Dental materials

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(First two lectures for DR Rababaah)

Definition

Dental materials is an interdisciplinary area that applies biology, chemistry, and physics to the development, understanding and evaluation of the materials used in practice of dentistry.
Involving restorative dentistry, prosthodontics, pedodontics and orthodontics.

History of dental materials

-Hippocrates used to use gold wire ligature
-filling of carious teeth involved using Lint, Lead (which was soft and they later knew that it caused lead poisoning) and also cadaver.
-They also used animal tooth as a replacement.
-In the middle ages, the muslim scientists, الزهرواي و الرازي, added a lot to dentistry. They invented dental tools that are still being used till now.
Al razi is considered one of the greatest people who wrote about and practiced dentistry in Arabs. Al zahrawi was ranked as the first dental surgeon.
- lost wax technique (making dentures from wax models) began in 1558 by Benvenuto Cellini
-In 1744 Duchateu makes the first recorded porcelain denture. (As written in the book)
-In 1808 Giuseppangelo Fonzi, an Italian dentist, was the first to imbedded the porcelain tooth, holding it in place.
-In 1826, Taveu was the first to prepare amalgam filling (silver and mercury paste)
-In 1839, The first dental journal was published: *American journal of Dental science*
-In 1844, Horace Wells discovered the anesthetic effect of nitrous oxide, more commonly known as ''laughing gas'', leading to painless extraction of teeth.
** refer to chapter 1.2 in the book for more about dental materials history. You can also refer to table 1.2.1 in the same chapter :)

Why do we need to Study dental materials?

Some animals like Hyena or Crocuta Crocuta, can crush their preys bone and chew them up to bite sized pieces, making their teeth very strong and resistant to change in environmental factors.
However that's not the case for human teeth, they are affected by the oral environment including: Temperature, Saliva and fluids, Micro-organisms, and occlusal forces. Making human teeth more susceptible to damage.
And as dentists, we need to study dental materials that are needed to replace or fix damaged tooth/teeth to restore normal function (chewing), and good appearance (for self esteem, beauty and confidence).

The aspects in which we study DM

-Composition
-Properties
-Selection

Interaction of DM with Human body is either local or systemic
1) Positive interaction (ex: Titanium Implants)
2) Negative interaction (ex: Chemical burn from acid etch and amalgam tattoo from amalgam filling)

Dental treatment phases:

Examination >> Diagnosis >> Prevention >> Rehabilitation >> Stabilization

DM covers all aspects of existing dental practices, including:
-Restorative Sciences
-Diagnostic Sciences
-Surgical Sciences
-Preventive Sciences

Restorative Materials

Classified into:

1) Direct and indirect

#Direct: reaction needs to take place while in contact with the tooth during restoration.

-Heat and by products of direct restorative materials doesn't damage the tooth/patient (this limits strength of material as harder material needs more energy)

example: amalgam, composite, glass ionomer cement

#Indirect

including porcelain (ceramic), gold and composite

2) Temporary and permanent

Temporary RM are used to improve patients comfort, provide sedative effect or as a short-term restoration before placing the permanent restorative material

3) Fixed and Removable

Types of restorative materials:

-Amalgam (silver-mercury paste)

-Composite

-Acrylics Polymers

-Restorative metals

  > Precious alloys (gold based / palladium based)

  > Non-precious alloys (cobalt-chromium / Titanium)

-Impression Materials (used to record the shape of the teeth and alveolar ridges)

* refer to pictures in the slides

How can we select the appropriate DM?

By evidence based approach including:

-systemic review

-Randomized controlled clinical trials (Interventional)

-Controlled clinical trials

-Observational clinical studies (Retrospective)
-Tissue scaffolding studies
-Follow up studies of material longevity
-Animal Experiments
-Physical and mechanical properties data (laboratory studies)

Quality Control

specific bodies for testing and approval of Dental materials include:
>ISO standards
>ADA
>CE certified

Mechanical Properties of DM

As dentists we must understand the main mechanical properties of dental materials which are relevant to the current dental practice.

Occlusal Forces

-Average occlusal forces for fully dentate patients is 150N in the anterior region and 500N in the posterior region
-Maximum occlusal force is 3500N
-The occlusal forces of edentulous (no teeth) patients is 22.5N in anterior region and 75N in the posterior region. (15% the force exerted by dentate persons)

Bulk properties

They are intensive physical properties that doesn't depend on the system size of amount of material in an object (Ex: Temp, density, hardness, elasticity, stress, strain)

1) Stress

-A force exerted on one body that presses on, pulls on, pushes against, or compresses another body
-Stress is an internal force that resists an externally applied load
- It is the force divided by the perpendicular cross sectional area over which the

force is applied.

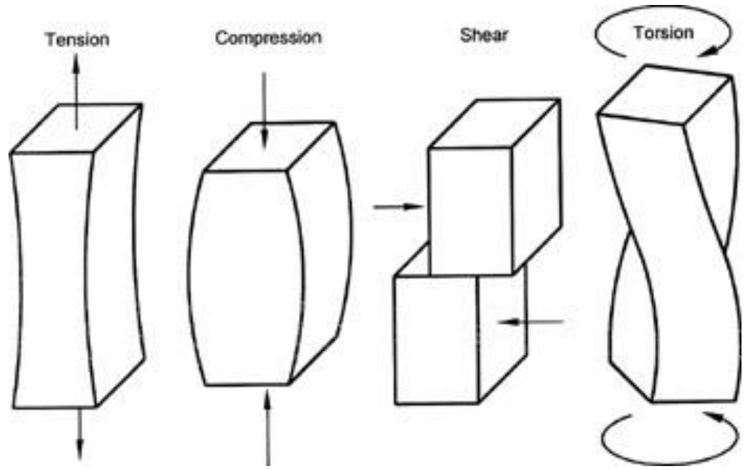
-$\sigma = \frac{Force}{Area}$

-Units: N/m^2 = Pascals

-Types of stresses:

> Axial: compressive/ Tensile

> Non-Axial: Shear/ Torsion/ Bending



2) Strain

-change in length when a stress is applied

-stress = change in length/original length

- $\varepsilon = \frac{L_1 - L_0}{L_0}$

- Strain has no units

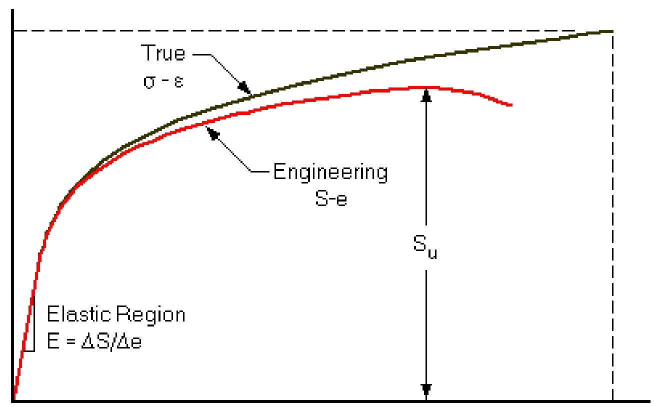
Stress-Strain Curve

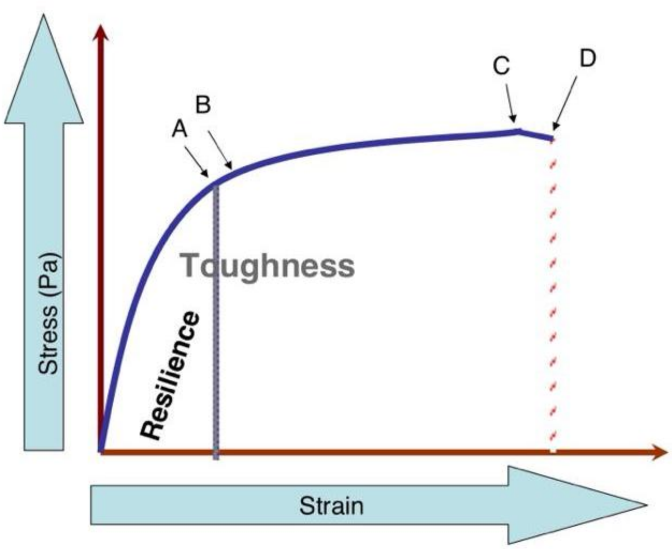
1)Engineering stress-strain curve

stress=force/original constant area

2)True stress-strain curve

stress=force/ variable instantaneous area





A: Proportional limit/ Elastic limit

B: Yield strength

C: Ultimate Tensile strength

D: Fracture strength

Area under elastic region: Resilience

Area under whole graph: Toughness

Slope of Curve: Elastic modulus

Terms related to the Curve:

- Proportional limit (also called elastic limit) is the greatest stress that a material will reach without being permanently deformed. The region below the curve up to this point is called the elastic region (as it returns to its original shape when force is removed) and the area of this region is called the Resilience.

-**Resilience** is the resistance of a material to permanent deformation. (unit: Joules/m^3)

-**Yield strength** is the stress at which a material exhibits a specified limiting deviation from proportional limit. It indicates a degree of permenant deformation (usually 0.2%)

**NOTE: In the book this definition is given to what's called "proof stress" and Yield strength is defined as the stress at which plastic deformation begins! (اختر ما شئت, أنا بيري ذمتي P:)

-Ultimate Tensile/Compressive strength is the maximum stress that a material can withstand before failure/ fracture. (still no fracture)

It gives an indication of the needed thickness of the restoration materials before failure.

-Fracture Strength is the stress at which the material Fractures.

-**Elastic modulus** (also known as Young's Modulus) is a measure of stiffness of a material

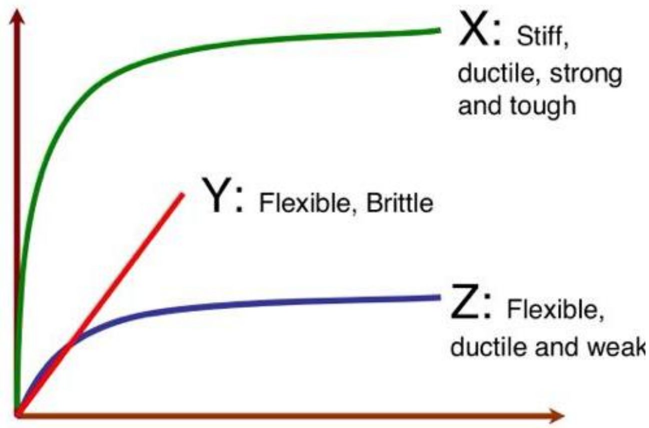
E = $\frac{\text{Stress}}{\text{Strain}}$ Unit: N/m^2

-**Toughness** is the resistance of a material to fracture

-Fracture toughness is the amount of energy required for fracture. It's the ability of a material to resist the propagation of a sudden performed crack.

Sudden crack/break/fracture happens in: glass, ceramics, and dental amalgam.

Stress -strain curves for materials with different properties.



Poisson's ratio

When a material is compressed in one direction, it usually tends to expand in the other two directions perpendicular to the direction of compression. Conversely, if the material is stretched rather than compressed, it usually tends to contract in the directions transverse to the direction of stretching. This phenomenon is called the Poisson effect. Poisson's ratio (ν)is a measure of this effect. It is the negative ratio of transverse to axial strain within the elastic range.

$$\nu = -\frac{\varepsilon_{trans}}{\varepsilon_{axial}}$$

Ductility and malleability

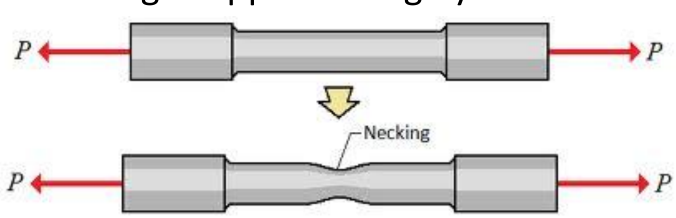
Ductility: The ability of a material to be plastically deformed under tensile stress (ability to be stretched into thin wires)

- Represented in percentage elongation.

-The amount of plastic strain produced in the specimen at fracture

-example of ductile metal is mild steel

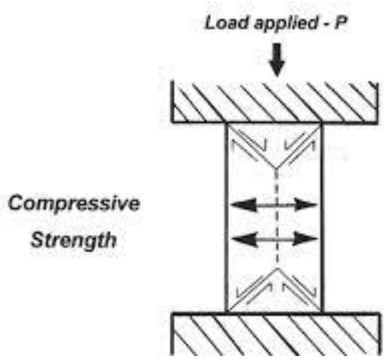
- ''necking'' happens in highly ductile material

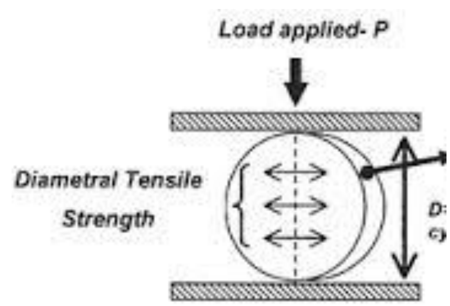


Malleability: The ability of a material to be plastically deformed under compressive stress (ability to be hammered or rolled into thin sheets)

Tests

1) Compression Test & Diametral compression test: mainly performed for brittle dental materials (since these materials are only used under conditions of compressive loading)



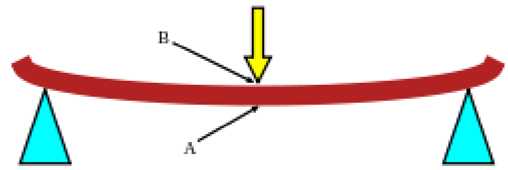


2) Tensile test: a sample of material is stretched in an unaxial direction in a tensile tester under a constant strain
3) Hardness test: the resistance of a material to scratching or abrasion, by measuring its resistance to an indenter or cutting tool
4) Impact test: test the resistance of a material to sudden application of load
5)Fatigue test: subjecting the sample to cyclic loading for a range of loads
6) Bond strength test: determines the stress required to rupture a bond formed by an adhesive between two metal blocks (between two dental materials). Often, the test involves the measurement of the shear or tensile bond strength.
7) Creep test: material can deform permanently under a constant stress which may be much below the elastic limit. A time dependant deformation of materials is known as creep and will eventually lead to fracture of the material. (used for study of new amalgam materials)

Transverse Strength

Also known as Flexural strength, modulus of rupture, bend strength, or fracture strength, a mechanical parameter for brittle material, is defined as a material's ability to resist deformation under load.

The transverse bending test is most frequently employed to measure the transverse strength, in which a specimen having either a circular or rectangular cross-section is bent until fracture.



Fatigue strength

-Materials are subjected to fluctuating stresses rather than static loads. The gradual accumulation of minute amounts of plastic strain produced by each cycle of fluctuating stresses is known as fatigue.

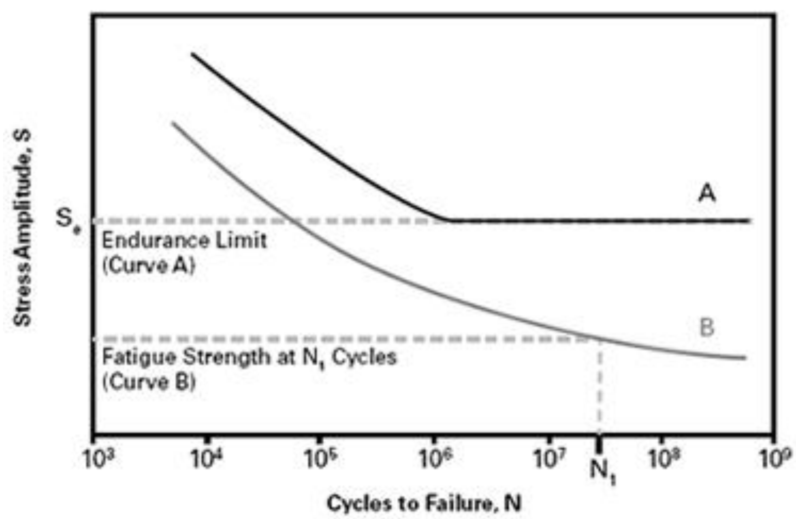
-Fatigue can lead to failure at stresses well below the yield stress of a material.

- Fatigue strength is the value of stress at which failure occurs after *n* number of cycles

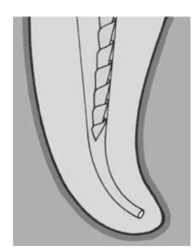
-Two forms of behaviors can be observed when applying the fatigue test:

1) For some materials, as the number of cycles of loading is increased, the allowable stress decreases.

2) In other materials, there is an endurance limit, which is a level of stress below which the material can be subjected for an indefinite number of cycles without fracturing



-Bending and torsion is an important property of dental materials that should be taken into consideration, especially in Endodontic files and reamers used in root canal treatment. (We don't want the material to break inside the root canal)



Physical Properties

Viscoelasticity

- a behaviour intermediate between an elastic solid and a viscous fluid
- The viscous fluid prevents the elastic material from responding elastically with the load, and prevents it from returning to its unstrained state when the load it removed.
-important for elastomeric impression materials
note: it's also important for impression materials to have a high tear resistance (tear strength).

Viscosity

- the resistance of a fluid to flow
-example: water has very weak bonds & flows easily (low viscosity)
-high molecular weight polymers have high viscosity
-viscosity=$\frac{shear\ stress}{shear\ rate}$
-shear stress happens when we stir a liquid, and shear rate is the of the degree of vigour at which we stir.

-unit of viscosity $Nm^{-2}s^{-1}$ = Pascal seconds
- The science that study the viscous behaviour of fluid like material is called rheology. (The study of flow of materials)
-for fluids, flow is measured by viscosity, while for solids we consider viscoelasticity.

Viscous Fluids behaviour

1) Newtonian behaviour: linear relationship between shear stress and shear rate
2) Dialiant behaviour : as shear rate increases, viscosity increases (i.e. stirring faster will make is harder to stir)
3)Pseudoplastic behaviour: as shear rate increases, viscosity decreases (i.e. stirring faster will make it easier to stir)

4) Plastic behaviour: will not flow until an initial shear stress is reached
5) thixotropic behaviour: the viscosity of an increasing shear rate, is different from the viscosity of a decreasing shear rate >> **Hysteresis.**
It happens due to molecular rearrangements caused from lack of time for molecules to return to their normal arrangement after mixing before the next cycle of fluid mixing begins.

Surface Mechanical Properties

Indentation hardness (Hardness test)

-Measures the resistance of a material by an indenter or cutting tool by pushing it into the surface of the material. It gives an indication of the resistance of material to scratching or abrasion.
-There's a correlation between hardness of material and its ultimate tensile strength
- The indenter must be harder than the material being tested
- The indenter can be a shape of a:
1) ball (Brinell hardness test)
2) pyramid (Knoop hardness test)
3) 136 degrees diamond pyramid (Vickers hardness test)
3) metal cone (Rockwell hardness test)

Wear

-Loss of material due to contact between two surfaces
-Types of wear:
1. Adhesive wear (due to frictional contact)
2. Corrosive wear (performed by chemical reaction rather than mechanical)
3. Surface fatigue wear (material is weakened by cyclic loading -micro cracks)
4. Abrasive wear (when a hard surface moves across a soft surface)

Stress analysis

By:

-Lab based studies

-photo elasticity (accurate picture of stress distribution)

-Finite element Analysis (numerical technique of analysis)

Surface phenomena:

-Atoms and molecules at the surface are different from those to the bulk. This is because the atoms at the surface are exposed to the external atmosphere

- for example in steel, there is a surface oxide layer (rust), due to exposure of the surface to air.

- stainless steel is corrosion resistant; doesn't rust.

How to characterize a surface?

- X-ray photo emission spectroscopy
- Electron spectroscopy
- Auger electron spectroscopy

Colloidal systems

-Two or more phases with one highly dispersed on the other

-Types:

1. Gels: Entangled framework of solid colloidal particles in which liquid is trapped (dispersion medium is solid and dispersed phase is liquid)

Example: Agar

2. Sols: Dispersion medium is liquid and dispersion phase is solid

Example: Blood

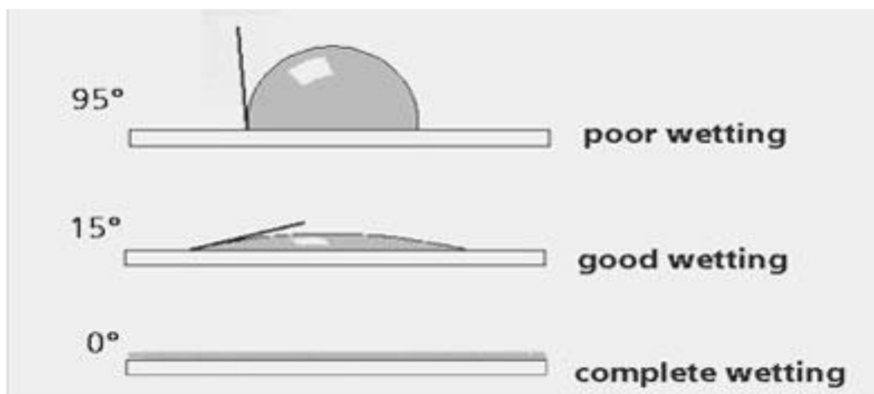
3. Emulsions: A uniform dispersion of minute droplets of one liquid into another with the aid of an emulsifier (dispersion medium is liquid and dispersion phase is liquid)

Ex: milk, Hand cream

Surface Tension and Wetting

-Surface tension is the surface energy in liquids
-one of the effects of surface tension is the tendency for a liquid to take a spherical shape in preference to any another shape, as taking a spherical shape would cause a minimal surface area of contact and thus minimum surface energy.
-Wetting is the ability of a liquid to cover a surface. Good wetting is covering the surface completely.
- These two properties are important for dental adhesives that are placed between two materials (substrates) to make them stick together.
- Contact angle is the angle between a solid surface and a liquid surface, which depends on surface tension of liquid and surface energy of solid.

-Perfect/complete wetting is when the contact angle is zero (surface is completely covered with adhesive and maximum bond strength is achieved)



-The higher the surface tension of a liquid, the more spherical shape it takes and the less the wetting.
- surfactants are used in restorative dentistry to lower the surface tension and thus achieve a smaller contact angle and better wetting.

Adhesion

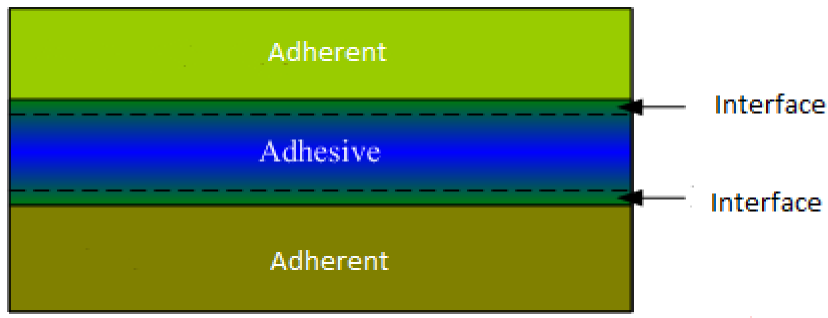
It's the bonding between dissimilar materials by either:
1)chemical bonding (true)
-Ionic/covalent/ hydrogen bonding
2)mechanical bonding (retention)

- mechanical interlocking due to surface irregularities (ex: adhesive penetrates into pits/pores)

>Example of good adhesion: glass + water

>Example of poor adhesion: two solids (since contact would be at small points only)

#Since adhesion between solids is poor, an adhesive is used as a third substrate between the two solids/substrates/adherents. The contact between the adherents and the adhesive is described as the interface.



Optical properties

- There are three primary colors: Red, Blue, Green

(They are only 3 since the human eye is **tri**chromatric)

-The american artist A.H munsel came up with a method of describing colors: Hue, Chroma, and Value

<u>**1)** Hue</u>

-represents the dominant color of the light spectrum (Basic color)

<u>**2)** Chroma</u>

- represents the strength of hue

-how vivid a color is (colorfulness or saturation)

<u>**3)** Value</u>

- brightness or darkness of an object

Hue and Chroma are properties of the object, while Value depends on the incident light hitting the object.

Metamerism
The fact that objects can change color under the influence of different light sources is called **Metamerism.** And that's because objects have different light reflecting properties.
(For example: two objects may appear the same color under one light source, and then when viewed under another light source they appear different).

Fluorescence
Fluorescence is the emission of light by a substance that has absorbed light or other electromagnetic radiation.
- Enamel is naturally florescent. Therefore, if a the material used in construction restoration doesn't have a fluorescent property, then the tooth would look dark in comparison to the naturally fluorescent tooth.

Transparency and Translucency
-Transparent material allows light to pass through it with little distortion that an object would be seen clearly through it
-Translucent material allows some light to pass and absorbs, scatters and reflects the rest. Therefore, an object viewed through it would have a distorted appearance.

Thermal properties

-Specific heat capacity (energy needed to raise temperature)
-Latent heat of fusion (energy needed to change the state)
-Thermal diffusivity: heat transfer
(ex: water has low diffusivity >> good heat insulator)
-linear coefficient of thermal expansion (the change in length due to change in 1˚C in temperature)
In ideal cases the restorative material has an identical coefficient of thermal expansion to the tooth. Otherwise, change in temperature would lead to different changes in length in the tooth and the material, leading to instability of

the material in its position.

- **Glass transition** is the reversible transition in amorphous materials (non-metallic structures; glasses polymers) from a hard and relatively brittle state into a molten or rubber-like state.

The transition is not itself a phase transition of any kind; rather it is a laboratory phenomenon.

The glass-transition temperature lies over a wide range of temperatures and is always lower than the melting temperature of the crystalline state of the material.

Electrical properties

-Galvanism is an induction of an electrical current.

Dental galvanism occurs due to the presence of two or more dissimilar metals in dental restorations that are bathed in saliva. It might be strong enough to irritate the dental pulp and cause sharp pain.

-Galvanism might cause electrochemical corrosion as oxidation is facilitated in the presence of electron acceptor.

Note: This summary is written with reference to the slides and the topics mentioned there. It doesn't include all the chapters in the book.

يعني أنا ما إلي دخل إذا بالامتحان إجا إشي زيادة من الكتاب :P

ولا تنسونا من الدعاء :)

Good Luck ^_^