Mechanical Properties of Glass Ionomer Cement for Dental Restorative Material

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Abstract- In this study, mechanical properties of glass ionomer cement (GIC) with epoxy resin were synthesized to improve mechanical properties of GIC for clinical dentistry. GIC samples were characterized by XRD, SEM and tensile tests using Universal Testing machine (UTM). The glass Ionomers cement did not show any sharp peaks on XRD pattern and demonstrated amorphous material in nature. SEM images did not depict any definite shape of used material. The EDX spectrum of glass ionomers cement displayed the main peaks of Al, Ca, F, Na and Si elements. Mechanical tests were performed using UTM Instron 5966, U.K. Young modulus was improved with the concentration of GIC (1wt. % to 3 wt. %) adding epoxy resins material. Tensile tests of glass ionomer cement showed the highest value of Young modulus at (3 wt. %) concentration of GIC due to excessive cohesive forces and higher bonding strength at higher concentration. This study concludes that mechanical properties of glass ionomer cement have been improved using epoxy resins for dental restorative material for clinical application.

Keywords- Glass Ionomers, UTM, Young modulus, XRD, SEM, Epoxy Resins.

I. INTRODUCTION

Glass-ionomer cement (GIC) is a clinically appealing dental material with unique features that make it good for therapeutic and adhesive applications. It also includes the adherence to the moist dental structure and base metals, anti-cariogenic effects due to fluoride release, biocompatibility, low toxicity, and thermal compatibility with tooth enamel [1-2]. GIC is acid-base material formed by the reaction of mild polymeric acids (PA) with basic alumino-silicate glass powders, resulting in the creation of GIC [3-4]. GIC has been in powders form containing some PA in dried form, allowing for the prevention of excessive viscosity in the acid solution for high strength. High-viscosity glass-ionomers exhibit this sort of formulation, which is often used in materials with ratio of more than 3.6-1. Among the many applications for glass-ionomer cement in clinical dentistry are full restorative materials, particularly for kids teeth, bases, liners, bonding agents for orthodontic brackets, and fissure sealants [5]. In the case of the atraumatic restorative treatment (ART) approach, they are the material of preference over several years because they have demonstrated strong durability and good clinical results [6].

A wide range of therapeutic uses of glass-ionomer cement is possible due to its physical properties by altering the chemical composition [7]. However, their uses may be limited due to their hardness and low mechanical strength [8].

Dental cement such as glass ionomer cement (GIC), or resin-based composites are the most often utilized in today's dentistry. The mechanical properties of GIC are generally inferior to those of composite materials in general [9]. Glass-ionomer cement may be used in many clinical applications due to modifying its tangible features by changing chemical composition[10]. In this work, different concentration of glass ionomer cement was ued in definite amount of epoxy resin inorder to improve the mechanical properties of the dental materials for clinincal application.

II. EXPERIMENTAL METHODOLOGY

Z-Epoxy 300, Epoxy Hardener, Glass ionomer cement (Jacek Kazimierz Kudas ul. Gorkiego 51/9 92-519), Acetone were used to prepare the samples. Glass ionomer cement was taken in powder state. While preparing the 1st sample, 5-gram of epoxy was weighted, then acetone was added to make the liquid thinner, and 4-gram hardener was added. The sample was mixed properly to make thin film for mechnical tests. Then GIC sample (1 wt. %) was prepared and added in epoxy resin. Hardener was added with a mixture of epoxy and GIC. Similarly, 3 wt.%, samples were prepared in same manner. These samples were placed in the oven for 24 hours at 40 ºC to get homogeneity in mixture of samples.

III. Results and Discussion

X-Rays Diffraction (XRD) of GIC

Nano powder of glass ionomer cement was analyzed with X-Ray Diffractometer (Equinox 300 ARL-France), using Cu as a targeted source of X-rays production with Kα_1 radiation having the wavelength of λ=1.54 ÅThe powder sample was evaluated in the angle range of 2θ=15-60° at the scanning speed of 0.02°/min and step size of 0.031° and step time of 0.3 sec. Powder sample of glass ionomer cement has crystalline nature shown in Fig.1. The glass ionomer cement sample in Fig.1 does not refelct any sharp peaks which is the poor crystallinity of the samples in XRD pattern and confirms the material is the amorphous in nature. Broad X-ray diffraction halos were produced between 20-30° (2θ) representing the typical amorphous characteristic of as-quenched glass, as shown in Fig.1. Glassy structure was achieved by melting glass and the material is amorphous because there is no crystallinity phase was obtained in XRD pattern[11]. There is no crystalline peak was obtained in XRD pattern except one broad peak 20-30° (2θ) was obtained which represents the amorphous characteristics of SiO_2 well matched with (JCPDS # 00-029-0085), which means commercially available GIC maintained non-crystalline structure having $Al_2O_3.SiO_2$ [12-13]. The presences of these materials can also be conformed with EDX spectrum. The obtained result correlated well with those described previously by M. R. A. Jabouri et al.[14].

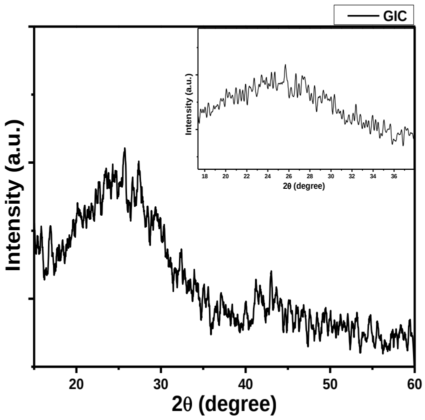

Fig.1. XRD pattern of Glass Ionomer Cement (GIC)

SEM and EDX Analysis

The surface morphology of GIC was studied through SEM model JEOL/EO version 1.1. instrument JSM-5910 at 20.0 kV in University of Peshawar. Fig. 2. shows the SEM image of GIC. In this study, SEM images reveal that the GIC has larger and more irregular particles, random in shape and no specific morphology. The size of the particles is in μm range. GIC had particles with an average diameter of 3-6 μm and irregular and amorphous structures (Fig.3.). Current experimental results were like those studied in the references[15-16]. Numerous studies about the GIC have adptaed the different glass-ionomer composition or the addition of particles (>3 μm) that may be enhaned its physical profile [17-18]. Fig. 3 showed the EDX spectrum of GIC. The desire peaks of different materials at different binding energies conformed the glass materials. The weight% and atomic% of elements in these materials are listed in Table 1.

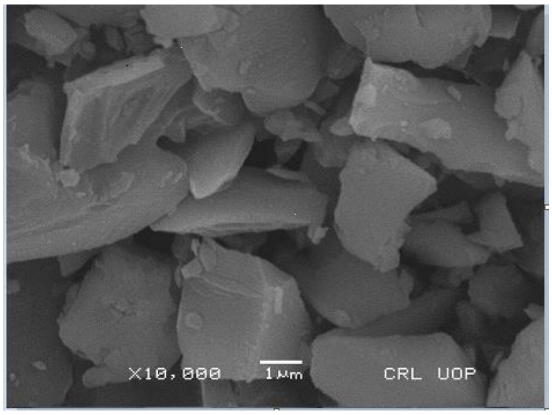

Fig. 2 SEM image of Glass Ionomer Cement GIC)

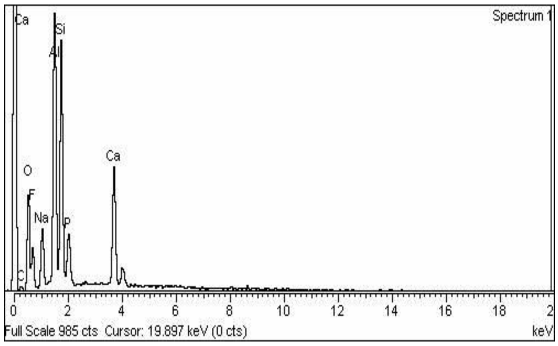

Fig.3. EDX spectrum of Glass Ionomer Cement (GIC)

Table. I. EDX analysis of GIC

Glass Ionomer Cement (GIC)		
	Weight%	Atomic
C K	3.95	7.00
O K	28.35	37.70
F K	15.04	16.84
Na K	5.46	5.05
Al K	15.46	12.19
Si K	16.33	12.37
P K	4.31	2.96
Ca K	11.08	5.88
Total	100.00	

Mechanical Properties of Glass Ionomer Cement

Mechanical properties of material are extremely significant for dental restorative material. These materials must be able to withstand the forces created during mastication in order to provide the best possible service[19]. It is observed by the nature of the material and the strength of the atomic bonds that a solid substance will remain stable under an applied force. Restorative materials used in dentistry should be strong enough to withstand the complex stresses generated repeatedly throughout the chewing process, called mastication forces. During chewing, an average force of approximately 200–400 N was observed[20].

A significant number of dental restoration materials have been investigated for their mechanical qualities, including tensile strength, fracture toughness, flexural strength, and compressive strength[21-22]. Over the past few years, numerous efforts have been made to improve the mechanical features of GICs, each with its own set of advantages and disadvantages. Irie et al. reported on the insertion of amalgam silver and metal powders into GIC powder which had a poor aesthetic appearance and a little bonding strength [23]. When a load is applied to a receiving body, it causes tension in the receiving body and a reaction in the opposite direction of the applied force. Examining the characteristics of the applied load might be beneficial in determining the amount of stress generated by the provided specimen. Specifically, in the present experiment, epoxy resin was added in the manufactured glass ionomers cement in order to enhance the mechanical features of epoxy-based GIC and to determine its physicsl strength such as maximum load, stress at maximum load, strain at break and automatic modulus[24].

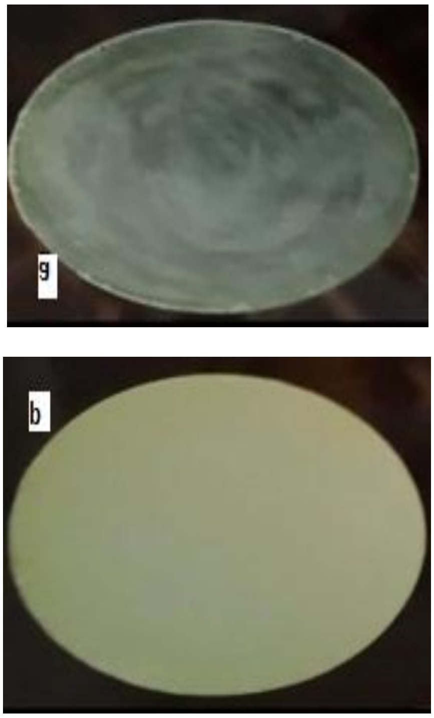

Fig. 4 (a). Thin film of pure Epoxy Resin (b) Thin film of ER with GIC.

Tensile Test

The specimens were put through their paces on the Universal Testing Machine Instron 5966, United Kingdom. A thin film of 10.8 g, containing 0, 1 % wt. and 3 % wt. was made using Z-epoxy 300 for tensile testing. The results are given in Figure 4, which shows the thin film composition (a, b). The thin films were cut into the shape of a dog bone to be tested for tensile strength. Table 2. compares my tensile test findings with those of other researchers who conducted tensile testing. The Young modulus of Epoxy with GIC (3 % wt.) was found to be the highest at its strain and stress at maximum load decreases. With increasing content of GIC from 1 wt. % and 3 wt. % , the modulus value increases upto a certain value, and then further increasing content of GIC it decreases the modulus value. The tensile test of epoxy-based GIC cement revealed the high value of Young modulus at 3 wt. % concentration of GIC attributed to high cohesive forces among epoxy and GIC maerials. Resultanlty, mechanical profile of dental material need high stress load, starin at maximum load and high modul value as well low toxicity, and cost-effectiveness of restorative material for research in biomaterials [25]. Current research demontrated the prerequisite criteria to preactical use in applied dentistry .

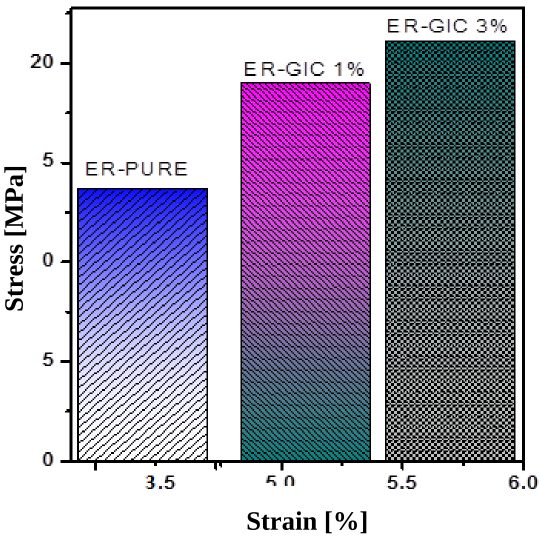

Fig.5. Stress–strain of pure ER and GIC (1 wt. %, 3wt. %)

Table-II. Tensile tests of Pure ER and ER + GIC

Specimen	Maximum Load (N)	Stress at Maximum Load (MPa)	Strain at maximum Load [%]	Strain at Break [%]	Automatic Modulus [MPa]
ER-GIC 1%	415.32	18.945	5.1	5.1	502.53
ER-GIC 3%	430.8	21.064	5.7	5.7	541.33
Pure ER	136.45	13.645	3.7	3.8	492

IV. Conclusions

In this study, mechical properties of glass inomers cement were investigated using epoxy resins. XRD pattern showed GIC is amorpous material in nature and sharp peak remained absent during XRD analysis. The EDX spectrum of glass ionomers cement displayed the main peaks of Al, Ca, F, Na and Si elements and confirmed the presence of glass material. Tensile test of glass ionomer cement improved when the concentration of GIC (1 % wt. to 3 % wt.) was enhanced due to epoxy resins. Tensile tests of glass ionomer cement showed the highest value of Young modulus at (3 wt. %) of concentration of GIC due to excessive cohesive forces and high bonding strength amnog GIC and epoxy resin. This study concludes that mechanical properties of glass ionomer cement may be enahnced with epoxy resins for dental restorative material.

V. Acknowledgments

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