الجامعة السورية الخاصة SPU

كلية طب الأسنان –قسم التعويضات

مقرر مواد سنية 1

Dental Material-1

المحاضرة الرابعة Mechanical **Properties of Dental Materials**

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الفصل الأول

MECHANICAL PROPERTIES OF DENTAL MATERIAL

INTRODUCTION

In the oral environment, restorations are subjected to heavy **masticatory forces**. These forces act on teeth and/ or material producing different reactions that lead to **deformation,** which can ultimately compromise their durability over time.

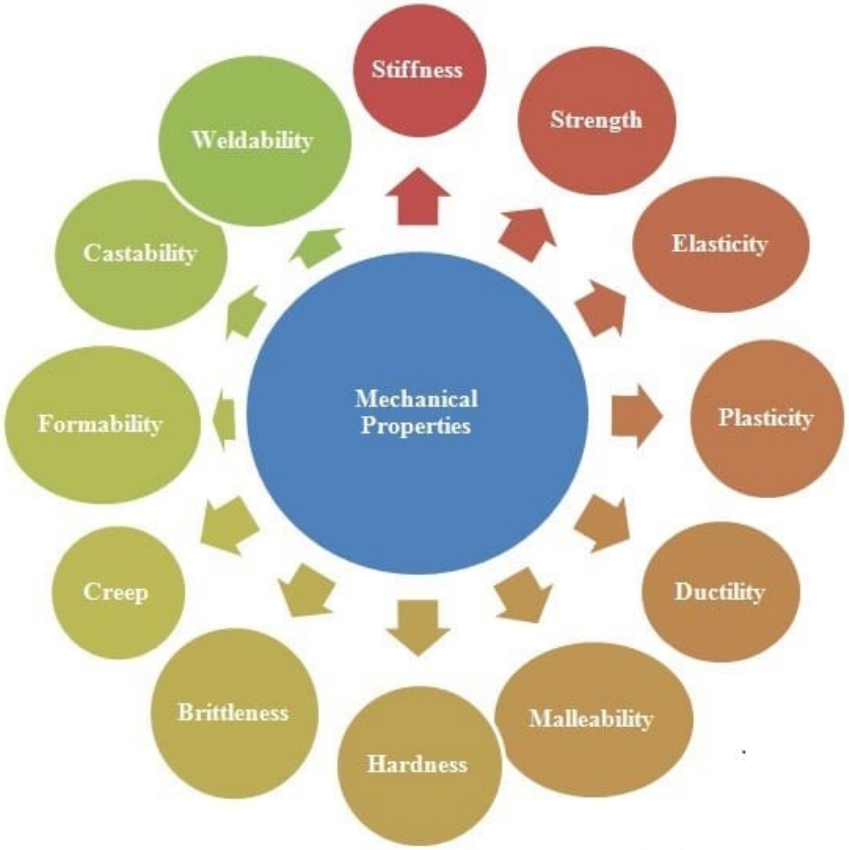
It is important to introduce some concepts that are extremely relevant to understand the performance presented by such materials under specific test conditions.

Property of the material is the key term which helps us to identify the characteristics of material and utilize it in application to get most out of it with minimum efforts. Just like length, width and height, of an object, a material also possesses certain characteristics which make them different from another. Here is the list of some basic definition of mechanical properties of materials.

خاصية المادة هي المصطلح الذي يساعدنا على تحديد خصائص المادة واستخدامها في التطبيق لتحقيق أقصى استفادة منها بأقل جهد ممكن

تمامًا مثل طول الجسم وعرضه وارتفاعه وطبيعته، تمتلك المادة أيضًا خصائص معينة تجعلها مختلفة عن غيرها.

MECHANICAL PROPERTIES OF DENTAL MATERIAL



DEFINITION

Mechanical properties are subset of physical properties that are based on the laws of mechanics that is the physical science that deals with energy and forces and their effects on the bodies.

These properties are expressed most often in units of stress and strain.

Mechanical Properties of Dental Material

- **A mechanical property is the behavior of the material when it's linked to the application of force.**
- **The mechanical properties of a material describe how it will react to physical forces.**

One of the most important properties of dental materials is the ability to withstand the various mechanical forces placed on them during use as restoration, impression , models, appliances and tools.

Elastic solids may be **stiff or flexible**, **hard or soft**, **brittle or ductile**, and **fragile or tough**. However, these are qualitative mechanical properties that do not describe how similar or dissimilar dental materials of the same type may be. 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.

الخصائص الميكانيكية

- هي خصائص المواد التي تعكس آلية تعاملها وتفاعلها مع الأحمال والقوى المركزة عليها، وتُستخدم لتحديد العمر الزمني المتوقع للمادة ومدى فاعليتها عبر مرحلة ما بعد التصنيع، وتساعد الخصائص الميكانيكية أيضاً على تصنيف المواد وإعطاء هويتها؛ قصفة، مرنة، لدنة، صلبة.. حيث تُعرف الخصائص الميكانيكية للمواد بأنّها متغيرة وليست ثابتة حيث تتغير تبعاً للوضع المحيط بها، فالتغير في درجة حرارة الغرفة مثلاً يسبب تغيراً في خصائص المواد الميكانيكية، لذلك تُجرى اختبارات تحديد الخصائص على درجة حرارة معيارية معيّنة.

1-STRESS

- When a force acts on the body, tending to produce deformation, a resistance is developed within the body to this external force. The internal resistance of the body to the external force is called stress. Stress is equal and opposite in direction to the force (external) applied. This external force is also known as load. Since both applied force and internal resistance (stress) are distributed over a given area of the body, the stress in a structure is designated as a force per unit area.
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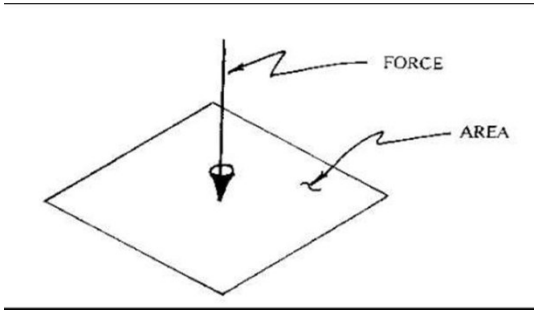
- $$\text{Stress} = \frac{\text{Force}}{\text{Area}} = \frac{F}{A}$$



الجهد : stress

- هو القوة المؤثرة عموديا على وحدة المساحة ووحدات الإجهاد هي (N/m^2) أو ($dyne/cm^2$)

هو رد الفعل الداخلي لجسم ما تجاه القوى الخارجية المطبقة عليه

TYPES OF STRESS

Depending on the type of force applied, following stresses are produced

Axial (Tensile and Compressive)

Shear (sliding)

Flexural

أنواع الجهود : Types of Stress

1- جهد الشد **Tensile Stress**:

وفيه تؤثر قوتان متساويتان بالمقدار متعاكستان بالاتجاه تقعان على نهايتي الجسم وعلى نفس خط التأثير .

2- جهد الضغط **Compressive Stress**:

وفيه تؤثر قوتان متساويتان بالمقدار متقابلتان بنفس الاتجاه تعملان على ضغط الجسم وتقصير طوله .

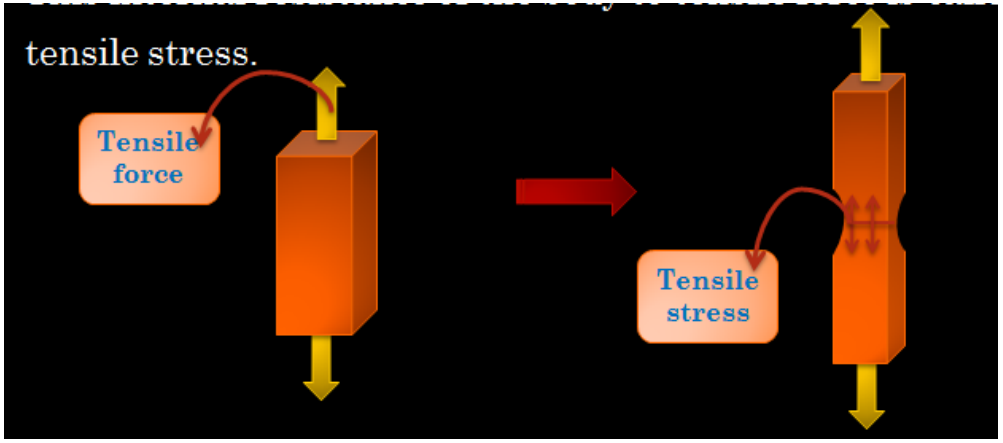
3- جهد القص Shear Stress

4- جهد الانحناء(الانعطاف) Flexural Strength

جهد الشد-Tensile stress

It is the force per unit area induced in the body in response to externally applied force **which tends to elongate or stretch the body**, it is accompanied by tensile strain.

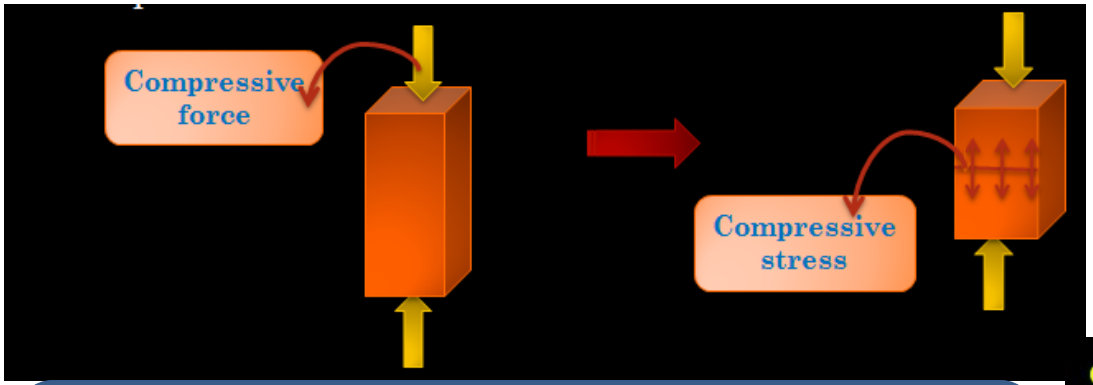
(two sets of forces directed away from each



تطبيق قوة شد على جسم على استقامة واحدة باتجاهين متعاكستين

compressive stress-جهد الانضغاط

It is the force per unit area induced in the body in response to externally applied **force which tends to compress or shorten the body**, it is accompanied by compressive strain.
Investment materials, restorative materials and models should have high compressive strength



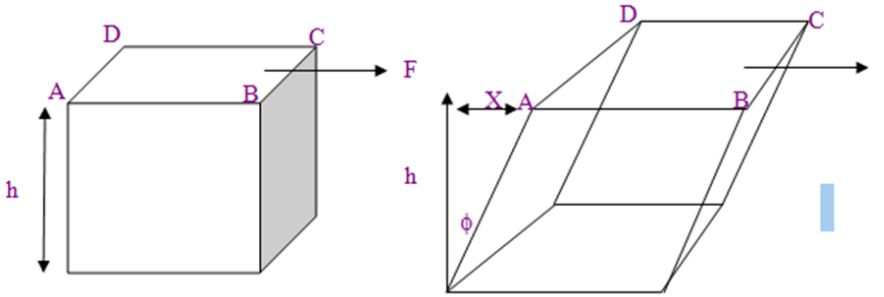
هي القوة المطبقة على جسم محاولة ضغطه وتهشيمه
تقابلها مقاومة على نفس الاستقامة

3- جهد القص : Shear Stress

في بعض الأحيان لا يكون انفعال المادة المرنة تغير في الطول أو الحجم بل قد يكون تغير في الشكل بمعنى أنه إذا بذل قوة على مكعب ونتيجة هذه القوة أصبح المكعب متوازي مستطيلات فبذلك نقول أن المادة حدث لها قص كما هو موضح بالشكل التالي.

نفرض أن المكعب الموجود بالشكل يتعرض وجهه ABCD لقوة (إجهاد قص) أدت إلى إزاحته يمينا كانت نتيجته أن أصبح المكعب متوازي مستطيلات .

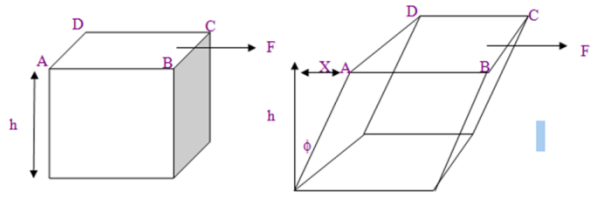
وبهذا فان **إجهاد القص فيه تؤثر قوتان متساويتان بالمقدار متعاكستان با سم وعلى خطوط تأثير**

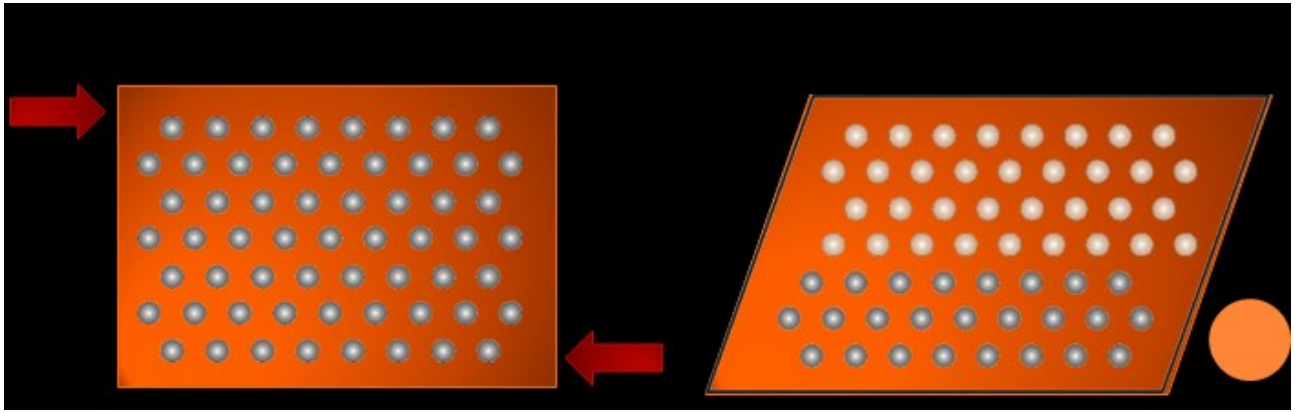


SHEAR STRESS

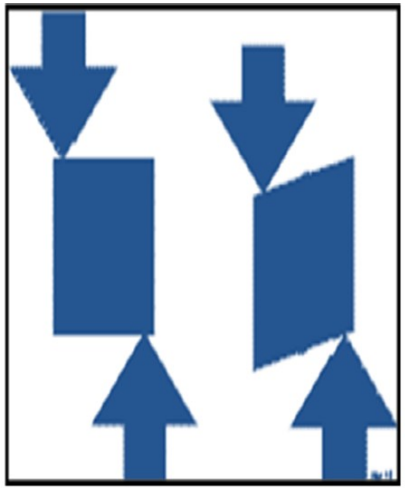
Shear stress is a result of two forces directed parallel to each other. A stress that tends to resist a twisting motion, or a sliding of one portion of a body over another is a shear or shearing stress

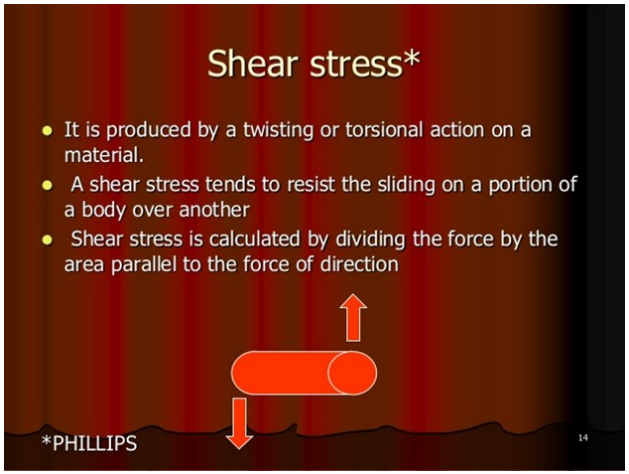
One portion of the material is forced slide by another portion .

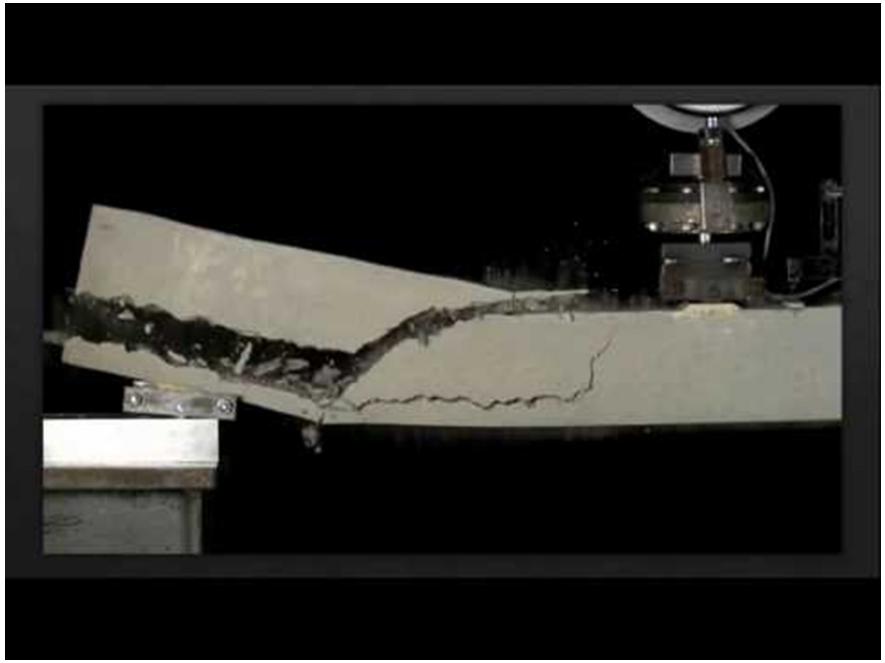


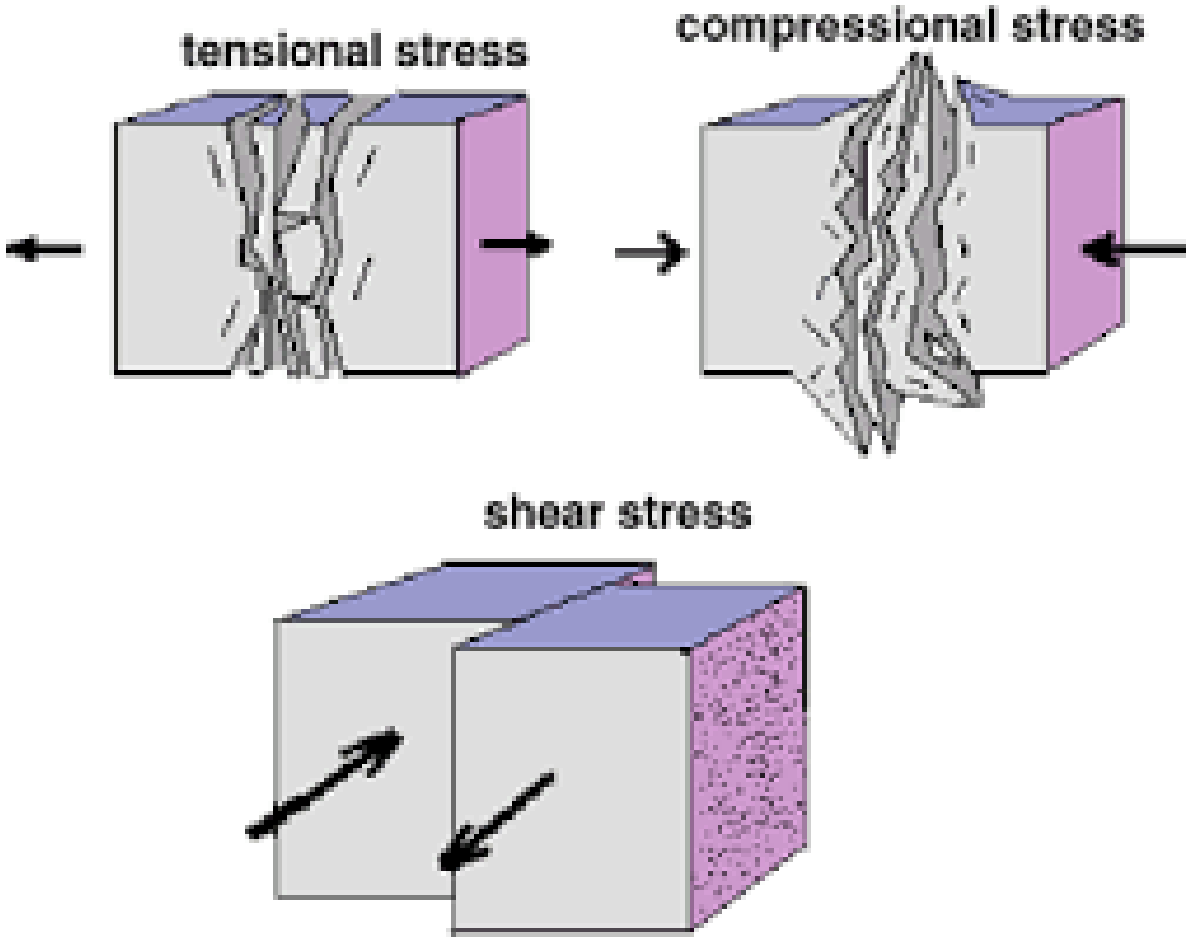


SHEAR STRESS



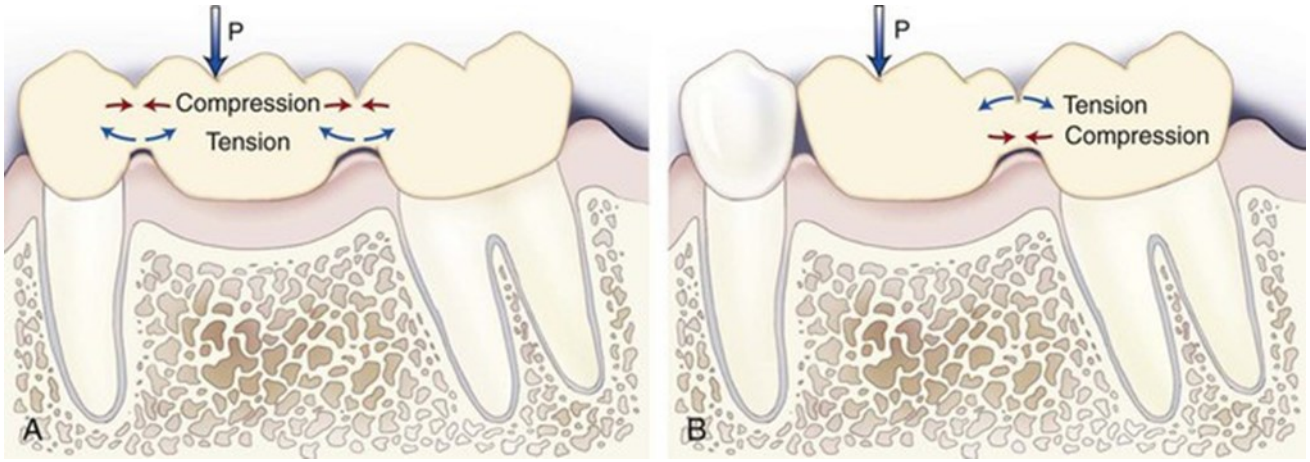





tensional stress
compressional stress
shear stress

COMPLEX STRESSES

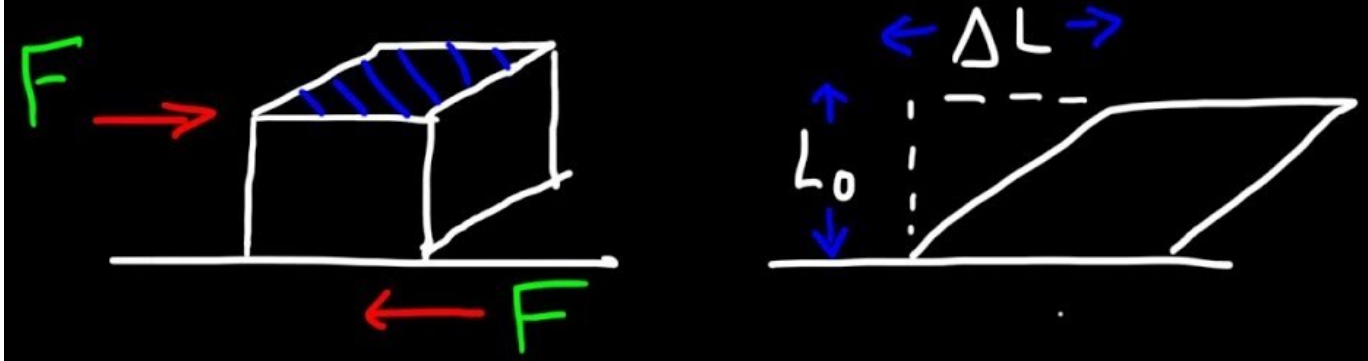
Tensile and compressive stresses along with shear, are the three simple examples of stress which form the basis of all other more complex stress patterns.



Stress & Strain

Tensile

Compression



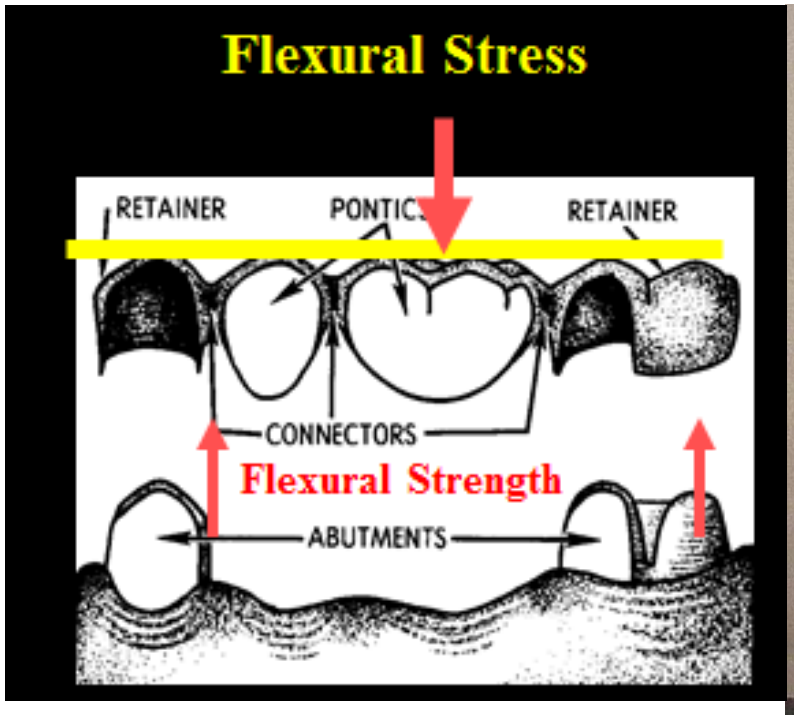
Shear

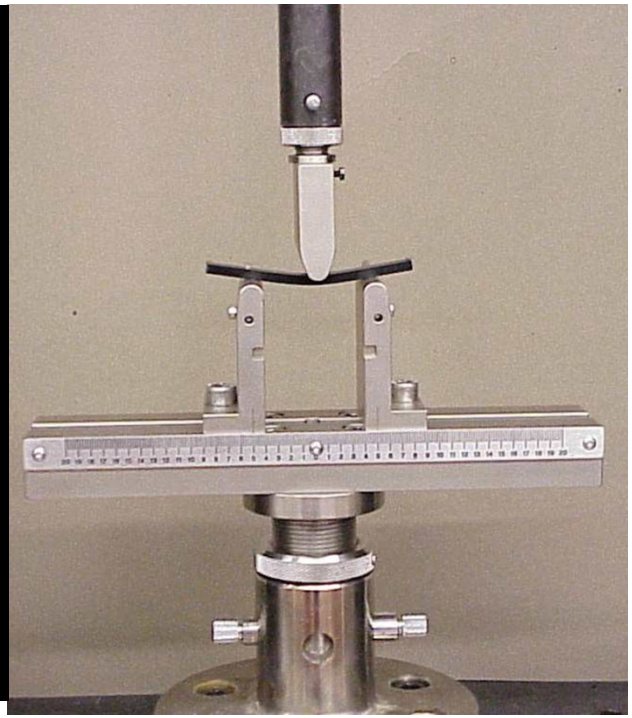
Flexural Strength (جهد الانحناء(الانعطاف

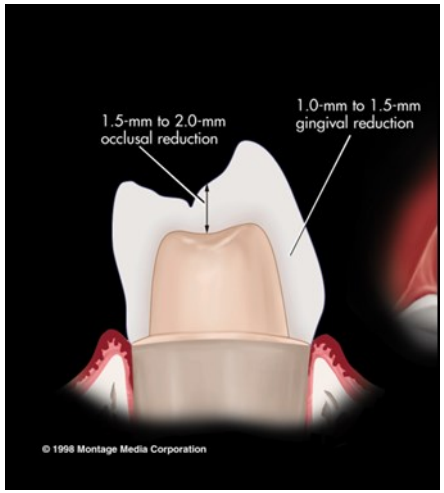
Also called as **bending stress**.

Produced by **bending forces** over the dental appliance

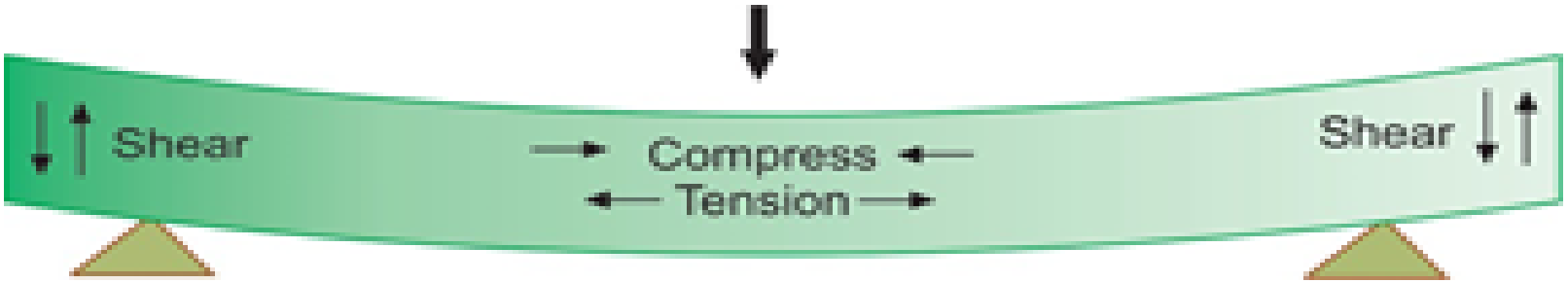
اختبار ثلاثي النقاط



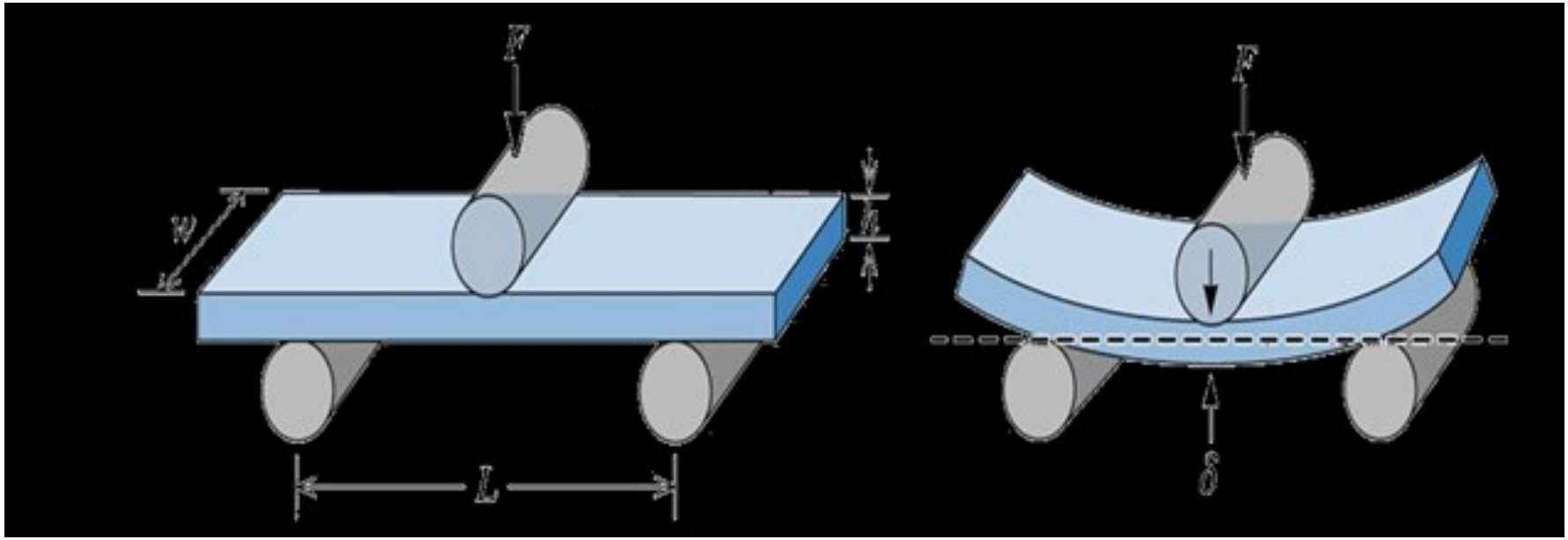




FLEXURAL STRESS



Complex stresses produced by a three-point loading of a beam.

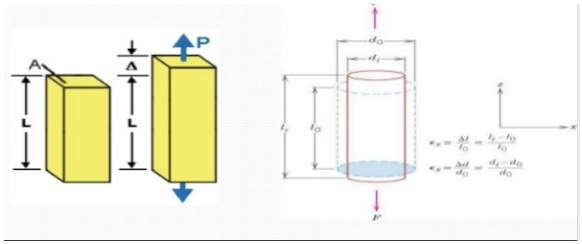


2-STRAIN-
الإجهاد(الانفعال)

- The application of an external force to a body results in a change in dimension of that body. The magnitude of which depends on the applied force and the properties of the material.

- هو التبدل الحجمي الذي تعاني منه المادة استجابة للجهود(stress)عليها يحسب بتقسيم التبدل الحادث في الطول على الطول الأصلي.

- Strain = Change in length/Original length.=ΔL/L



الإجهاد- الانفعال : Strain

هو التبدل الحجمي الذي تعاني منه المادة استجابة للجهود (stress)عليها .يحسب بتقسيم التبدل الحادث في الطول على الطول الأصلي.

STRESS-STRAIN RELATIONSHIP

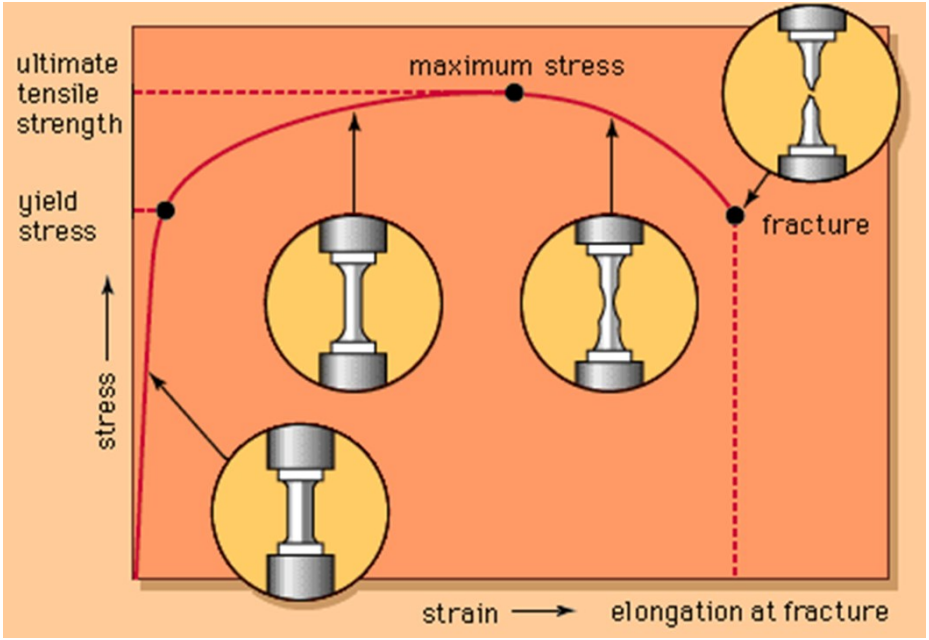
Each type of stress is capable of producing a corresponding deformation in the body.

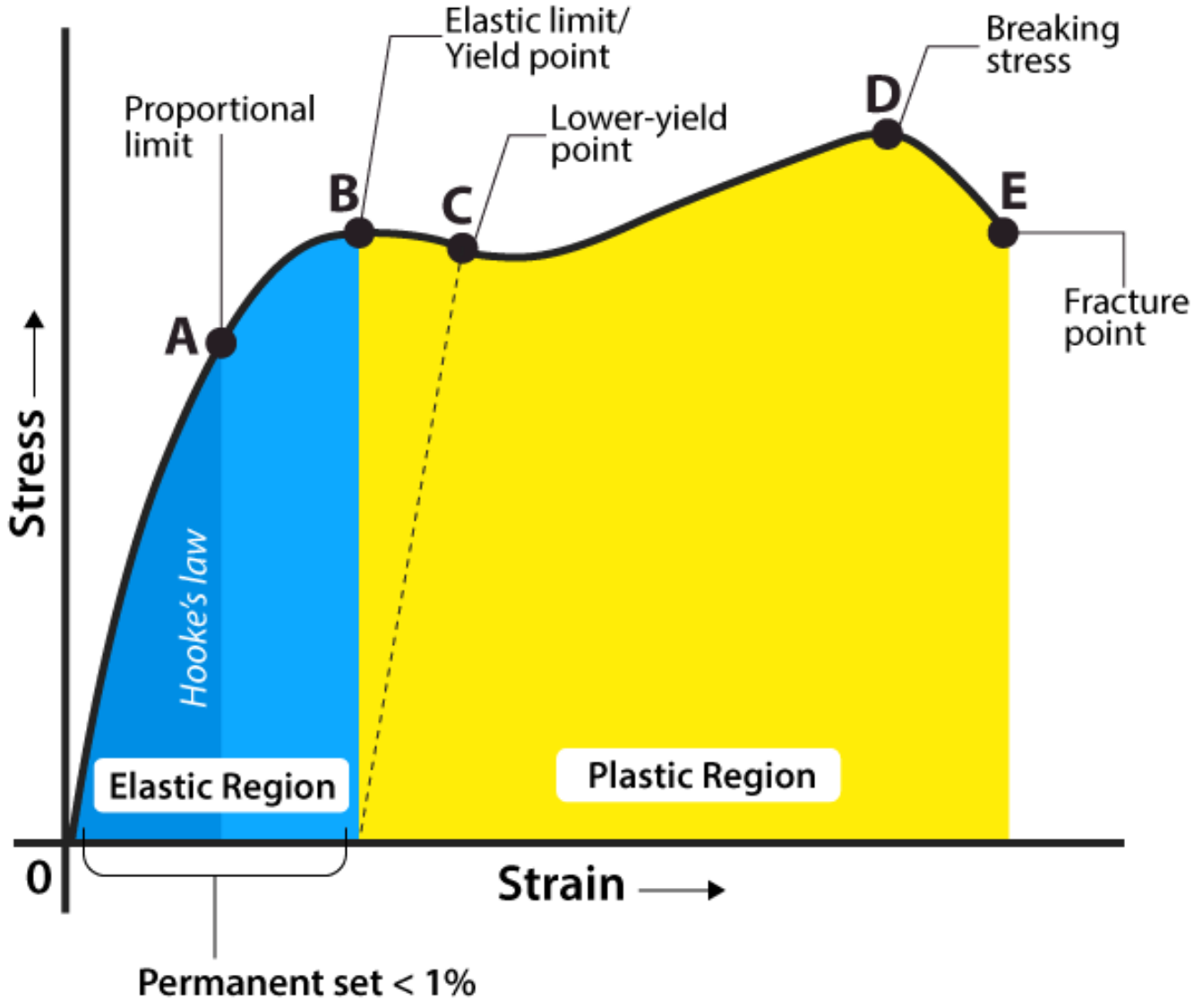
Therefore, **stress and strain** are not independent and unrelated properties, but they are **closely related** and may be seen as **cause** and **effect**.

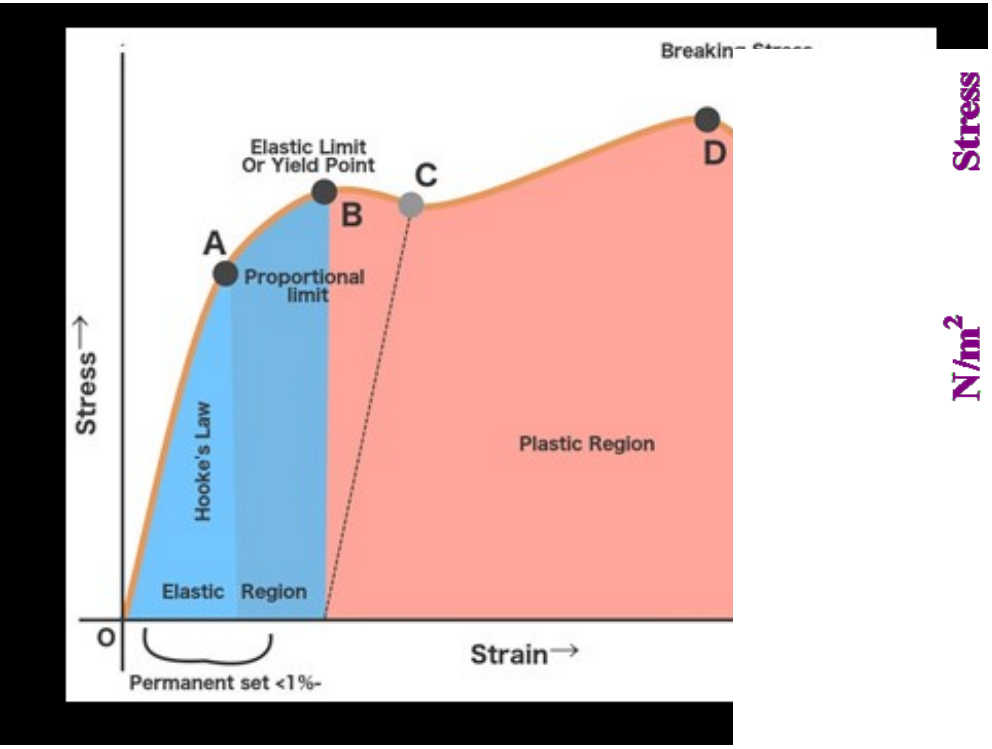
The **relationship of stress and strain** is often used to characterize the **mechanical properties of materials**

STRESS AND STRAIN

Experience shows that **any material subjected to a load may either deform**, **yield** or **break**, depending upon the , The Magnitude of load , Nature of the material , Cross sectional dime.




Elastic limit/
Yield point
Breaking
stress
Proportional
limit
Lower-yield
point
D
B
C
E
A
Fracture
point
Stress
Hooke's law
Elastic Region
Plastic Region
0
Strain
Permanent set < 1%


Elastic Limit
Or Yield Point
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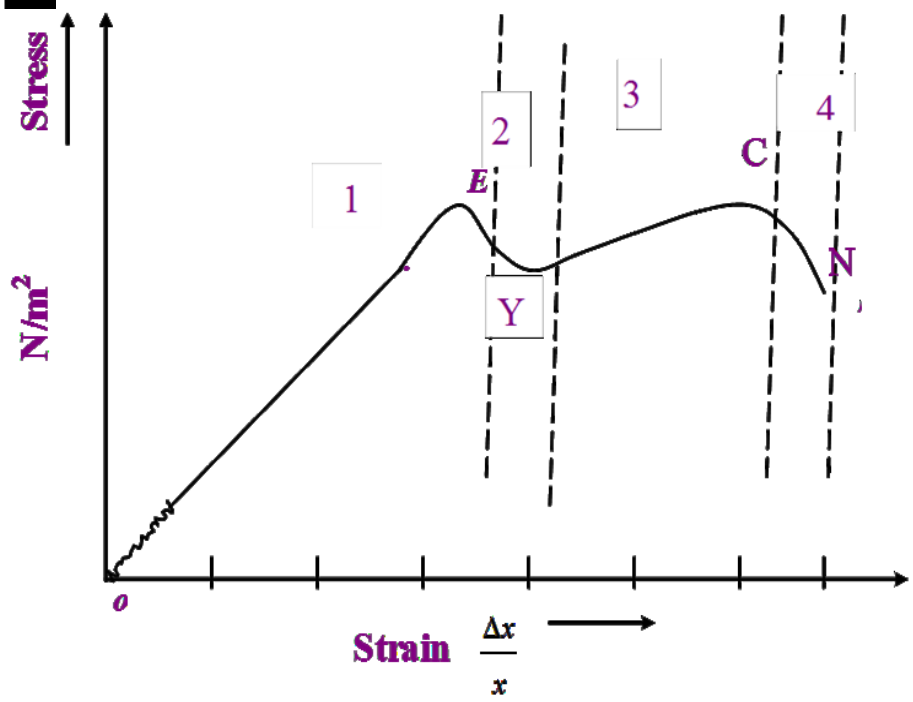
Strain
Permanent set <1%-


Stress
N/m²
1
2
3
4
E
C
Y
N
o
Strain
Δx
x

نقطة الخضوع: yield point هي الحد الفاصل التي تنتهي عنده صفة المرونة وتتميز بان المادة عندها تصبح ضعيفة نسبيا وتبدأ بالتشوه بانفعال اكبر تحت أي زياده في الاجهاد ويكون تشوهها دائم.

3-STRENGTH

The strength of a material is its **capacity to withstand destruction** under the **action of external loads**. It determines the ability of a material to withstand stress without failure. The maximum stress that any material will destruction is called ultimate withstand before str

Strength is power & stress is weakness....

When you a going through a problem and you think on it again and again its – STRESS

WHEN YOU OVERCOME YOUR PROBLEM ITS

STRENGTH

strength

Your strength is the physical energy that you have, which gives you the ability to perform various actions, such as lifting or moving things.

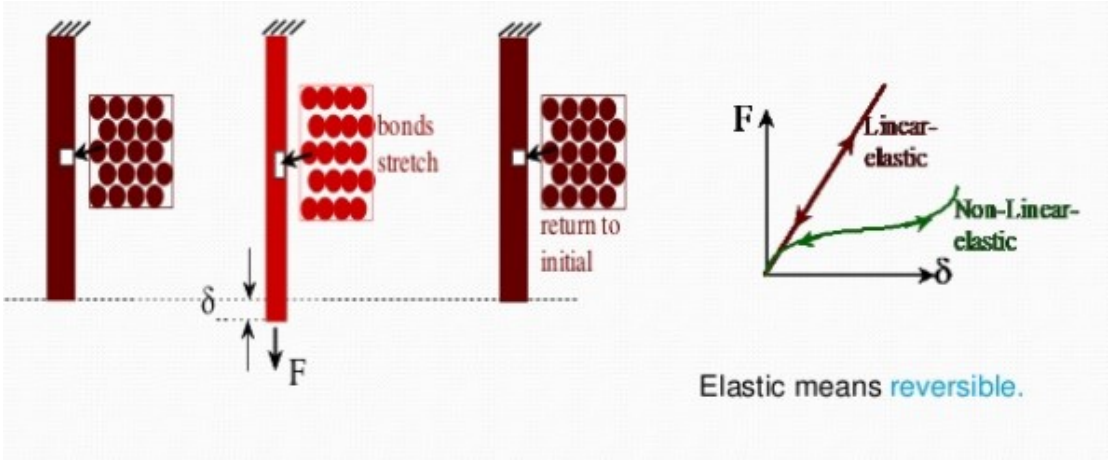
4-ELASTICITY

elasticity is the resistance of a material to deformation and to return to its original shape and size when the load is removed.

المرونة :قابلية المادة على التشوه تحت تأثير القوى الخارجية ثم العودة الى الشكل والابعاد الاوليين بعد زوال المؤثر الخارجي

ELASTICITY

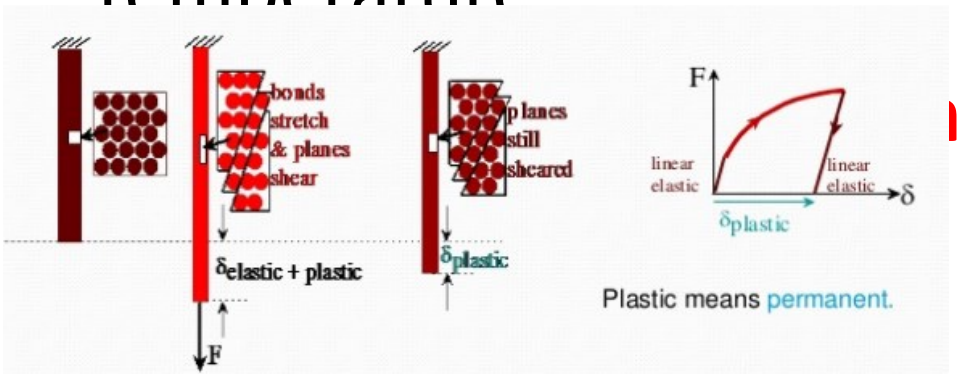
The property of material by virtue of which deformation caused by applied load disappears upon removal of load. Elasticity of a material is the power of coming back to its original position after deformation when the stress or removed . **Elastic means reversible** load is .



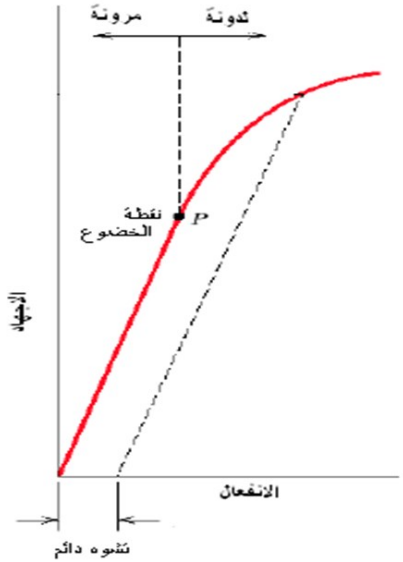
5- PLASTICITY

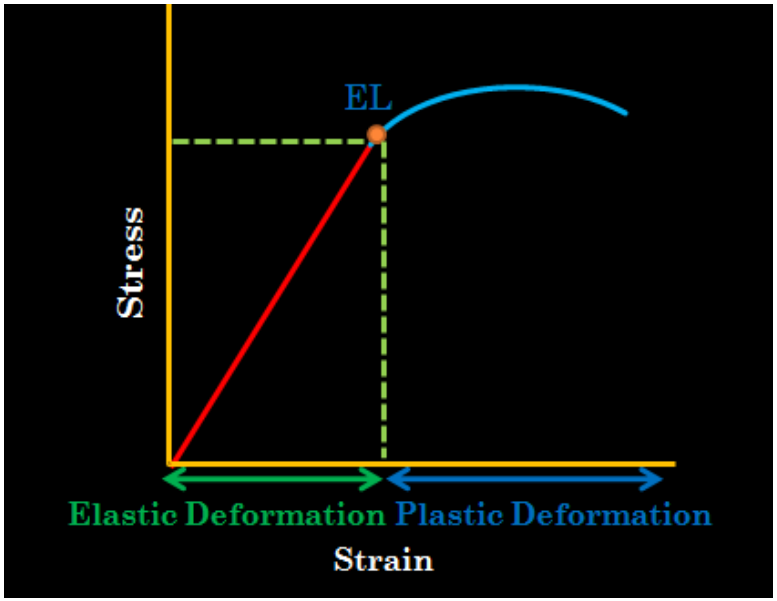
The plasticity of a material is its ability to undergo some degree of **permanent deformation without rupture or failure**. Plastic deformation will take only after the elastic limit is exceeded. It increases with inc

temperature



اللدونة خاصية المادة التي تتعلق بتغير دائم وغير ردود لإبعاد وشكل مادة تحث تأثير قوة خارجية





NOTE

Elastic deformation → Bonds stretched→ No permanent damage

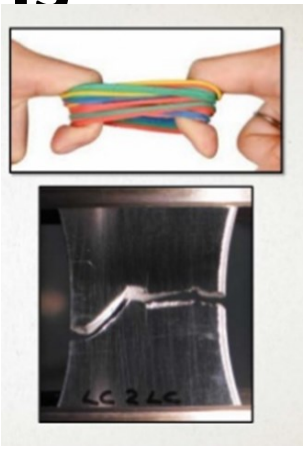
Plastic deformation → Bonds broken→ Permanent damage

6-RESILIENCE

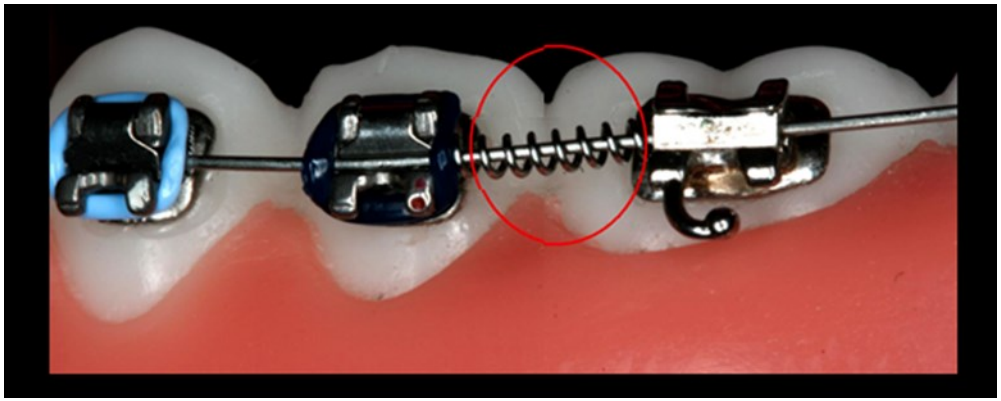
Resilience is the energy absorbed by a material to regain its original shape

Resilient-الرجوعية

As adjectives the difference between resilient and elastic is that **resilient is able to endure tribulation without cracking** while **elastic is capable of stretching; particularly, capable of stretching so as to return to an original shape or size when force is released**



Resilience has particular importance in the evaluation of orthodontic wires . It determines the magnitude of the force that can be applied to the tooth and how far the tooth can move before the spring is no longer effective.

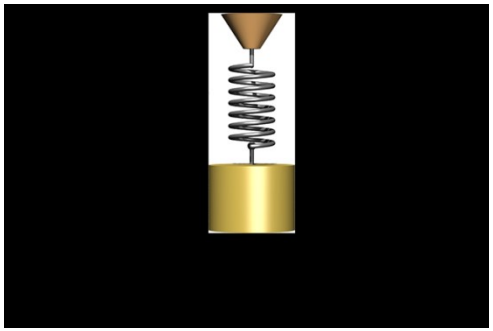


Elastomeric soft liners absorb considerable amounts of energy **resilient** without being permanently distorted when stressed and the energy stored is released when the material springs back to its original shape after removal of the applied stress. Therefore, these materials act as cushion between the hard denture base and soft tissues to reduce mas
transmitted by prosthesis to t
tissues.

7-STIFFNESS

The resistance of a material to elastic deformation or deflection is called stiffness or rigidity. A material which suffers slight deformation under load has a high degree of stiffness or rigidity. E.g. **Steel beam** is more stiffer or **more rigid** than **aluminum bream.**

Unit of stiffness is Newton per meter.



Stiffness

is the tendency of a material to react with a small deformation when the material is stressed. It is measured with **Young's Modulus**, which is the angular coefficient, or slope, of the linear stress-strain curve. This **property depends directly on the bond type between the atoms**. **The stronger the bond, the higher the modulus (or the stiffness).**

الصلابة : stiffness

الصلابة : stiffness

وهي تعطي الدليل على إمكانية ثني أوليَّ المادة دون حدوث تشوه دائم أو كسر، وتعتمد على عامل المرونة وحجم وشكل العينة.

Clinical application

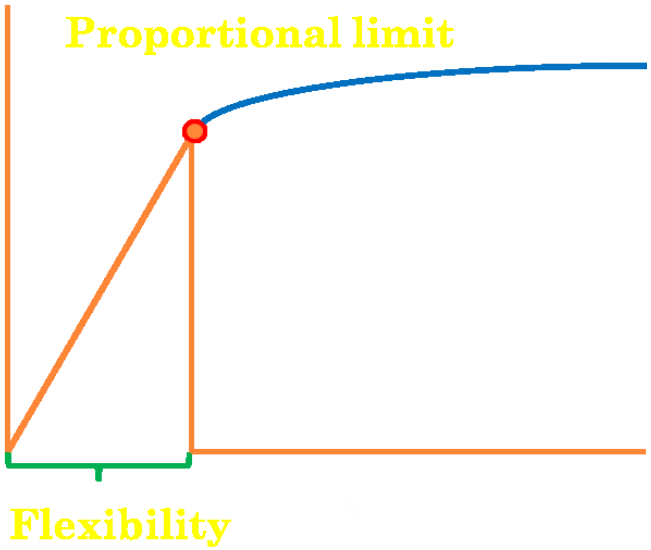
The metal frame of a **metal-ceramic bridge** should have a high **stiffness**. If the metal flexes, the porcelain veneer on it might **crack or separate**. Such a material would possess a comparative high modulus of elasticity.

A polyether material have greater stiffness than all other elastomeric impression materials. Thus a greater force is needed to remove a impression tray from undercuts in mouth

FLEXIBILITY

It is the maximum elastic (recoverable) strain that occurs when a material is stressed to proportional limit.

Therefore, it follows that greater the strain for a given stress in a material, greater will be it's flexibility.



RESILIENCE

It indicates the amount of energy necessary to deform a material to proportional limit. OR it is amount of energy absorbed by a structure, when it is stressed to proportional limit.

Resilience is measured by the area under the elastic portion of stress strain curve

8-FLEXIBILITY

الليونة

the ability to be bend with out breaking

الرجوعية - RESILIENCE

يشير إلى كمية الطاقة اللازمة لتشويه مادة ما إلى الحد التناسبي. أو هي كمية الطاقة التي يمتصها الهيكل ، عندما يتم التشديد عليه إلى حد متناسب. يتم قياس المرونة من خلال المنطقة الواقعة تحت الجزء المرن من منحنى الجهد و الإجهاد

الليونة - FLEXIBILITY

إنها أقصى سلالة مرنة (قابلة للاسترداد) تحدث عندما يتم التأكيد على مادة ما إلى حد تناسبي .لذلك ، يترتب على ذلك أنه كلما زاد الضغط الناتج عن إجهاد معين في مادة ما ، زادت المرونة

Restorative materials should withstand high stresses and show **minimum distortion** or should have **minimum flexibility**.

Impression materials should have large flexibility or elastic deformation to withdraw through severe undercuts without permanent deformation.

Maxillofacial materials and soft denture relines should have high flexibility

9-TOUGHNESS

toughness is the **ability of a material to absorb energy and plastically deform without fracturing**.

material toughness is the amount of energy per unit volume that a material can absorb before rupturing.

It is also **defined as a material's resistance to fracture when stressed**.

TOUGHNESS

(fragile opposite of tough)

Materials known to be very tough are **stainless steels** and **titanium alloys**. Materials known to be **very fragile** are **ceramics** such as **glasses or porcelain**. The reason a ceramic plate shatters when dropped while your spoon will maybe only bend, is the difference in toughness between the two materials.

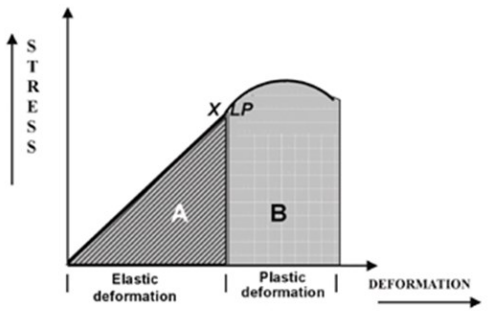
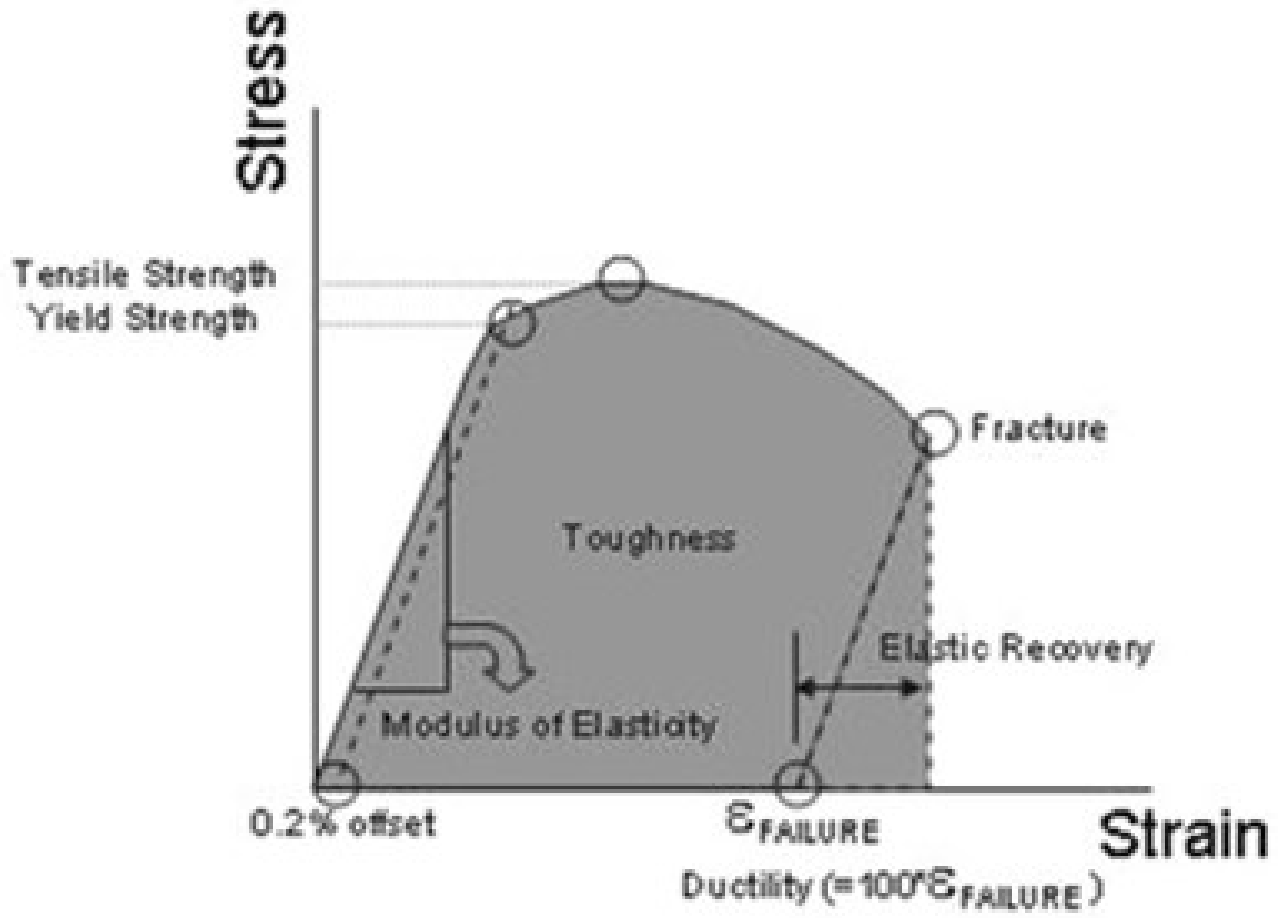


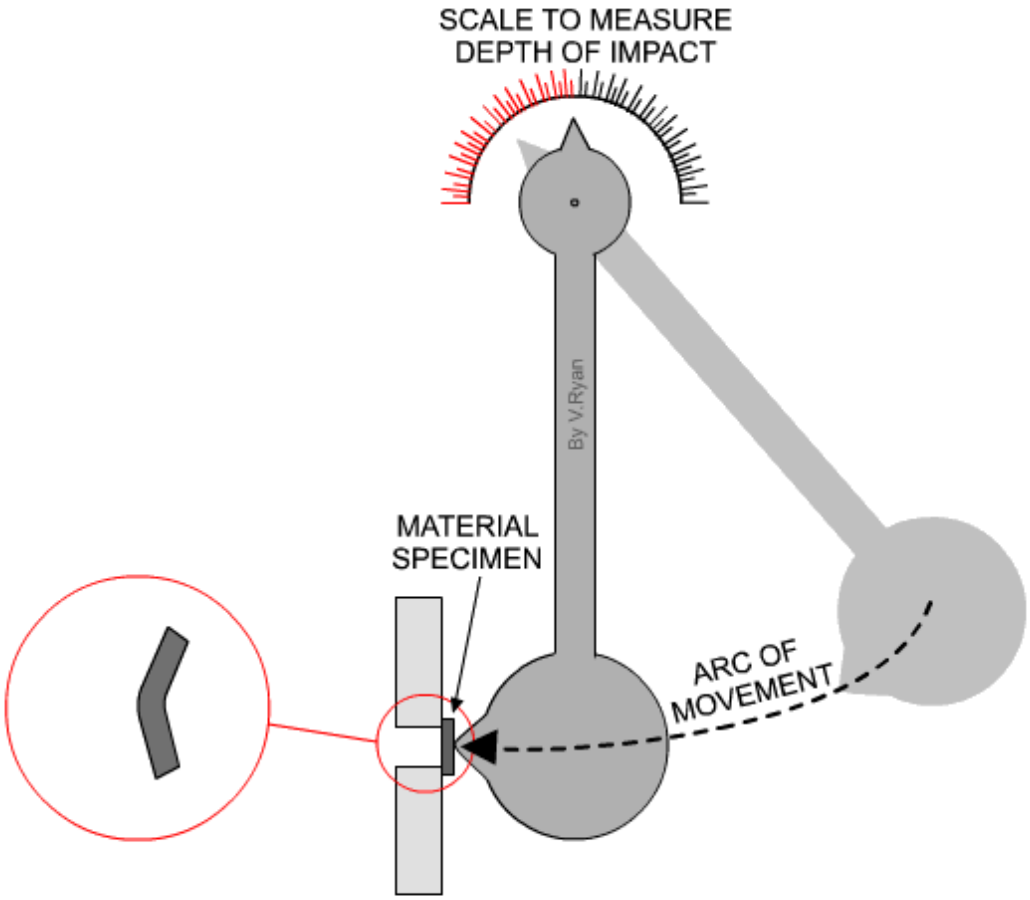
FIGURE 3- Areas indicating resilience (A) and toughness (A+B) of a material


Stress
Tensile Strength
Yield Strength
Fracture
Toughness
Elastic Recovery
Modulus of Elasticity
0.2% offset
$\varepsilon_{FAILURE}$
Strain
Ductility (= $100\varepsilon_{FAILURE}$)

Toughness-المتانة

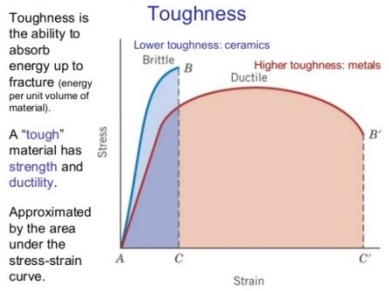
- **تعرف بكمية الطاقة في حجم المادة التي تستطيع امتصاصها قبل الانكسار. كما تعرف بأنها المساحة تحت كامل منحني الإجهاد-الانفعال (الانفعال المرن+ اللدن) حتى الانكسار وهو نفسه أيضا قياس المطيلية. تعكس متانة المواد قدرتها على امتصاص الطاقة وهذا يعتمد على شروط الاختبار (أي معدل الإجهاد) وعلى العيوب في العينة (أي الثلم). تكون المواد الخزفية عادة ذات رجوعية عالية ولكنها ذات متانة منخفضة لأن المنطقة اللدنة محدودة جدا. تكون المعادن متينة لأن لها منطقة لدنة كبيرة، ولكنها قد تتصف برجوعية منخفضة.**

TOUGHNESS


SCALE TO MEASURE
DEPTH OF IMPACT
By V.Ryan
MATERIAL
SPECIMEN
ARC OF
MOVEMENT

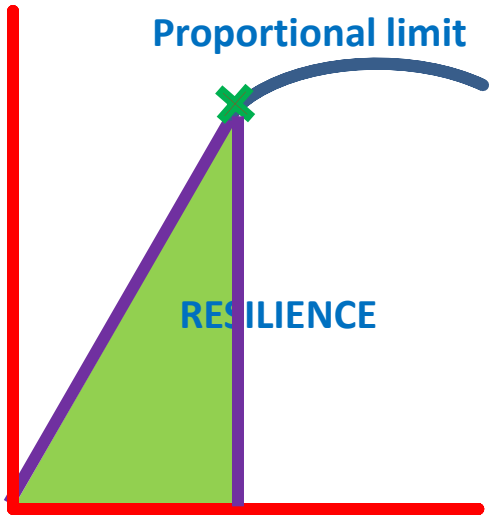
TOUGHNESS

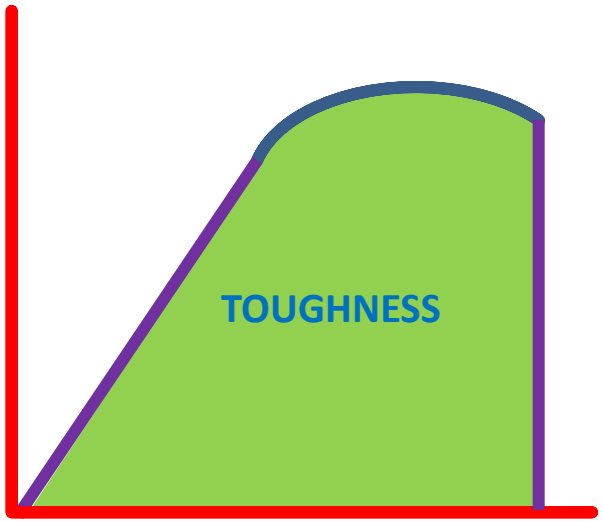
Toughness usually goes in the opposite direction of hardness, that is **if a material is very hard it is usually very fragile. Diamonds are fragile even though they are hard. Aluminum is tough but not hard at all**. The goal of every metallurgist would be to obtain a tough yet hard material. It is the most sought upon dream of structural materials



Difference between resilience and toughness

- **Toughness is the total amount of energy a material can absorb up to the point of fracture.**
- **Whereas resilience represents the energy required to stress a material to it's proportional limit OR The maximum amount of energy a material can absorb without undergoing permanent deformation.**





10-DUCTILITY

It is the property of a material which enables it to draw out into thin wires. E.g., **Mild steel** is a **ductile material**. The percent elongation and the reduction in area in tension is often used as empirical measures of ductility.

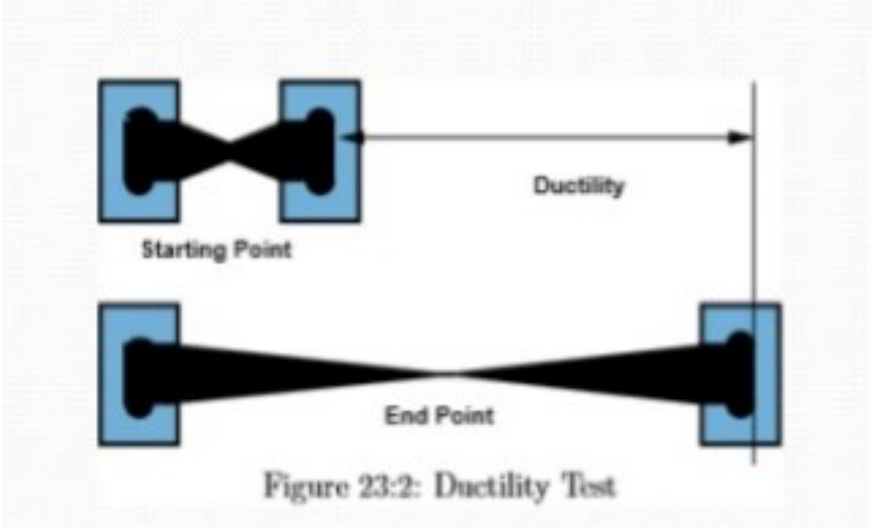
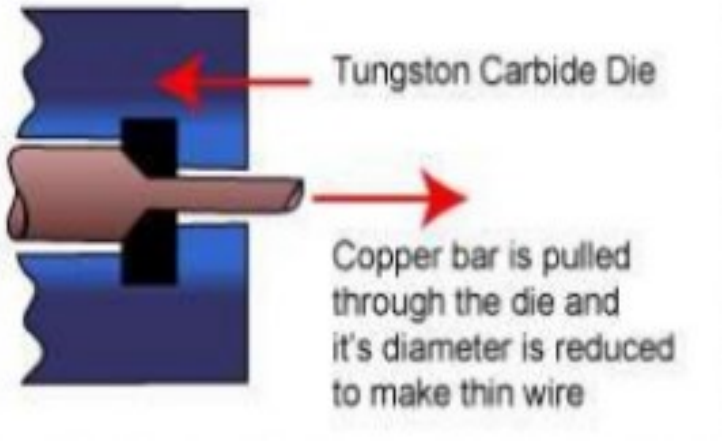


Figure 23:2: Ductility Test



Ductility

Definition:

The ability to be drawn into thin wires

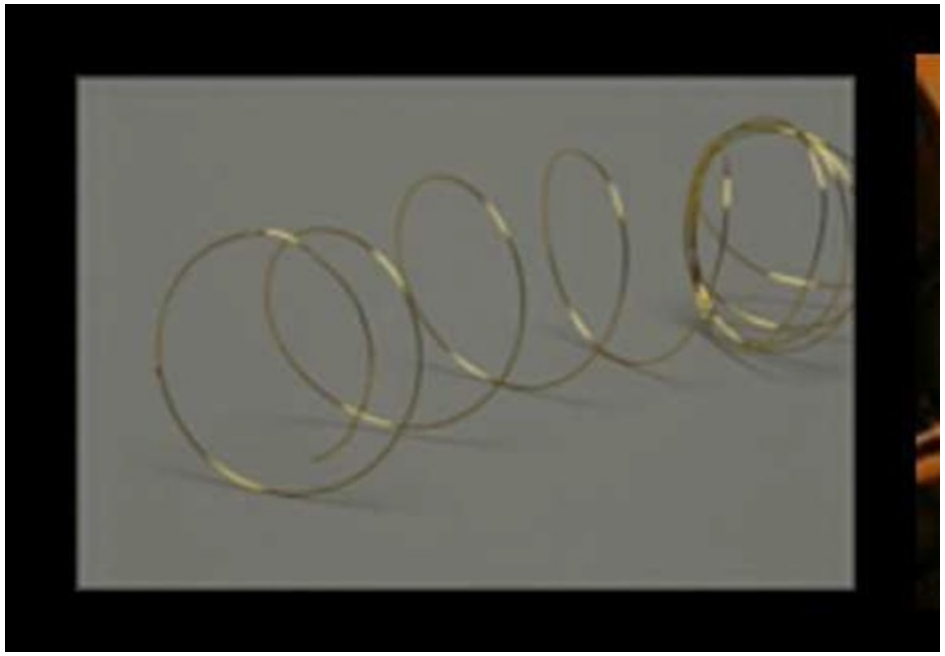
Example: Copper is used to make wires

DUCTILITY-قابلية المادة للسحب

المطيلية

وهي قابلية المادة للاستطالة عند التأثير عليها بقوة شد مشكّلةً أسلاكاً رفيعة أو خيوط دون أن تتحطم

عكس القصافة



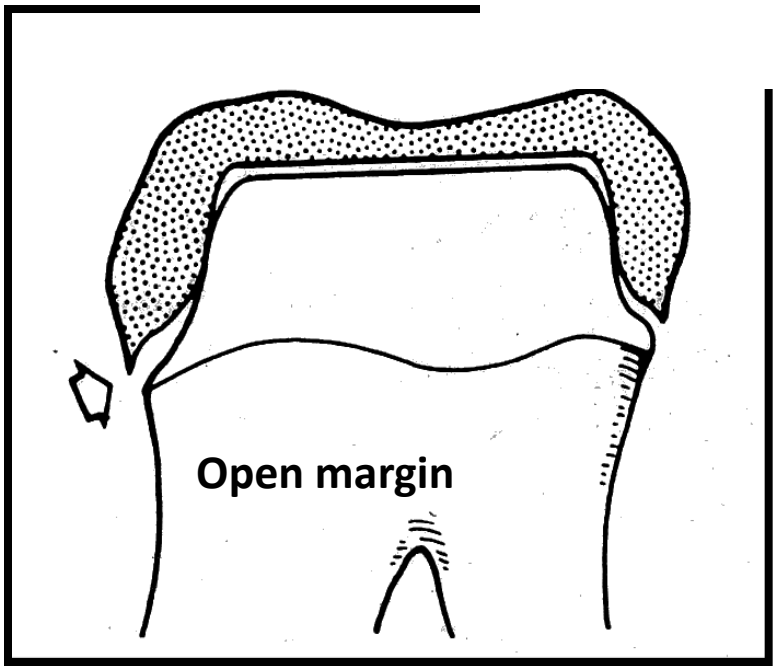
- Materials that experience **a large amount of permanent deformation are said to be ductile.**
- Materials that **undergo little or no plastic behavior are said to be brittle**. A brittle material fractures at or near its proportional limit.

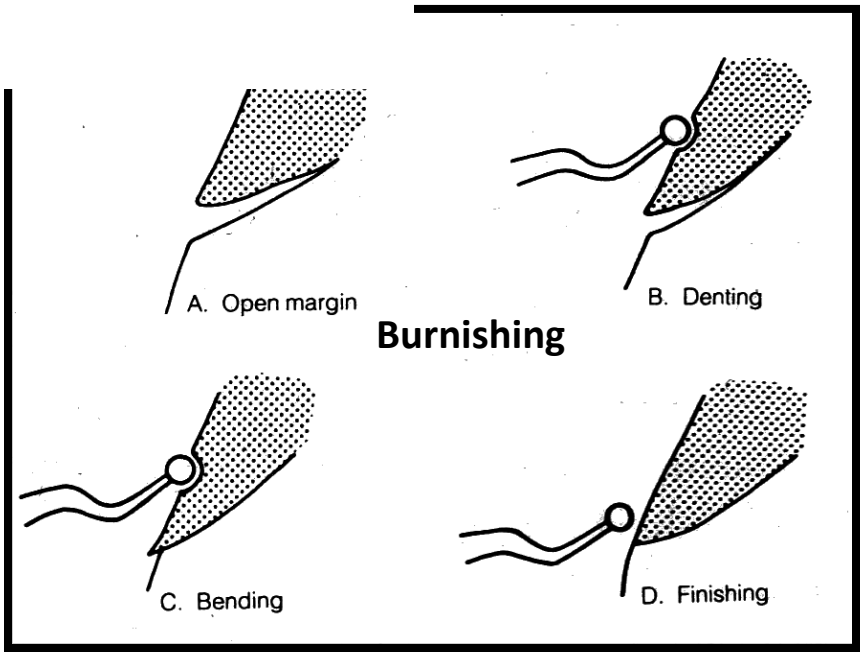
DUCTILITY

Importance of ductility in dentistry:

- Clasps can be adjusted, orthodontics appliances can be prepared, crowns or inlays can be burnished if they are prepared from alloys of high values of percentage elongation.

DUCTILITY





11-MALLEABILITY

- **DEFINITION** قابلية المادة للانطراق
- **The ability of a material to sustain considerable permanent deformation without rupture under compression, as in hammering or rolling into a sheet, is termed malleability.**
- **Gold is most ductile and malleable and silver stands the second.**
- **Platinum is third most ductile and copper is third most malleable.**

Malleability الطروقية

Definition: The ability to be pounded into thin sheets

Example:

Aluminum can be pounded flat to make aluminum foil

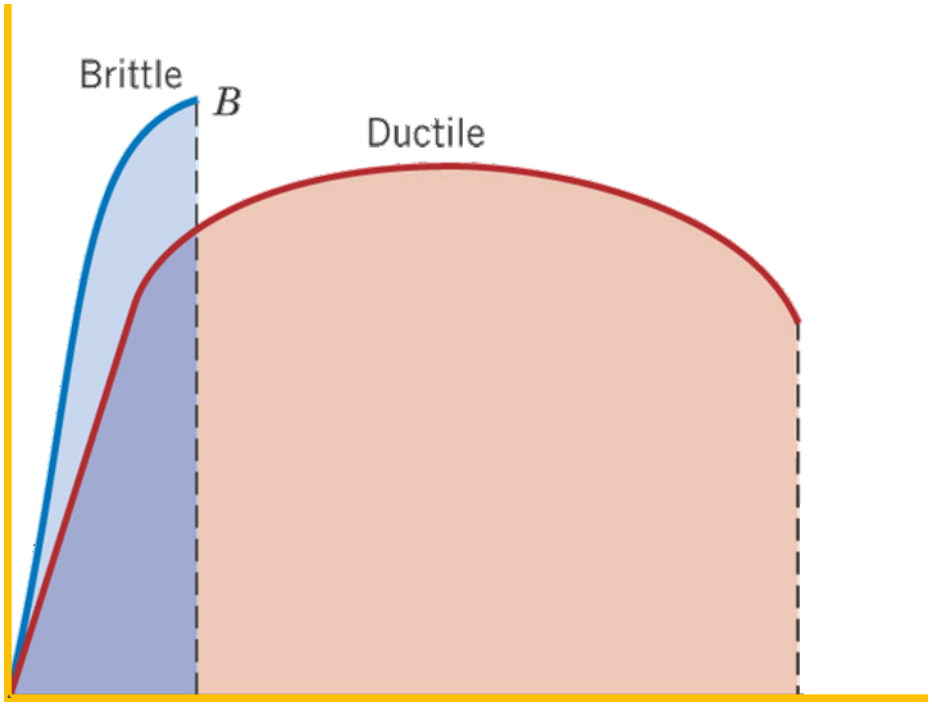
✓ هي قابلية المادة للتمدد طولاً وعرضاً دون أن يحصل تشوه فيها تحت تأثير قوى الضغط لتصبح على شكل صفائح . (كما هو الحال في تحويل اسطوانة نحاسية إلى صفيحة كبيرة ورقيقة دون حدوث تشقق أو تصدع أو ثقوب فيها).

12-BRITTLENESS

القصافة

BRITTLENESS

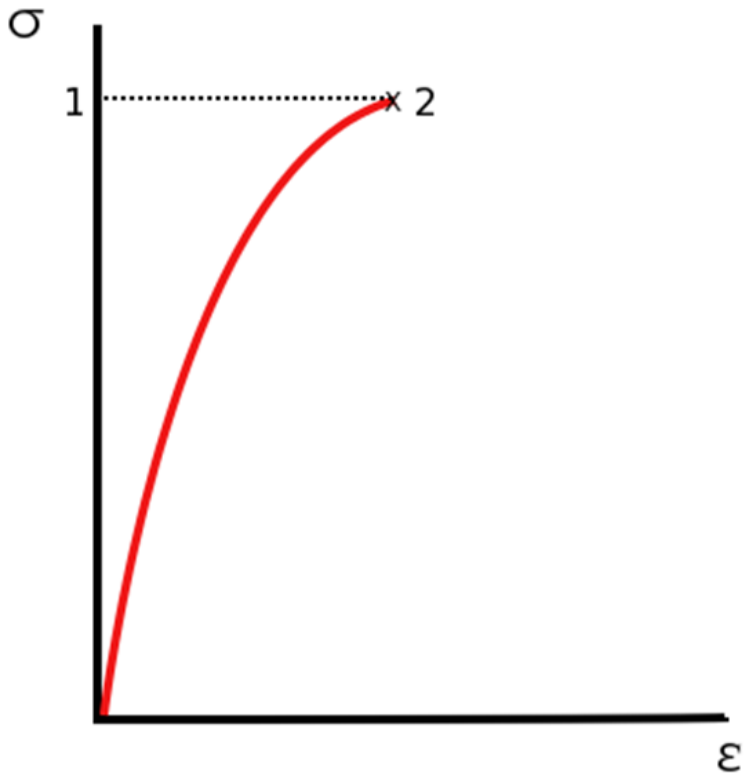
It is the opposite of ductility, it requires lack of plasticity



انخفاض قابلية المادة على التشوه اللدن.

Ductility of metals in decreasing order	Malleability metals in decreasing order
Gold	Gold
Silver	Silver
Platinum	Aluminum
Iron	Copper
Nickel	Tin
Copper	Platinum
Aluminum	Lead
Zinc	Zinc
Tin	iron

المواد القصفة-Brittle



- المواد القصفة وتشمل حديد الزهر، الزجاج والحجر. وتتميز بوصولها لمنطقة الكسر من دون اي تغيير ملحوظ في استطالتها. المواد هشة مثل الخرسانة و ألياف الكربون لا تملك نقطة خضوع، لذلك فان منطقة اقصى اجهاد هي نفسها منطقة اجهاد الكسر. المواد الهشة مثل الزجاج لا تظهر اي اجهاد في منطقة البلاستك بل تفشل في نطاق منطقة المرونة. أحد مميزات لفشل المادة الهشة هي انه يمكن تجميعها لإعادة تصنيع المادة بنفس الشكل حيث لن يحدث تعنق كما في المواد المطيلية. منحني الاجهاد انفعال لهذه المواد عادة سيكون خطي.

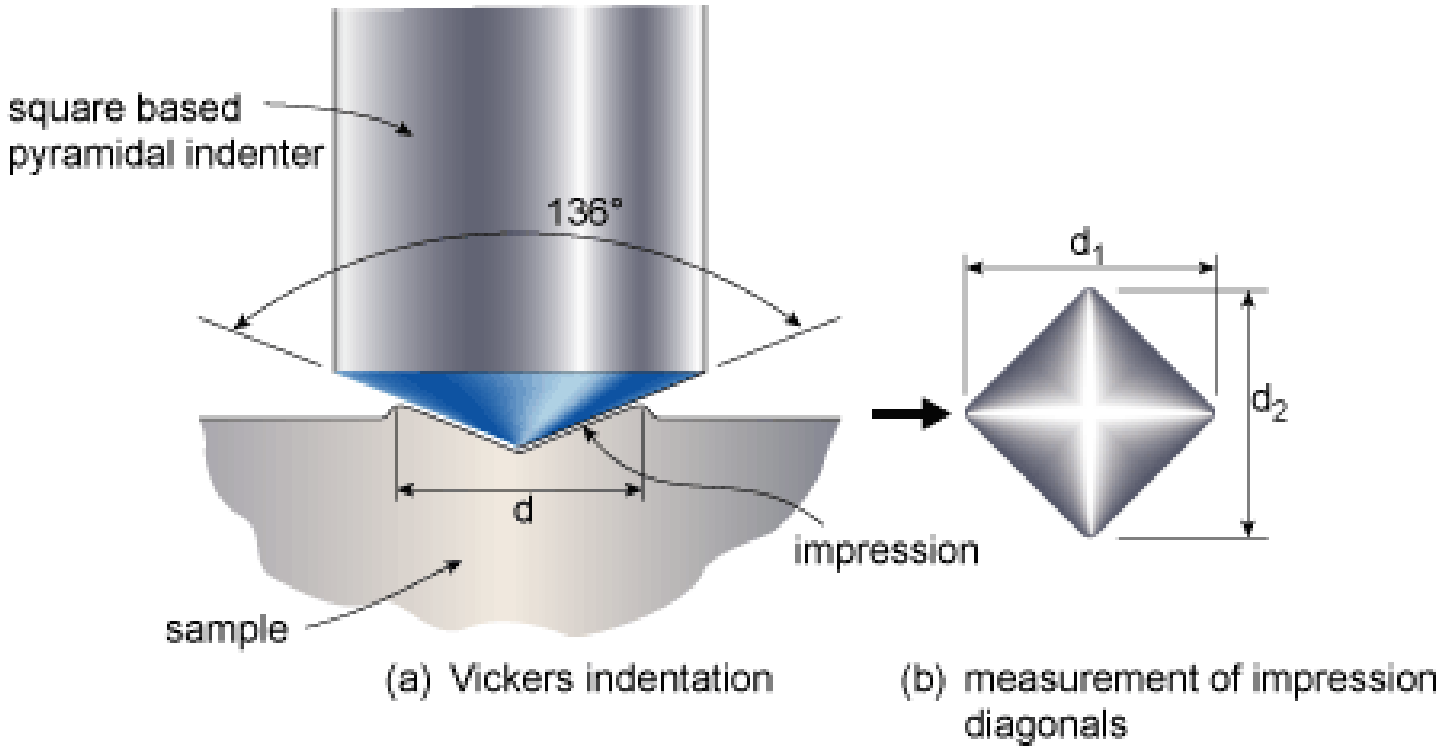
13-Hardness-القساوة

is the measurement of **how much a material resists to penetration from a semi-static force.** It is tested for with an indenter hardness machine usually (but not solely) by measuring the size of the indentation after releasing the load.

The most well known of the hard materials is **diamond**. It is so hard it is usually used as the penetration material (for the Vickers Hardness, for example). A typically soft material is aluminum metal, or any plastic.

Hardness correlates well with scratch proof ability meaning that harder materials are harder to scratch. It also correlates well with the yield strength (σ_y, that is the value of stress after which is deforms permanently) or the ultimate tensile strength of the material (that is the maximum load it can bear in a tensile test) through the empirical equation $Hv=\sigma_y/3$. So harder materials are also stronger materials.

Opposite of soft •



conclusion

Mechanical properties are very important in understanding and predicting a materials behavior under various conditions ,therefore it helps in **diagnosis of clinical failure**, whether they are caused by material deficiencies or human error ore patient factors thus it help in understanding the design modification that **will improve the fracture resistance of restoration and longevity**

Setting Time

زمن التصلب

Setting Time

It is **the time from the beginning of mixing the until the material hardens**. Setting time of gypsum products are often measured in term of their ability to resist penetration and divided into: Mixing time from addition of powder to the water until a homogeneous mix.

Working time

زمن العمل

Working time or initial setting time is **the length of time from the start of the mix until the setting mass reaches a semi-hard stage**. It represents the available time for manipulating the product, and it indicates partial progress of the setting reaction

The Fatigue-(الكلل) التعب

Fatigue can be explained as the **weakening of a material due to the application of fluctuating loads that result in damage to the material's structure and eventual failure.** The damage starts locally and builds up over time and can end in a catastrophe.

التعب (الكلل)-The Fatigue

هو صعوبة عودة المادة إلى شكلها الأصلي بعد تعرضها إلى قوى دورية تفوق حد التناسب.

فعند بداية تعرض جسم ما لهذه القوى الدورية يتشكل تصدع صغير لا يلبث أن يتنامى تدريجياً، مع استمرار تطبيق هذه القوى يحدث تشوه دائم في الجسم.

Mechanical Properties of Dental Materials

The End

Prof. dr. Elian Abusamra

2021-2022