Mechanical Properties:

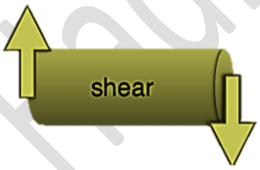
Force: is the interaction of one object with another during actions of push or pull, and the quantity of force is measured using the unit of newton (N).

Stress (σ): Force per unit area within a structure subjected to a force; depending on the direction of force relative to the object, there are tensile, compressive, and shear stresses.
The unit of stress is N/m^2 and is known as a pascal (Pa).

1. Tensile Stress: Two forces applied away from one another in the same straight line.

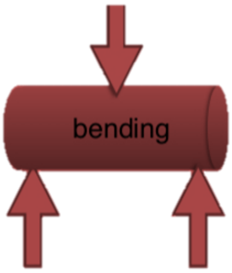
2. Compressive Stress: Two forces applied toward each other in the same straight line.

3. shear stress: Two forces applied toward one another but not in the same straight line.



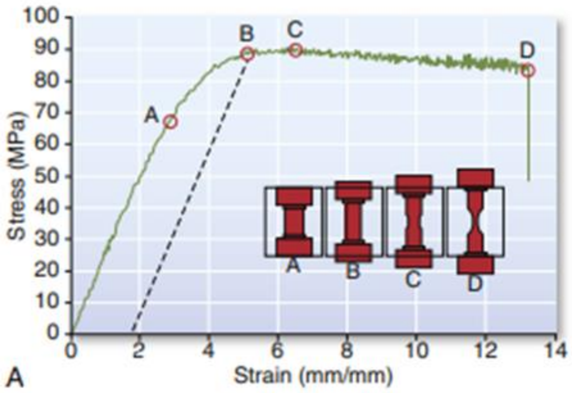
4. Torsion results from the twisting of a body.

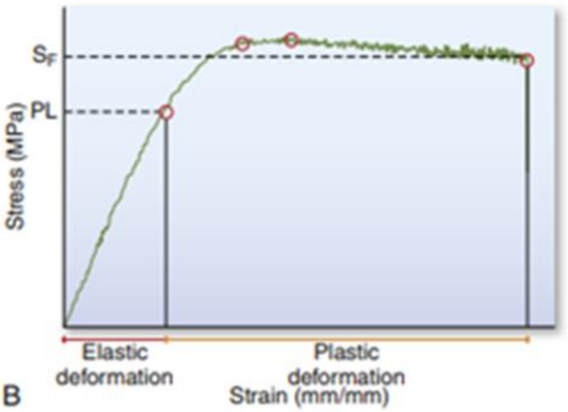
5. Bending or flexure results from an applied bending moment.



Strain (ε): is changing shape or dimension of the material in response to force.
Whenever there is a stress applied on a material, the material should exhibit a corresponding strain.
*Elastic strain is a form of strain in which the distorted body returns to its original shape and size when the deforming force is removed (reversible deformation).
*Plastic strain is a form of strain in which there is a permanent distortion of the material (irreversible) when the deforming force is removed.
The deformation from a tensile force is an elongation in the axis of applied force, whereas a compressive force causes compression or shortening of the body in the axis of loading.
Strain is an important consideration in dental restorative materials, such as orthodontic wires or implant screws, in which a large amount of strain can occur before failure. Wires can be bent and adjusted without fracturing.
Strain is also important in impression materials, where the material needs to recover without permanent distortion when removing it from hard tissue retentive areas.

Proportional and Elastic Limits: In stress-strain curve for a hypothetical material subjected to increasing tensile stress until failure ,stress is plotted on the Y-axis while strain is plotted on the x-axis. As the stress is increased, the strain is increased. In the initial portion of the curve, from 0 to A, the stress is linearly proportional to the strain. As the strain is doubled, the stress is also doubled. After point A, the stress is no longer linearly proportional to the strain. Hence the value of the stress at A is known as the proportional limit (S_{PL} or σ_{PL}), defined as the highest stress at which the stress-strain curve is a straight line; that is, stress is linearly proportional to strain. Below the proportional limit, no permanent deformation occurs in a structure. When the force is removed, the object will return to its original dimensions. Below the proportional limit, the material is elastic in nature. The region of the stress-strain curve before the proportional limit is called the elastic region.
When an object experiences a stress greater than the proportional limit, permanent or irreversible strain occurs. The region of the stress-strain curve beyond the proportional limit is called the plastic region. This characterization refers to linearly elastic materials such as many metals in which the relation between stress and strain is linear up to the proportional limit, and nonlinear thereafter. There are exceptions to this general rule, however. Materials described as super elastic exhibit nonlinear elastic behavior; that is, their relationship between stress and strain in the elastic region does not follow a straight line, but removal of the load results in a return to zero strain.





The elastic limit (S_{EL} or σ_{EL}) is defined as the maximum stress that a material will withstand without permanent deformation. For linearly elastic materials, the proportional limit and elastic limit represent the same stress within the structure. While is superelastic materials the two terms differ in fundamental concept; one deals with the proportionality of strain to stress in the structure, whereas the other describes the elastic behavior of the material.

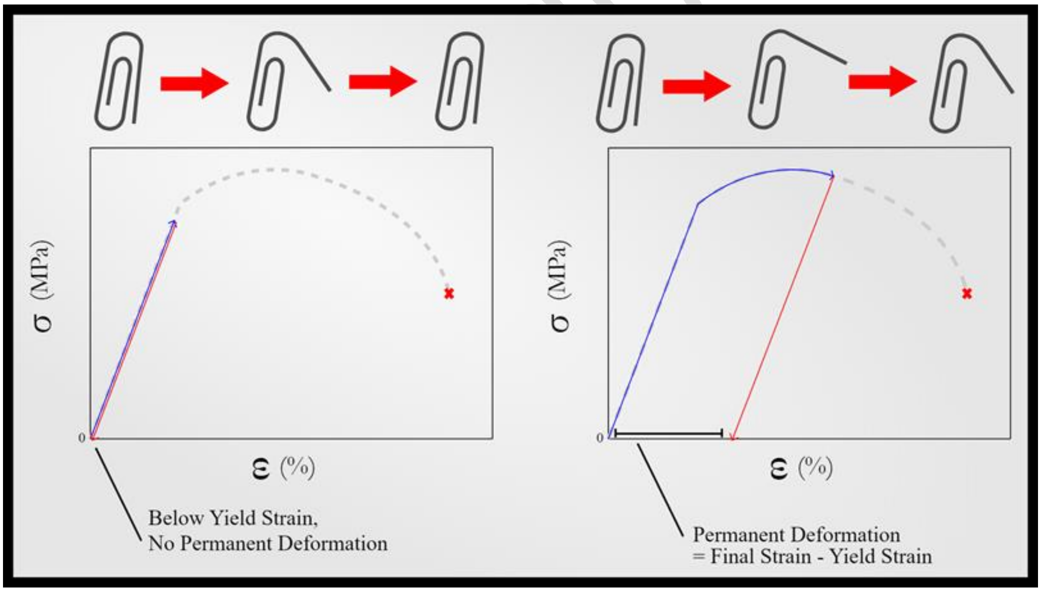
*When the stress is less than the proportional or elastic limit, the strain is reversible (elastic deformation)

Whereas

*When the stress is greater than the proportional or elastic limit, there is an irreversible or permanent strain in the object (plastic deformation).

The yield strength is defined as the stress at which a material deforms plastically and there is a defined amount of permanent strain. (point B in the curve)

This yield stress is slightly higher than that for the proportional limit because it includes a specified amount of permanent deformation. Note that when a structure is permanently deformed, even to a small degree (such as the amount of deformation at the yield strength), it does not return completely to its original dimensions when the stress is removed. For this reason, the elastic limit and yield strength of a material are among its most important properties because they define the transition from elastic to plastic behavior.



Imagine a patient biting on a bolus of food, as shown exerting enough load to generate tensile stresses at the area noted as tension of the bridge alloy. As the patient gradually applies the load, the tensile stress in these areas will increase proportionally to the magnitude of the load applied. If the stress generated is below the elastic limit and up to the proportional limit, the removal of the load will always result in an elastic recovery of the bridge from the slight bending that occurs. If the patient at any time exerts a load that creates stresses in the tension area that are equal to or exceed the elastic limit of the material used, the bridge will be permanently deformed, and then break. Accordingly, one must choose materials with adequately high elastic limits for the construction of a dental bridge. If the size of the connector is too small, greater tensile stress is generated. A properly designed restoration is also important.

Any dental restoration that is permanently deformed through the forces of mastication usually loses its functionality to some extent. For example, a fixed partial dental prosthesis (such as a three-unit prosthesis) that is permanently deformed by excessive occlusal forces would exhibit altered occlusal contacts. The restoration is permanently deformed because a stress equal to or greater than the yield strength was generated. It is important to remember that dysfunctional occlusal loading also changes the stresses placed on a restoration. A deformed restoration may therefore be subjected to greater stresses than originally intended because the occlusion that was distributed over a larger number of occlusal contacts may now be concentrated on a smaller number of contacts. Under these conditions, fracture does not occur if the material is able to plastically deform. However, this permanent change in shape represents a destructive example of deformation.

Permanent deformation and stresses in excess of the elastic limit are desirable when shaping an orthodontic arch wire or adjusting a clasp on a removable partial denture. In these examples, the stress must exceed the yield strength to permanently bend or adapt the wire or clasp.

Elastic deformation occurs as the wire or clasp engages and disengages a retentive region in the cervical area of the tooth. Retention is achieved through small-scale elastic deformation. This elastic or reversible deformation describes the function of elastic bands, clasps, o-rings, and implant screws.

The ultimate tensile strength or stress (UTS) is defined as the maximum stress that a material can withstand before failure in tension (point C in the curve), whereas the ultimate compressive strength or stress (UCS) is the maximum stress a material can withstand in compression.

The yield strength is often of greater importance than ultimate strength in design and material selection because it is an estimate of when a material will start to deform permanently.

Fracture strength or fracture stress (S_F or σ_F): The stress at which a brittle material fractures (point D in the curve).

Elongation: The deformation that results from the application of a tensile force is elongation. Elongation is extremely important because it gives an indication of the possible manipulation of an alloy.

The elongation of a material during a tensile test can be divided conveniently into two parts:

(1) the increase in length of the specimen below the proportional limit (from 0 to A), which is not permanent and is proportional to the stress; and

(2) the elongation beyond the proportional limit and up to the fracture strength (from A to D), which is permanent.

Total elongation is commonly expressed as a percentage.

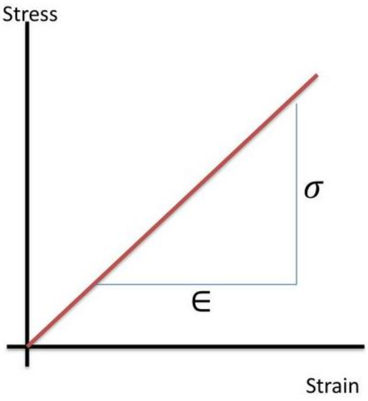
Total elongation includes both the elastic elongation and the plastic elongation. Plastic elongation is usually the greatest of the two, except in materials that are quite brittle or those with very low stiffness.

A material that exhibits a 20% total elongation at the time of fracture has increased in length by one-fifth of its original length. Such a material, as in many dental gold alloys, has a high value for plastic or permanent elongation and, in general, is a ductile type of alloy, whereas a material with only 1% elongation would possess little permanent elongation and be considered brittle.

An alloy that has a high value for total elongation can be bent permanently without danger of fracture. Clasps can be adjusted, orthodontic wires can be adapted, and crowns or inlays can be burnished if alloys with high values for elongation are used. Elongation and yield strength are generally related in many materials, including dental gold alloys, where, generally, the higher the yield strength, the lower the elongation.

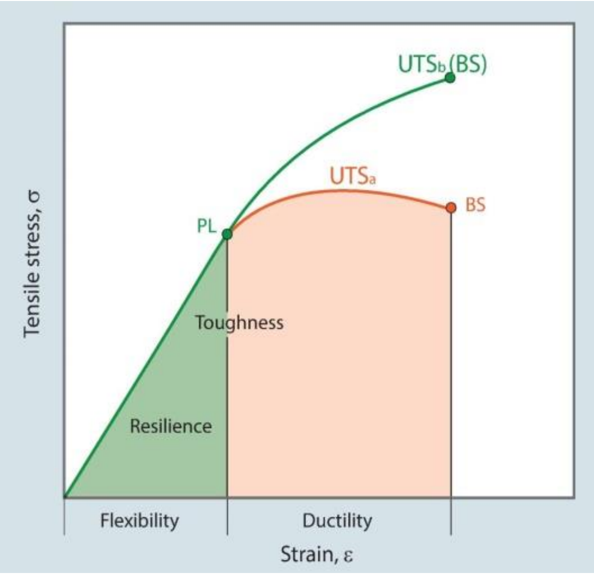
Elastic Modulus (Young's Modulus or Modulus of Elasticity)(E): The word modulus means ratio and in this case, the ratio of stress to strain. The elastic modulus represents the stiffness of a material within the elastic range.

$$\boxed{E=\frac{Stress}{Strain}}$$



$$E=\frac{\sigma}{\in}$$

Example, if wire A is much more difficult to bend than wire B of the same shape and size, considerably higher stress must be induced before a desired elastic deformation can be produced. As such, wire A is considered to have a comparatively higher modulus of elasticity than wire B. Thus wire A, with a higher modulus of elasticity, stretches less than wire B under the same stress. Elastomeric impression materials have a greater stiffness (elastic modulus) than alginate-based impression materials. Thus a greater force is needed to remove an elastomeric impression tray from undercut areas in the mouth.

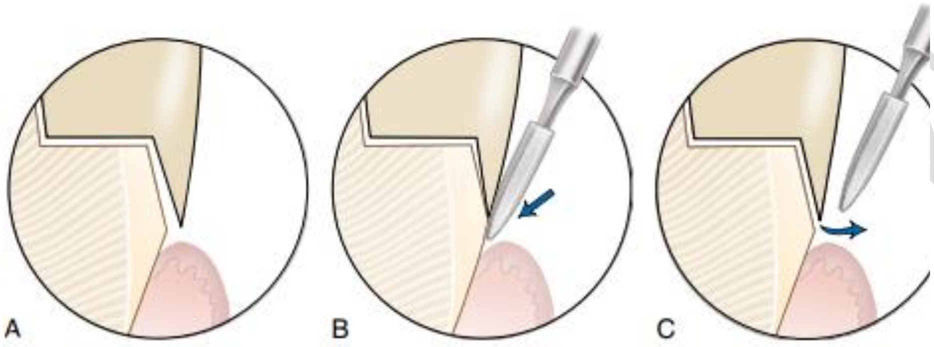


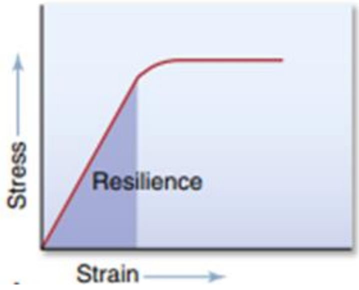
Flexibility: is defined as the elastic strain shown on a stress-strain curve or the reversible flexural strain of a bending test.

Ductility: represents the amount of permanent deformation a material can sustain under a tensile load up to the point of fracture. Platinum ranks third in ductility.

Malleability: is the amount of permanent deformation a material can sustain without rupture under compression, such as hammering or rolling a metal rod into a thin sheet. Gold is the most ductile and malleable pure metal, followed by silver. Of the metals of interest in dentistry, copper ranks third in malleability.

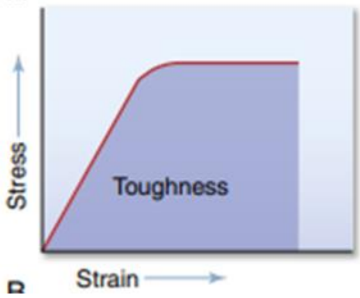
Burnishing of a cast metal margin to reduce the width of a gap between the crown margin and the tooth surface is a good example of flexibility and ductility at work. In burnishing procedure of an open metal margin, a smooth, dull instrument is used as a burnishing tool to press the metal margin against the tooth and close the marginal gap. This movement is possible as a result of the elastic plus plastic strain of the metal. After the instrument is removed, the margin springs back an amount equal to the total elastic strain. Because at least 25 µm of space must be provided for the cement between the tooth and the crown, total burnishing on the tooth or die is usually adequate because the amount of elastic strain recovery is relatively small .Pushing the margin further while pressing against the tooth to compensate for the anticipated elastic recovery may be required. Naturally, the metal should have relatively high ductility to prevent fracture of the margin during burnishing and moderate yield strength to facilitate the procedure.





Resilience (Ur) is the ability of a material to absorb energy when it is deformed elastically *or it is* the amount of strain energy absorbed within a unit volume of a structure being stressed to its proportional limit.

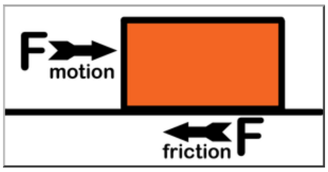
Brittleness is generally considered to be the opposite of toughness



Toughness: is the resistance of a material to fracture, is an indication of the amount of energy necessary to cause fracture. It is measured as the total area under the elastic and plastic portions of a stress-strain curve.
Toughness increases with an increase in strength and ductility. The greater the strength and the higher the ductility (total plastic strain) are, the greater the toughness is. Thus we can conclude that a tough material is ge erally stron*g* although a strong material is not necessarily tough.

Surface Mechanical Properties:

Hardness : Resistance of the surface of a material to plastic deformation, which is typically produced by forcing a pointed or spherical indenter on the surface. The hardness of dental materials generally is reported in Knoop hardness. Tthe larger indentations are in cementum, and the smaller are in dentin. Examples of Knoop hardness Enamel and ceramic are two of the hardest materials, Friction: it is the resistance between contacting bodies when one moves relative to another.



Wear: it is a loss of material resulting from removal and relocation of materials through the contact of two or more materials. Wear is usually undesirable, but under controlled conditions during finishing and polishing, controlled wear can be very useful.

The wear process can also produce shape changes in the object that can affect function. For example, wear of teeth and restorative materials is characterized by the loss of the original anatomical form of the material. Wear may result from mechanical, physiological, or pathological conditions. Normal mastication may cause attrition of tooth structure or materials. Bruxism is an example of a pathological form of wear in which clenching and grinding of teeth produces occlusal and incisal wear. Abrasive wear occurs when excessively abrasive toothpastes and hard toothbrush bristles are used when brushing teeth.


Attrition


Abrasion


Abfraction


Erosion

Absorption: refers to the uptake of liquid by the bulk solid.

Adsorption: indicates the concentration of molecules at the surface of a solid or liquid, an example of which is the adsorption of components of saliva at the surface of tooth structure or of a detergent adsorbed on the surface of a wax pattern.

Sorption: (adsorption plus absorption).

Solubility of a material is simply a measurement of the extent to which it will dissolve in a given fluid, for example, water or saliva.

Wettability: is a measure of the affinity of a liquid for a solid as indicated by spreading of a drop. The wettability of solids by liquids is important in dentistry; for example, the wetting of denture base acrylics by saliva, the wetting of tooth enamel by pit and fissure sealants, the wetting of elastomeric impressions by water mixes of gypsum materials, and the wetting of wax patterns by dental investment.