantage.

Physical properties :

*A **physical property** is any measurable parameter that describes the state of a physical system.

***Physical properties** determine how materials respond to their environment.

***Physical properties** are based on the laws of mechanics, acoustics, optics, thermodynamics, electricity, magnetism, radiation, atomic structure, and nuclear phenomena.

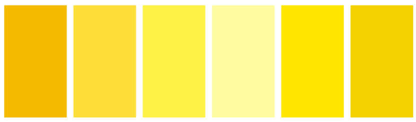
Color and Optical Effects:

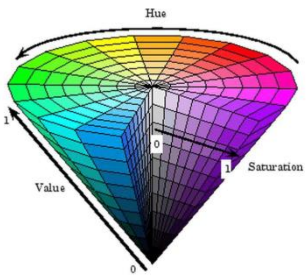
1. **Color**: is a physical property based on the laws of optics.

   i. Hue: The dominant color of an object, for example red, green, or blue. It depends on the wavelength.

   ii. Value: Value is also known as the gray scale. Lighter shades have (higher value) and darker shades have (lower value).

   iii. chroma: is the degree of saturation of a particular hue. For example, the yellow color of a lemon is a more saturated than that of a banana, which is a less saturated. The higher the chroma, the more intense the color.

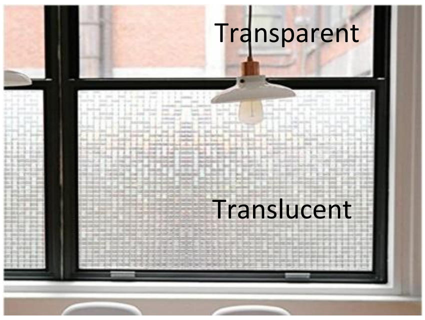




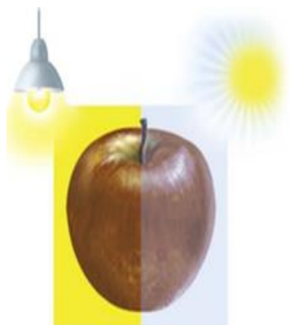
2. **Translucency**: is a property of substances that permits the passage of light but disperses the light only to reveal a distorted image that can be viewed through the material. Enamel is translucent. For acceptable esthetics, the translucency of a composite restoration must be similar to that of tooth structure.

3. **Opacity:** is a property of materials that prevents the passage of light. No image and no light can be seen through an opaque object. The opposite of opacity is translucency.

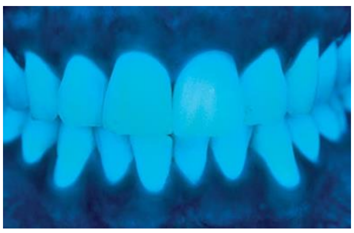
4. **Transparency:** The extent to which light passes through a material and to which an undistorted image can be seen through it. A clear glass window can be described as transparent. A stained glass window is translucent. It is not, however, transparent.



5. **Metamerism:** Phenomenon in which the color of an object under one type of light source (e.g., room light) appears to change when illuminated by a different light source (e.g., sunlight).
   The quality and intensity of light are factors that must be controlled when matching colors in dental restorations. Because the light spectrum of incandescent lamps, fluorescent lamps, and the sun differ from each other, a color match between a restorative material and tooth structure in one lighting condition might not match in another. Whenever possible, shade matching should be done in conditions where most of the patient's activities will occur.



6. **Fluorescence:** is the emission of light by an object at wavelengths different from those of incident light. The emission ceases immediately on removal of the incident light. Sound human teeth emit fluorescent light when excited by ultraviolet radiation. Some anterior restorative materials and dental porcelains are formulated with fluorescing agents to reproduce the natural appearance of tooth structure.



Thermal properties:

1. **Thermal conductivity (κ)**: is the physical property that governs heat transfer through a material by conductive flow.

Materials that have a high thermal conductivity are called conductors, whereas materials of low thermal conductivity are called insulators. The higher its thermal conductivity, the greater the ability of a substance to transmit thermal energy.

The relatively high value of conductivity for dental amalgam indicates that this material could not provide satisfactory insulation of the pulp. For this reason it is normal practice to use a cavity base of a cement such as zinc phosphate which has a lower thermal conductivity value.

2. **Thermal diffusivity(h) :** is a measure of the speed with which a temperature change will spread through an object when one surface is heated.

   There are occasions on which a high value is beneficial. For example, a denture base material, ideally, should have a high value of thermal diffusivity in order that the patient retains a satisfactory response to hot and cold stimuli in the mouth.

Note: both thermal conductivity and thermal diffusivity are important parameters in predicting the transfer of thermal energy (Heat flow) through a material.

Gold has about about 500 times the thermal conductivity, and about 600 times the thermal diffusivity. Thus a pure gold filling would provide the tooth pulp with very little protection against thermal shock compared with natural dentin. The thermal conductivities and thermal diffusivities of cementing materials (glass ionomer, zinc phosphate, and composite) compare favorably with enamel and dentin, in contrast with the markedly higher values for metallic restorative materials. Thus, when the remaining dentin between the cavity and the pulp is too thin to provide sufficient thermal protection, an additional layer of an insulating base material, such as the dental cements, pulp protection, should be placed.

Thermal diffusivity plays a more important role than thermal conductivity clinically.

3. **Coefficient of thermal expansion (α):** 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).

   Tooth structure and restorative materials in the mouth will expand when warmed by hot foods and beverages but will contract when exposed to cold substances. Such expansions and contractions may break the marginal seal of a filling in the tooth, particularly if the difference between the coefficient of expansion of the tooth and the restorative material is large.

   Note: 1. color and thermal expansion are of particular importance to the performance of dental ceramics.

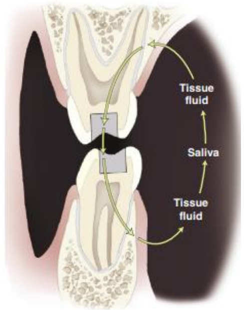
   2. For filling materials, the most ideal combination of properties would be a low value of diffusivity combined with a coefficient of thermal expansion value similar to that for tooth substance.

Electrochemical Properties:

1. **Corrosion**: Chemical or electrochemical process in which a solid, usually a metal, is attacked by an environmental agent, resulting in partial or complete dissolution. In most cases corrosion is undesirable. However, a limited amount of corrosion at the margins of dental amalgam restorations may be beneficial, since the corrosion products tend to seal the marginal gap and inhibit the ingress of oral fluids and bacteria.

2. **Galvanic corrosion (electrogalvanism)** Accelerated attack occurring on a less noble metal when electrochemically dissimilar metals are in electrical contact within a liquid corrosive environment. Example when a gold restoration (cathode) is placed in contact with an amalgam, corrosion of the amalgam (anode) can be expected as a result of the large differences in electromotive force (EMF) of the two materials. The corrosion process can liberate free mercury, which can contaminate and weaken the gold restoration.

3. Pulpal pain caused by an electrical current produced when two dissimilar metals are brought into contact, known as **galvanic shock**. An example would be a dental amalgam restoration placed on the occlusal surface of a tooth directly opposing a gold inlay. Because both restorations are wet with saliva, an electrical circuit exists with a difference in potential between the dissimilar restorations. 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.



4. **Tarnish** is a surface discoloration on a metal or a slight loss or alteration of the surface finish or luster when a reaction with a sulfide, oxide, chloride, or other chemical causes surface discoloration through formation of a thin oxidized film. . In the oral environment, tarnish often occurs from the formation of deposits on the surface of a restoration.

Note: Tarnish and corrosion are electrochemical properties that strongly affect the performance of metals and their alloys.

Rheology is the study of the deformation and flow characteristics of matter under stress, whether liquid or solid.

Viscosity (η) : is the resistance of a fluid to flow. Highly viscous fluids flow slowly.

Thixotropic: Property of gels and other fluids to become less viscous and flow when subjected to steady shear forces through being shaken, stirred, squeezed, patted, or vibrated. When the shear force is decreased to zero, the viscosity increases to the original value over a short time delay.
Dental prophylaxis pastes, plaster of Paris, resin cements, and some impression materials are thixotropic. The thixotropic nature of impression materials is beneficial because the material dispensed from the syringe will maintain a lower viscosity for a while, allowing better wetting of the tissue. The material then stops moving when a state of higher viscosity is regained. This property is important because it takes time for the impression material to adapt to the surface.
For instance, prophylaxis paste does not flow out of a rubber cup until this is rotated against the teeth to be cleaned.

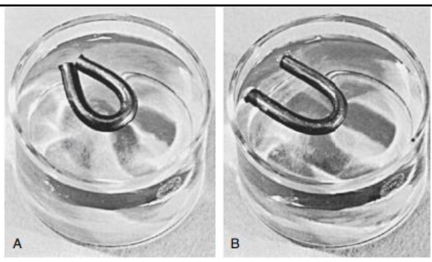
Pseudoplastic material: displays decreasing viscosity with increasing shear stress and recovers its viscosity immediately upon termination of shear stress.
Both pseudoplasticity and thixotropy are shear-thinning processes; the difference is that changes in pseudoplastic viscosity do not exhibit the time dependency characteristic of thixotropy.

Dilatant: Resistance to flow increases as the rate of deformation (shear strain rate) increases. The more rapidly dilatant fluids are stirred or forced through a syringe, the more viscous (thicker) and more resistant to flow they become.
Pseudoplastic character is opposite from dilatant behavior.

Viscoelastic/viscoelasticity: The ability of a material to strain instantaneously like an elastic solid during rapid stretching or to resist shear flow and to strain linearly over time (like honey) when a stress is applied continuously. All elastomeric impression materials are viscoelastic and exhibit both viscous and elastic characteristics.

Structural Relaxation: Structural relaxation is a rheological phenomenon of solids that occurs so slowly that it is not noticed until the process completes.

1. Stress relaxation: is the reduction in stress in a material subjected to constant strain.



A, A stick of inlay wax is bent into the shape of a horseshoe and floated on water at room temperature. B, After 24 hours, the same stick of wax relaxes and becomes distorted.

2.Creep: Permanent (plastic) deformation (increase in strain) under constant load (stress) after the material has set. Creep may cause unacceptable deformation of dental restorations (e.g., low-copper dental amalgam) made from a material that is used clinically at a temperature near its melting point for an extended period.

Dental amalgams contain from 42% to 52% of mercury by weight and begin melting at temperatures only slightly above room temperature. Because of its low melting range, dental amalgam can undergo creep at a restored tooth site under periodic sustained stress, such as would be imposed by patients who clench their teeth. Because creep produces continuing plastic deformation, the process can, over time, be very destructive to a dental amalgam filling.

Flow: flow, rather than creep, has generally been used in dentistry to describe the rheology of amorphous materials such as waxes. By definition, is a measure of the degree of permanent deformation of the material at a given temperature below the melting temperature of the wax. The flow of wax is a measure of the potential to deform under a small static load, which includes its own mass.

Biocompatibility: A material is considered biocompatible if it does not produce harmful or toxic reactions in the tissues it contacts or adverse systemic reactions as a result of elements, ions, and/or compounds it releases.
All materials used in dentistry interact with tissues, producing changes in both the materials and the surrounding tissues; there is no such thing as an "inert material."

Several factors affect the biocompatibility of a material:

1. The chemical composition and structure of the material affect the type and quantities of chemicals released.
2. The characteristics of the site of use also influence a material's biocompatibility. For example, many variables in the oral environment affect the release of components from dental materials. Chemical factors, such as bacterial metabolic products, water, enzymes, and polar and nonpolar solvents, can accelerate the release of components.
3. Mechanical factors in the site of use can also affect the biocompatibility of a material.