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Review Article

# Hardness of Dental Materials is an Essential Property that Determines the Life of Restorations - An Overview

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## Abstract

Hardness is an important mechanical property, which has to be ascertained for the dental materials to ensure longevity of restorations placed in the mouth. Technically it is evaluated by making surface indentations and calculating the resistance offered by the material. Many time-tested tests are available to assess hardness. Such engineering tests are modified to the oral situations. An overview of hardness testing is given in this article.

**Keywords:** Hardness; Wear Resistance; Scratch Resistance; Abrasion Resistance; Indentation Testing

## Introduction

Hardness is defined as a measure of how well materials resist localized deformation - with minerals it is scratches and with metals it is indentations. In fact, the test of hardness indicates how the material performs with a select test. Hardness is a consolidated manifestation of different properties like compressive strength, proportional limit, and ductility. International standard organisations have included hardness in the specifications for dental materials. Test methods of hardness are described on the basis of the ability of a material surface to resist penetration by a specified indenter. Commonly used tests to determine hardness of dental materials are: Brinell, Rockwell, Vickers, Knoop, Barcol and Shore.

### Rockwell hardness testing (HR)

This testing has been in use for more than a century. It is a rapid testing method and used as a quality control measure. It uses a diamond cone or steel ball and apply a minor load of 3kgf and subsequently a major load exceeding 10kgf is applied. For experiments with dental materials, 30kgf is the preferred final load. Based on the changes in depth that has occurred between the minor and major loads, the Rockwell hardness number is calculated. This test is mainly used for metals. The convenience of measuring the depth of penetration has made this test very popular but it is not suitable for brittle materials (Figure 1,2).

### Brinell hardness testing (HBW - Hardness Brinell Wolfram Carbide)

Brinell hardness testing can use loads up to 3000kgf. Brinell indenters are tungsten carbide spheres with diameter of 1.6 - 10mm that leave a relatively wide and deep indentations and hence used for larger samples. The indentation is measured using Brinell microscope. Usually, two diameters which are mutually perpendicular are used to calculate the Hardness number. Brinell is suitable for inhomogeneous metals and metals containing coarse structural elements for example castings and forgings (Figure 3).

**Figure 1:** Rockwell hardness tester.
(https://www.huyett.com/blog/rockwell-testing)

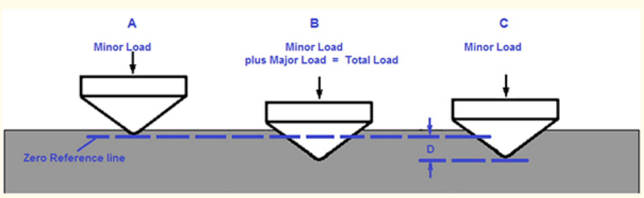


**Figure 2:** Rockwell hardness indenter position.
(https://www.huyett.com/blog/rockwell-testing)

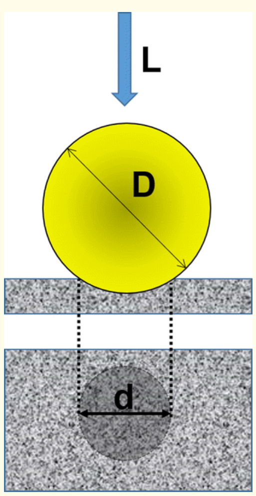


**Figure 3:** Brinell hardness testing - spherical indenter.
(https://www.giessereilexikon.com/)

## Knoop hardness testing (HK)

Knoop hardness testing was developed specifically for fragile materials like ceramics, plastics, thin metal sheets or surface coatings. In general, Knoop microhardness testing uses loads of no greater than 1kgf and the indenter is of elongated pyramidal shape. The longest diagonal of the diamond shaped indentation is measured by a calibrated microscope., Elastic recovery occurs in the direction of the shorter diagonal, when the indenter is removed. The hardness of tooth enamel can be compared with that of gold, porcelain, resin, and other restorative materials using this test. The load may be varied over a wide range to suit the material to be tested (Figure 4).

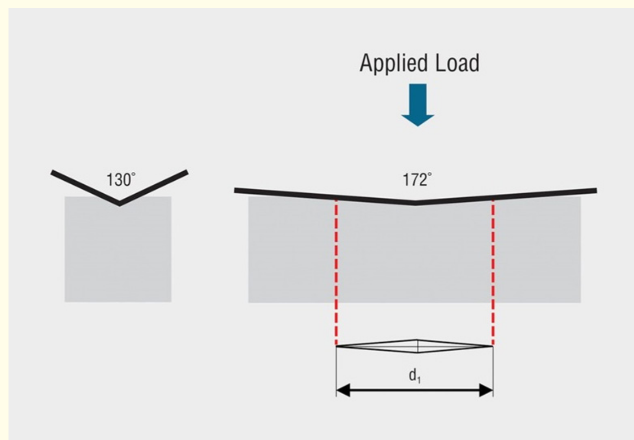


**Figure 4:** Knoop hardness testing.
(https://en.m.wikipedia.org/wiki/
File:Knoop_hardness_test_indenter.svg)

## Vickers hardness testing (HV)

Vickers hardness testing and Knoop microhardness testing performs almost similarly. A Vickers probe has a shape of uniform pyramid which is pressed on the surface of the material and allowed to dwell for certain period of time before it is removed. Length of the diagonal of indentation is measured to calculate hardness. Both the diagonals are measured using a microscope. The load applied is not more than 1kgf. Vickers is very well suited for dental materials. With one indenter, this can be adapted to micro or macro ranges by varying the loads. The Vickers test has been used to determine the degree of polymerization of resins. The diamond tip remains

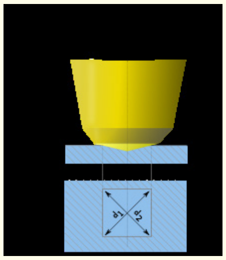

**Figure 5:** Vickers hardness indenter.
(https://link.springer.com/article/10.1007/s11249-016-0805-5)

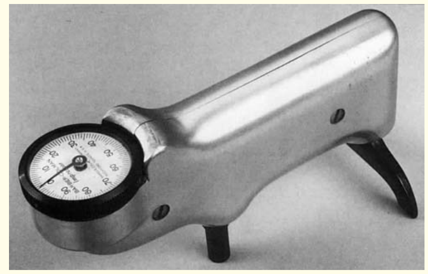

**Figure 6:** Barcol hardness tester.
(https://www.checkline.eu/prod/durometers/positector-bhi)

without deformation for a long time and hence the measurements are considered accurate (Figure 5).

### Barcol hardness testing

The Barcol is a small portable Hardness Tester having a weight of around 1 Kg. Barcol Hardness tester is designed for testing the hardness of rigid plastics, fiber-reinforced polymer composites and soft metals such as copper, brass, aluminium and aluminium alloys. Barcol hardness testing of a material determines its ability to resist deformation. Another use of Barcol Hardness Testers is to measure the degree of curing and cross-linking. It is a known fact that hardness increases with the progress of curing.

Apply uniform pressure after placing the specimen under the indenter of the Barcol hardness tester. The depth of the penetration is then converted into Barcol numbers. Specimens should have a minimum thickness of 1/16$^{th}$ of an inch. This is a hand operated instrument.

Barcol is an indentation-type of hardness testing, where uniform pressure is applied on the surface of a specimen till the dial indicator gives maximum reading (0 to 100). The Barcol number is thus automatically generated by the Barcol instrument. Both analogue and digital models are available (Figure 6,7).


**Figure 7:** Digital Barcol hardness tester.
(https://www.indiamart.com/a1qualiity-instruments/hardness-tester.html)

### Shore hardness testing

Hardness of Polymers like rubbers, plastics is measured by Shore testing. As with other hardness testing, Shore hardness is also a measure of the resistance of a material to penetration. In this test, a spring-loaded needle-like indenter is used. 'Shore A scale' is used for the testing of soft elastomers (rubbers) and other soft polymers. Hard elastomers and other polymer materials belonging to thermoplastics and thermosets are measured by Shore D scale.

Shore hardness testing instrument is known as Durometer. Durometer has an indenter loaded with a calibrated spring. The hardness is determined by the penetration depth of the indenter happening under the load. For Shore A and D, two different indenter shapes are used having two different spring loads. The loading forces of Shore A is 1.812 lb (822g) and Shore D is 10 lb (4536g). Shore hardness value is represented by numbers ranging from 0 to 100. Maximum penetration for each scale is 0.097-0.1 inch (2.5-2.54 mm). This value corresponds to minimum Shore hardness number 0. Maximum hardness value 100 corresponds to zero penetration. Rubber bands have Shore A value of 35 and Automotive tyres have 65 Shore A value. Resilient denture liner has a Shore A value of 30-40 (Figure 8, 9).


**Figure 8:** Shore A hardness tester.
(https://www.kern-sohn.com/shop/en/measuring-instruments/hardness-testing-of-plastics-shore-/HB/)

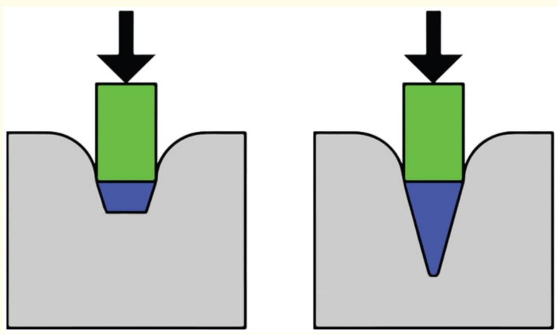

**Figure 9:** Indenters for Shore A and B hardness testing.
(https://www.gmtrubber.com/what-is-shore-hardness-rubber)

| Dental Tissues and materials | Vickers hardness values |
| --- | --- |
| Enamel | 274.8 ± 18.1 |
| Dentin | 65.6 ± 3.9 |
| Amalgam | 90 |
| Dental Ceramic | 420 |
| Gold alloy | 130-135 |
| Denture teeth | 17 - 47 |
| Composite resin | 86.3-124.2 |
| Zirconia | 1250 |
| Titanium alloy | 349 |
| Glass ionomer cement | 34 - 56 |
| Denture base resin | 18 |
| Provisional resins | 5 - 15 |
| Human mandible | 14 - 33 |

**Table 1:** Hardness values of dental materials and tissues [1,2,3].

## Abrasion resistance

Harder materials offer more resistance to abrasion when compared to softer materials. Abrasion resistance (wear resistance) is of great interest to dental professionals because dental restorations are to be functional against food, opposing teeth, dental materials such as ceramic crowns or porcelain denture teeth. Abrasion resistance gains relevance in the case of natural teeth which oppose dental restorations. If a restorative material is too hard, it may cause wear of the opposing teeth at an unacceptably accelerated pace. Excessive wear happening on the natural teeth that oppose porcelain restorations is a classic example of this. Hardness of the restoration must be optimum so that it will not wear away easily and at the same time will not cause wear of natural dentition situated in the opposing arch. This is a classic example of the *Goldilocks principle:* not too hard; not too soft; just right. In other words, properties of a material should fit within a particular range of values. Maximum value is not always considered as ideal for the material of choice.

The Goldilocks principle is named by analogy to the children's story "The Three Bears". The story goes like this" a young girl named Goldilocks tastes three different bowls of porridge and finds she prefers porridge that is neither too hot nor too cold but has just the right temperature". That is how the usage has become popular. It is applied across many disciplines, viz. biology, economics and engineering and in particular, developmental psychology,

**Figure 10:** Enamel wear due to erosion.
( https://www.aegisdentalnetwork.com/id/2012/05/chairside-cad-cam)

**Figure 11:** Worn off amalgam restoration. https://www.aegisdentalnetwork.com/id/2012/05/chairside-cad-cam

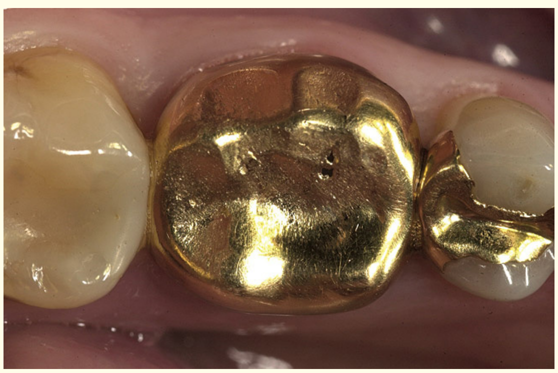

**Figure 12:** Worn off gold crown. https://www.aegisdentalnetwork.com/id/2012/05/chairside-cad-cam

## Human teeth

Enamel is the hardest material in the human body and it helps in grinding food while protecting dentin. Enamel can resist wear and dentin can absorb bite forces. Replacing restorative material for enamel should have a hardness value that is similar to or lower than that of enamel. However, the elastic modulus of restorative material should be similar to or more than that of dentin. The hardness value of zirconia is approximately 4.5 times higher than that of enamel and approximately 20 times higher than that of dentin. In view of the high mechanical properties and hardness when compared to dental tissues, Zirconia cannot claim superior compatibility.

In the case of dental implants made of titanium alloys, having higher mechanical properties and hardness, bite forces can induce stresses in the jawbone. Therefore, a new implant material that has mechanical properties similar to dental hard tissues with osseointegration capability needs to be developed for efficient functional recovery through dental treatment.

Future restorative materials should have properties matching those of enamel and dentin with acceptable colour. Hardness is a critical property to be considered while selecting materials for crowns, FDPs and intra coronal restorations**.** Sufficient hardness ensures that the dental restorations remain successful for a reasonably long-time offering resistance to scratches and abrasion experienced during mastication [1-8].

## Conclusion

Many classic hardness testing methods are available in the field of engineering and they are adapted to suit the dental materials because their functional relevance remain in the oral cavity. Hardness will decide the success of dental restorations which have to function against the hardest material available in the human body.

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