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MECHANICAL PROPERTIES OF SOME COMPOSITE MATERIALS

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Abstract: The paper deals with the study of mechanical properties such as hardness and breaking strength of dental restorative cements and milk tooth. While hardness of tooth can influence caries susceptibility because of the exposition of enamel to environment oral factors, the breaking strength is often used as a measure of the ability of a material to withstand the forces of mastication. Hardness measurement was performed using a Vickers hardness tester and the breaking strength was calculated using a universal testing machine. Dental cement with greater hardness and strength is desirable for better durability over time. Glass ionomer cement with its higher value of hardness [83.2 ± 3.30 Kg mm^{-2}] and breaking strength [282.8 ± 7.50 MPa] may be a cement of choice for filling of cavities.
Keywords: Glass ionomer, Zinc Polycarboxylate, Vickers Hardness, breaking strength.

1. Introduction

Many materials used in dentistry are not homogeneous solids but consists of two or more essentially insoluble phases. There may be one continuous phase and one or more dispersed phases or there may be two or more continuous phases, with each of this phases containing one or more dispersed phases. These materials are called composites and the physical and mechanical properties of the composites are different from those of the separate phases. The trend in the development of materials for various applications is towards composites rather than completely new classes of materials. Since most of the mastication forces are compressive in nature, it is important to investigate materials under this condition. Compressive strength is a useful property for the comparison of dental amalgam and cements and for determining the qualities of other materials such as plaster, impression materials, or waxes.

Study and analysis of hardness of teeth and restorative materials is very important for understanding how masticatory strains are distributed throughout the tooth, and for predicting how stresses and strains are altered by dental restorative procedures, age and disease. Hardness may be defined as the resistance to permanent indentation or penetration. Some of the methods of testing the hardness of restorative materials are Brinell, Knoop, Vickers,

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Rockwell and Shore A hardness test. Saraswati Venkataraman [1] determined the Vickers hardness number of tooth using a Leitz tester at 100 g and noticed a difference in hardness number of tooth enamel, dentin and pulp because of difference in HAp content. Yli-Urpo et al [2] studied the compressive strength and surface characterization of glass ionomer cements modified by particles of bioactive glass and noticed a decrease in compressive strength of the specimens with increasing amount of bioactive glass. In the present study an attempt has been made to determine the Vickers hardness and breaking strength of dental restorative cements and milk tooth. Experiment was carried out at Vimta Lab, Hyderabad. Analysis of the results would help to suggest the cement that would withstand the forces of mastication and that could be used for filling of cavities.

2. Materials and Methods: The materials used in the present study were zinc polycarboxylate cement (Carboco-Germany), zinc phosphate cement (Harvard cement-Berlin), glass ionomer (GC Fuji II-Tokyo) and milk tooth. The dental cements and the liquids were mixed with a metal/plastic spatula on a glass plate according to their respective manufacturer's instructions. Zinc polycarboxylate cement was taken in the ratio of 3.0 gm. powder to 1.0 gm. liquid, zinc phosphate in the ratio of 2.1 gm. powder to 1.0 gm. liquid and glass ionomer in the ratio of 2.7 gm. powder to 1.0 gm. liquid. Immediately after mixing, the cement mixture was condensed in aluminum mold of a fixed diameter and thickness. To avoid cavities, smooth flat glass plates were placed above and below the mold and a uniform hand pressure was applied. Any extruded bulk cement was removed and the disc shaped samples were stored at room temperature. Milk teeth of children in the age group of 7 to 11 years were collected and circular and rectangular shaped samples were made out of them.

2.1. Measurement of Vickers hardness:

Micro hardness measurements were performed using a Vickers cum Brinell hardness tester (HPO-250, Blue star). The Vickers hardness is denoted by the quotient obtained from dividing the value of test load of the pyramidal indentation on the test surface formed by the pyramidal diamond indenter of the facing angle (θ = 136 degrees) by the surface area obtained from the diagonal length of a permanent indentation and can be calculated by the following equation: $\mathbf{HV = 0.1891\ F/d^2}$, where HV = Vickers hardness (kg/mm^2), F = testing load and d = average of diagonal length of indentation.

The disc shaped dental cement samples, flat and plain on both the sides, were taken and slightly polished on the surface with a cloth to remove irregularities and non-adhered particles on the surface. The samples were kept on the anvil of the Vickers cum Brinell hardness tester, focused with the help of rotating wheel. The load was set at 5 kg and the hardness measured was designated as HV 5 (Vickers hardness at 5 kg load). The diagonal lengths of indentation were measured by a micrometer attached to the machine. Average diagonal length was calculated and Vickers hardness was noted from the equipment manual based on diagonal length and load. The load holding time was 10 seconds which was maintained to be constant for all measurements. The milk tooth samples being irregular were mounted in cold setting compound and then polished. The sample was thus made flat and Vickers hardness of dentin was measured.

2.2. Measurement of breaking strength:

Measurement of breaking strength was carried out using a universal testing machine (UTN 60T- FIE) operated at a head speed of 10 mm per minute. The disc shaped dental cement samples were placed between two flat and smooth plates and subjected to compression load. As the samples continuously take load without getting broken, the load at which the samples break / get powdered was noted. Milk tooth samples which were brought to a definite shape contained both enamel and dentin and were subjected to breaking strength test. The load at which sample breaks is considered as breaking load and the breaking strength is calculated from the relation.

Breaking Strength = (Breaking load / cross sectional area) x 9.8

3. Results and Discussion: Sample preparation method, or the load, and/or the position of the indentation are important for correct measurement of indentation length. Figure 1a to 1d shows the shape of indentation of Vickers hardness for a load of 5 kg applied for 10 seconds. Indentations were not obtained for lower loads since the cement samples are elastic in nature. Lower loads also influence the indentation size. Two aspects for this load influence are that the sample surface is altered during the polish process producing a coating bigger than the biggest depth reached for the indenter and secondly with lower loads, the difficulty to read the indentation marks increases. The magnification in Figures 1a to 1d is the same which allows for the assessment of hardness difference for the dental cements and dentin of milk tooth. Zinc polycarboxylate cement with a bigger indentation length has lower hardness when compared to that of zinc phosphate, glass ionomer and dentin of milk tooth.

Figure 1a to 1d: Indentation during Vickers hardness testing

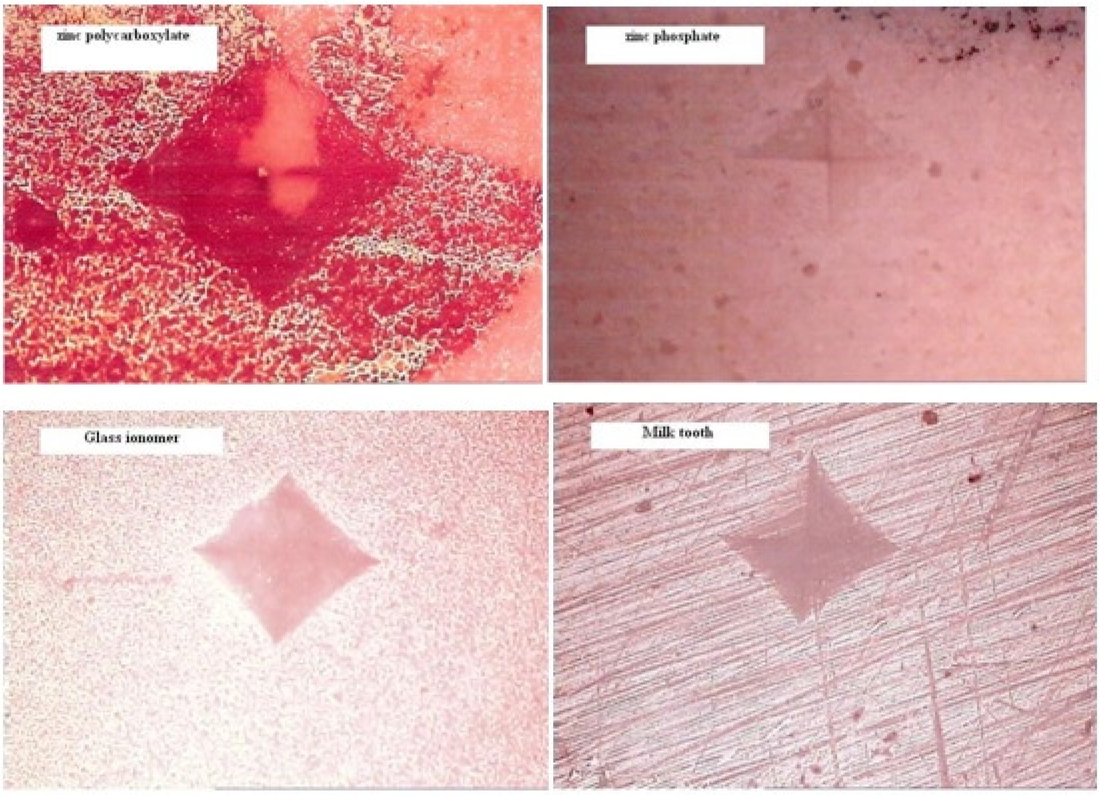

Table 1: Data on Vickers hardness and breaking strength.

Material	Vickers hardness(kg mm^{-2})	Breaking strength(MPa)
Zinc Polycarboxylate	48.4± 1.85	198.8± 4.50
Zinc Phosphate	80.42± 5.29	232.23± 13.22
Glass Ionomer	83.2± 3.30	282.8± 7.50
Milk Tooth	77.48± 1.88	118.67± 2.31

Table 1 presents data on Vickers hardness and breaking strength of dental cements and dentin of milk tooth. The Vickers hardness of zinc phosphate and glass ionomer cement with values of 80.42 ± 5.29 kg mm^{-2} and 83.2 ± 3.3 kg mm^{-2} respectively are comparable to that of dentin of children with a value of 77.48 ± 1.88 kg mm^{-2}. The Vickers hardness of zinc polycarboxylate is relatively low with a value of 48.4 ± 1.85 kg mm^{-2}. The breaking strength of glass ionomer is maximum with a value of 282.8 ± 7.50 MPa and that of milk tooth is least with a value of 118.67 ± 2.31 MPa. The samples of milk tooth consist of enamel and dentin joined in between by the wave shaped dentine-enamel junction. The breaking strength of zinc polycarboxylate and zinc phosphate is 198.8 ± 4.5 MPa and 232.23 ± 13.22 MPa respectively.

Forces on teeth are determined by muscular effort and this effort is controlled by the nervous system. The average force on a whole tooth varies according to the type of food chewed; Robert Craig [3] reported the value of 129 N for biscuit, 124 N for raw carrot and 93 N for meat. The energy of the bite is absorbed by the food bolus during mastication, as well as by the teeth, periodontal ligament and bone. The design of the tooth is an engineering marvel in that the tooth is generally able to absorb static as well as dynamic energies. Dentin is better able to absorb impact energy than enamel which is a brittle substance. Knowledge of mechanical properties of dental tissue is important to understand how mastication strain is distributed throughout a tooth and for predicting how stress and strain are altered by dental restorative procedures, age and mainly by caries disease. Hardness of tooth is the most widely studied property. The hardness can influence the caries susceptibility because of the exposition of enamel to environment oral factors.

The hardness of materials is useful to the engineer and furnishes valuable information to the dentist. The Vickers hardness of dentin of milk tooth with a value of 77.48 kg mm^{-2} is comparable to that of zinc phosphate and glass ionomer with values of 80.42 kg mm^{-2} and 83.2 kg mm^{-2} respectively. Fross et al [4] reported a value of 57 kg mm^{-2} Vickers hardness number for dentin and 294 kg mm^{-2} VHN for enamel. The difference between enamel and dentin is a result of the difference in the organic and inorganic material content. The VHN in enamel and dentin are influenced by the percentage of mineralization in these tissues. Tooth enamel is the most mineralized tissue of human body. Its composition is 96 wt. % inorganic material and 4 wt. % organic material and water. In dentin, the inorganic material represents 70 wt. % which is mainly composed by a calcium phosphate related to the hexagonal hydroxyapatite.

When a structure is subjected to compression, the failure of the body may occur as a result of complex stress formation in the body. Mechanical strength of materials can be assessed by measuring compression strength. Compression strength is often used as a measure of the ability of a material to withstand the forces of mastication. In this test, a complex stress pattern is developed. Hence, this parameter does not have a fundamental meaning, since theoretically, a material can fail only by the separation of planes of atoms (tensile failure) or by the slipping of planes of atoms (shear failure). The maintenance of compressive strength under prolonged aging is an indication of the mechanical integrity of a material. High strength bases such as zinc polycarboxylate, zinc phosphate and glass ionomer are used to provide mechanical support for a restoration. The ultimate compressive strength or breaking strength of these cements (Table 1) is greater than that of milk tooth with a value of 118.67 MPa. The strength of dental cements is influenced by the initial powder and liquid composition, the powder/liquid ratio and manner of mixing and the handling of the cement during its placement. The combination of enamel hardness 294 kg mm^{-2}as reported by Fross et al [4] and dentin hardness of 77.48 kg mm^{-2} (present study), with the additional elasticity of dentin gives the tooth properties to absorb compressive and tensile forces in an elastic and viscous way. The wave shaped border of dentino enamel junction gives it the ability to distribute and absorb the chewing forces from the harder enamel. The higher hardness value and breaking strength of glass ionomer may be attributed to the incorporation of glass particles in the glass ionomer powder and the ionic nature of the bonding between polymer chains which makes the cement rigid. Komal Ladha and Mahesh Verma [5] recommended zinc polycarboxylate cement for vital or sensitive teeth with preparation close to the pulp and for cementing single units or short span bridges in areas of flow stress.They also suggest glass ionomer cement for patients with high caries rate. Glass ionomer shows a degree of bioactivity when set that causes them to develop an interfacial ion exchange layer with the tooth, and this is responsible for the high durability of their adhesion to the tooth structure [6].

Considering the complexity of stress condition, chemical environment, design and geometry of the prepared tooth in the clinical situation, dental cement with greater hardness and strength is desirable for better durability over time. Glass ionomer cement with its higher value of Vickers hardness and breaking strength may be a cement of choice for filling of cavities.

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