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Review Article

# Strength of Restorative Materials

**Mohamed Hany Ahmad Abd Elghany[1]*, Abdulrahman Abdulghani Sarhan[2], Ahmed Dhdooh Soffiany[2], Abrar Yousef Johari[2], Wabel A Alharandah[2], Abdullah Saad Alruhaymi[2], Ali Hamza Algilani[3], Motaz Abdullah Alowein[4], Amal Ghalib Alharbi[4], Areej Ayidh Dirham[5], Ayat Ahmed Alakeely[6] and Hussam Nasser Kurdi[7]**

*[1]Cairo University, Egypt*

*[2]Ministry of Health, Saudi Arabia*

*[3]Ibn Sina College, Jeddah, Saudi Arabia*

*[4]Prince Sultan Military Medical City, Saudi Arabia*

*[5]King Abdulaziz University, Saudi Arabia*

*[6]Wroclaw Medical University, Wrocław, Poland*

*[7]Imam Abdul Rahman bin Faisal University, Saudi Arabia*

***Corresponding Author:** Mohamed Hany Ahmad Abd Elghany, Cairo University, Egypt.

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## Abstract

**Introduction:** The development of a variety of products in the market makes the selection of the materials a very complicated procedure. The oral cavity puts a plethora of forces and stress on the restorations which are very difficult to simulate in the laboratory environment and different restorative materials are supposed to be used in different clinical scenarios which in turn necessitates that the clinician has the basic knowledge of the mechanical properties of materials used to make the right choice of the material.

**Aim of the Work:** This review article focuses on the knowledge of the basic mechanical properties of dental materials that are used in clinical practice.

**Methodology:** The review is a comprehensive research of PUBMED from the year 1998 to 2019.

**Conclusion:** The rising awareness and development of so many new materials in the market make the dentists nowadays have a lot of options to choose from as restorative material. It is highly important that the basic knowledge of the materials should be present which makes it easier for the dentist to come to a final decision of the choice of the material.

***Keywords:*** *Flexural Strength; Compressive Strength; Poisson Ratio; Cention N; Shear Stress; Fatigue Resistance*

## Introduction

The strength of restorative material is of utmost importance in the world of dentistry. Different properties of dental materials have been studied in the recent literature which largely has an influence on the performance and sustainability of any dental material [1,2]. With the increase in the number of dental products that are developing every day the number of studies has also increased. Before any dental practitioner puts the material to use, he should be through with all the studies and clinical studies associated with the material [3].

The development of a variety of products in the market makes the selection of the materials a very complicated procedure. The oral cavity puts a plethora of forces and stress on the restorations which are very difficult to simulate in the laboratory environment and different restorative materials are supposed to be used in different clinical scenarios which in turn necessitates that the clinician has the basic knowledge of the mechanical properties of materials used to make the right choice of the material.

## Methodology

A comprehensive and systematic search was conducted regarding strength of restorative materials using PubMed search engine (http://www.ncbi.nlm.nih.gov/) and Google Scholar search engine (https://scholar.google.com) were the mainly used database. All relevant available and accessible articles were reviewed and included.

The terms used in search were: Flexural strength, compressive strength, Poisson ratio, Cention N, Shear stress, Fatigue resistance.

### Mechanical properties

The continuous mastication action present in the oral cavity predisposes the restorative materials to a certain amount of stress. The forces acting on the material cause various alterations in the structure of the material which reduces the durability of the material [4,5]. Some basic concepts should be introduced to understand the durability and longevity of the dental materials when used clinically. Stress is defined as the force which is applied per unit area of the material. When a specific amount of stress is applied on the tooth there is a change in the length of the material; this change in length per unit of the length is called strain. The ratio of stress to strain in a material is important to know the mechanical properties of the material [5]. The stress-strain relationship establishes a stress-strain curve. When a body is under stress, and there is no change in the resultant form of the material, it is called the elasticity of the material. This proportion happens until a fixed limit, which is termed as the proportional limit, and the deformation in shape that takes place is called elastic deformation (Figure 1). Till this point is reached, stress and strain are proportional to each other, and that determines the elasticity of the material, which is calculated by the stress-strain curve within the elastic limit. The proportionality seen is known as Young's modulus [5].

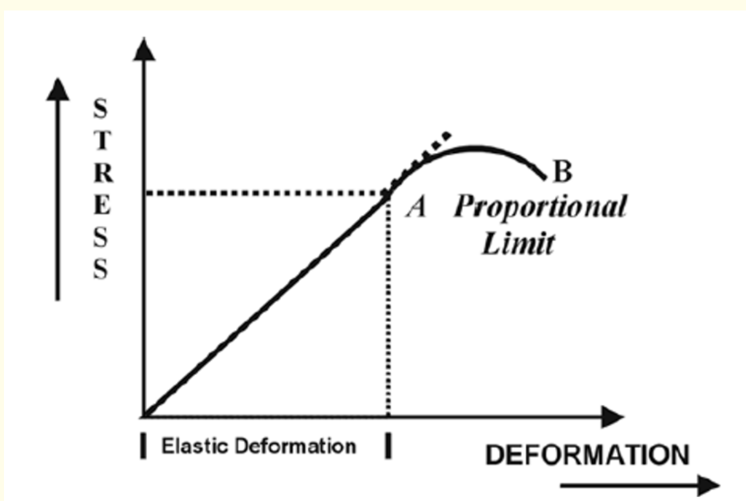


***Figure 1:*** *Stress-strain curve [6].*

### Tensile strength

When axial forces are applied on the tooth in a straight line and in the opposite direction there is a tension that occurs in the material. The resistance of the material to this stress is called tensile strength. The alteration in the length of the material at the point just before the material ruptures is called as the elongation of the material [7]. The numerical value of tensile strength is the load that is applied to the material by the unit area on which it is applied. Using the value of the stress and strain, a curve can be established, and this curve helps in the calculation of the resilience of the material, the elastic modulus and toughness. The ductility of the material is also an important factor to be considered in metallic restorative materials. Ductibility of the material is the potential of the material to change its form until any fracture occurs under tensile forces [7].

### Diametrical compression test

When materials rupture under low tension, they are characterized as fragile and are brittle. Since these cases have a low cohesive force, tensile strength is not advised to evaluate the reaction of the material. Compressive testing can be used to calculate tensile strength, which is called the Diametrical Compression. In this test, the sample is used in the form of a disk, and diametric compression is placed on it which produces tensile strength in the material [8] (Figure 2).

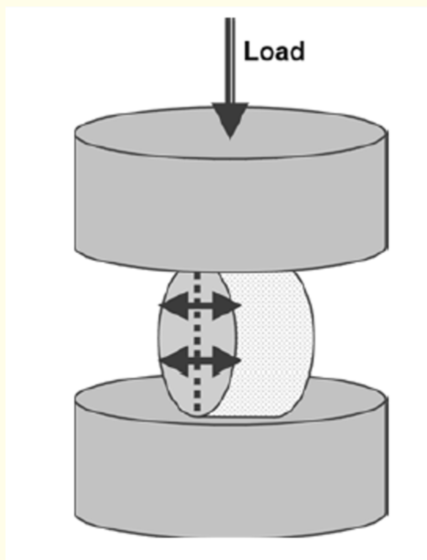


***Figure 2:*** *Diametrical compression test [6].*

### Compressive strength

If the pressure applied to the body tends to shorten or compress it, the resistance applied by the material is called Compressive stress. Similarly, like tensile strength, the compressive strength of a material is calculated by diving the load applied by the cross-sectional unit area [8].

### Shear strength

The resistance produced in the body of a material that is exposed to forces like twisting and sliding is called shear stress. In clinical practice it can be seen on the surface of the tooth. Failure of shear stress is generally seen in the resin luting cement when a sharp instrument is used to apply force parallel to the tooth surface which leads to debonding of the bracket [9].

### Flexural strength

The amount of stress a material can endure before bending is called the flexural strength of that material [9]. The flexibility a material achieves just before the proportional limit is achieved is defined as the flexural strength [10]. In the dental practice flexural strength is put into practice when a material is continuously twisted, bent or flexed. Dental materials are required to have a high flexural strength since they are constantly under chewing stress. The three-point bending test is used to evaluate the flexural strength (Figure 3). It uses specimens in the shape of bar, the bar is placed on two supports and a central load is applied. The amount of load that is applied to the material just before it fractures is calculated as the flexural strength [10].

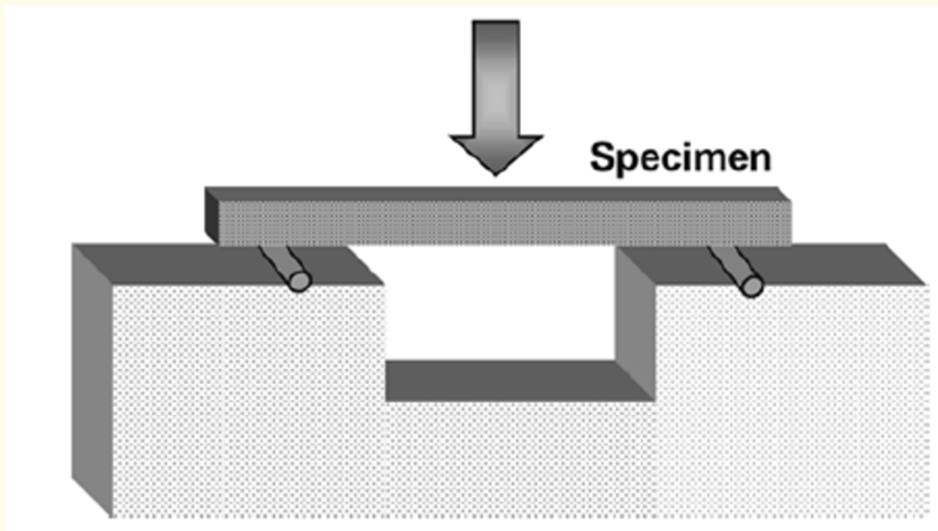


***Figure 3:*** *Three-point bending test used to calculate tensile strength [6].*

### Poisson ratio

A dental material when placed under tensile or compressive stress, a strain is developed in the material in the axial direction and sometimes in the lateral direction [10]. The application of tensile strength leads to elongation of the material in the axial direction and cross-sectional reduction. On the contrary, when a compressive force has applied, the length of the material decreases, and there is increase in cross-section. This reaction when occurring within the elastic limit ratio between axial and lateral strain is defined as the Poisson ration. In the clinical scenario, it can be used to see how brittle is material since the material, which is brittle, shows less reduction in cross-section than ductile materials [11].

### Fatigue resistance

Because of the complex environment in the oral cavity and various different forces that are applied on an individual tooth, any particular process of material failure is very complicated to define, and laboratory studies cannot be correlated with the clinical situation [12]. Behaviour of the material under stresses of lower value shows the resistance to fatigue and is evaluated as fatigue limit, with no fractures at a fixed number of stress cycles. The compressive fatigue limit is calculated when the material is put under a cycle of compressive stress. When defects are present in the microstructure of the material, there may be development of cracks, these cracks when exposed to more stress can lead to fracture of the material [12].

### Comparison of strength of restorative materials

Various studies have been conducted to compare the mechanical strength of different restorative materials in clinical situations. Amalgam is the oldest restorative material used and has the highest compressive strength. The fatigue strength of amalgam is the main cause of the failure of amalgam restorations. Because of the high mercury content, amalgam fracture is seen more because of high level of tarnish and corrosion when occlusal applied to it [13]. The invention of bonding agents in the recent past has increased the strength of restorative interface of the materials. Application of bonding agents leads to increase in the fracture resistance and decrease in microleakage of the material [14]. Teeth that are restored with bonded amalgam compared to the ones that use conventional amalgam restorations have more fracture resistance. This adhesive mechanism has a micromechanical bond with the tooth. For aesthetic restorations, Composite resin is the gold standard [15], Glass Ionomer Cement is also used, but higher failure rates are seen in glass ionomer cement restorations because of the low compressive strength of the material [16]. Recently developed Alkasite cement, Cention N has also been used as an alternative for restoration of teeth after endodontic treatment since it has a fracture resistance comparative to Composite resin and is esthetically more acceptable compared to GIC [17,18]. The mechanical properties of various restorative materials have been described in table 1.

| Dental Material | Tensile Strength (MPa) | Compressive Strength (MPa) | Shear Strength (MPa) | Elastic Modulus (GPa) |
|---|---|---|---|---|
| Enamel | ~10 - 15 | ~350 - 400 | ~90 - 100 | ~4 - 8 |
| Dentin | ~45 - 55 | ~250 - 300 | ~100 - 150 | ~1 - 2 |
| Composite | ~40 - 50 | ~200 - 250 | - | ~10 - 15 |
| Amalgam | ~50 - 55 | ~300 - 350 | ~150 - 200 | ~30 - 40 |
| GIC | ~10 - 20 | ~125 - 150 | - | ~15 - 25 |
| Porcelain | ~20 - 30 | ~125 - 160 | ~110 - 125 | ~120 - 180 |

***Table 1:*** *Comparative mechanical properties of dental materials [17,18].*

## Conclusion

The rising awareness and development of a plethora of new materials in the market, the dentists nowadays have a lot of options to choose as the restorative material. It is highly important that the basic knowledge of the materials should be present which makes it easier for the dentist to come to a final decision of the choice of the material. Different materials react differently under stress produced in the oral cavity, although there is a lot of difference between the environment of the oral cavity and mechanical set up the basic knowledge of the tests to be performed makes the decision easier for the dentist.

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