

# EVALUATION OF COMPRESSIVE STRENGTH OF CONVENTIONAL GLASS IONOMER CEMENT AND RESIN MODIFIED GLASS IONOMER CEMENT

Muhammad Adnan Khan<sup>1</sup>, Bilal Zaman Babar<sup>1,2</sup>, Anum Shereen<sup>1</sup>, Hassan Maqbool<sup>3</sup>, Waseem Khan Afridi<sup>1</sup>, Saad Liaquat<sup>1</sup>, Mehreen Imran<sup>4</sup>, Nawshad Muhammad<sup>1</sup>

<sup>1</sup>Institute of Basic Medical Science (IBMS), Khyber Medical University, Peshawar, Pakistan

<sup>2</sup>Women Medical and Dental College, Abbottabad, Pakistan

<sup>3</sup>Dr Jan and Associate Dental Practice, Peshawar, Pakistan.

<sup>4</sup>Peshawar Medical and Dental College, Peshawar

## ABSTRACT

**Objectives:** To assess the compressive strength of commercial resin-modified glass ionomer cement with conventional glass ionomer cement.

**Methods and materials:** Compressive strength of two conventional glass ionomer cement (Low viscosity - GC Fuji IX GP® and high viscosity - ChemFil Rock®) and two resin-modified glass ionomer cements (Auto-cure - Fuji-Plus® and Light activated - Fuji II LC®) were investigated at 24°C and 37°C after 1 and 28 days. All materials were mixed according to manufacturer's instructions. The samples were made in 6mm height and 4mm in diameter. Universal Testing Machine (Instron, M30K) at crosshead speed of 0.5mm/min was used according to ISO 9917-1:2007 (E) standards to evaluate compression strength. Paired T-test was used to find statistical difference between the commercial groups, keeping p value of  $\leq 0.05$  as significant.

**Results:** Resin-modified Glass ionomer cement showed low compressive strength ( $113 \pm 8$  MPa) as compared to the conventional Glass ionomer cement ( $179 \pm 20$  MPa) at both room temperature as well as at body temperature. Furthermore, ChemFill Rock® has the highest compressive strength, whereas Fuji-II® has the lowest compressive strength at 1-day and 28 day respectively.

**Conclusion:** Compressive strength was low for resin-modified Glass ionomer cement as compared to conventional glass ionomer cement. Chemifil-rock® material has achieved maximum compressive strength among all the commercial materials.

**Key words:** compressive strength, glass ionomer cement, Resin-modified glass ionomer cement.

## INTRODUCTION

Dental decay is the most common non-communicable disease worldwide. If untreated, it can result in pain and infection which may lead to tooth extraction. Various materials have been used to restore the dental cavities that are result of dental caries. Some of the material include glass ionomer cement, dental amalgam, dental composite resin etc <sup>1</sup>.

Glass Ionomer cement (GIC) was developed by Wilson and Kent in 1972<sup>2</sup>. This cement contains powder and a liquid where powder mainly is composed of glass, and liquid portion comprises of polyacrylic acid. Upon mixing, acid base reaction starts that result in formation of polyalkenoate glass matrix. GIC is a dental filling material that replaces lost tooth structure after dental decay. It not only restores the tooth structure<sup>3</sup> but has the capacity to release fluoride ions that arrest the dental decay from further progressing. Bonding to dental tissues including enamel and dentine is purely chemical in nature which will require no further cavity prepara-

### Correspondence:

**Dr Muhammad Adnan Khan**

Institute of Basic Medical Science

Khyber Medical University

Cell: +92335 5505510

Email: adnan.khan.37@hotmail.com

tion, thereby conserving healthy tooth<sup>4</sup>. GIC possess the minimum expansion characteristics of any commercial material present. Furthermore, its coefficient of thermal expansion is closest with dental tooth structure in terms of dimensional changes<sup>5</sup>.

Around the period of 1988, there was a modification done in GIC to make an innovative material known as resin-modified glass ionomer cement (RMGIC)<sup>6</sup>. In contrast with GIC, RMGIC is considered tooth coloured restoration material that can inherently bond to tooth structure<sup>7</sup>. The major contrast in their compositions was the addition of hydrophilic monomer that has the affinity for both tooth structure and composite resin. Water absorption in material can cause material matrix disruption and disintegration. Absorption of water by both GIC and RMGIC can modify the mechanical, physical and chemical properties<sup>8,9</sup>.

During the masticatory load in the oral cavity, the restorative materials placed in the oral cavity must possess enough compressive strength to withstand the compressive load<sup>6,10</sup>. Application of GIC is certainly limited as restorative material because of its low mechanical characteristics in areas of the mouth where mechanical stress is maximum<sup>11</sup>. Mechanically a material must have high strength to bear the heavy loads of masticatory forces in the oral cavity during the process of chewing<sup>12</sup>. In contrast to GIC, RMGIC has improved mechanical properties<sup>13,14</sup>. A number of studies have been conducted on compressive strength of GIC and RMGIC by keeping temperature at 37°C and storing medium as ionized water. However, few studies have assessed the mechanical properties at different time points (1 day and 28 day) and saliva as a storing medium. This study assessed the mechanical properties of the available commercial material over a time at 24°C and 37 °C. Objective of this study was to assess the compressive strength of commercial GIC and RMGIC at both room temperature (24 °C) and body temperature (37 °C).

## MATERIALS AND METHODS

Two conventional Glass ionomer cements (Low viscosity - Fuji IX and high viscosity - Chemifil-rock) and two Resin-modified Glass ionomer cements (Auto-cure - Fuji-Plus and Light activated - Fuji II LC) were investigated after keeping samples at room temperature and 37°C for 1 day and 28 days.

Forty test samples were prepared with reference to ISO 7486: 1986. The dimension of sample was 6mm height and 4mm diameter<sup>15</sup>. Each sample was prepared using a metal split mold. All samples were made according to manufacturer's instructions. Mixing was done at room temperature (24 °C). An cellulose acetate strip covered the top of split mold to achieve smooth surface<sup>16</sup>. The samples of light activated RMGIC (Fuji II LC), were cured using LED (3M ESPE Elipar LED curing light type II) for 20 seconds as per manufacturer's instruction in metal split mold. Every sample was thoroughly inspected for the presence of any imperfections such as air bubbles, chipping, rough surfaces etc. Perfect samples were chosen to carry out testing for compressive strength. The samples were divided on the basis of storage time and storage temperature. According to storage time they were tested after 1 and 28 days. According to storage temperature the samples were kept at normal room temperature (24 °C) and at body temperature (37°C). The compression test was carried out according to ISO 9917-1:2007E in an automated appliance (INSTRON M30K, USA). The maximum compressive strength was recorded at a crosshead rate of 0.5 mm/min and weight of 30 KN. Compressive strength was evaluated, using the following equation;  $C=4p/\pi d^2$

Where "p" is the maximum applied force causing a fracture and "d" is the diameter of the sample.

Compressive strength was presented in MPa.

**Table 1: Compressive strength of conventional GIC & RMGIC at room temperature (24 °C).**

Formulations	Compressive strength (MPa)	
	At 1-day	At 28-days
Fuji-IX®	144 ±16	191 ±26
ChemFill Rock®	161 ±12	179 ±31
Fuji-II LC®	150 ±8	167 ±8
Fuji-Plus®	88 ±14	109 ±9

**Table 2; Compressive strength of conventional GICs and RMGICs at body temperature (37 °C)**

Formulations	Compressive strength (MPa)	
	at 1-day	at 28-days
Fuji-IX®	169 ±33	198 ±28
ChemFill Rock®	179 ±20	221 ±7
Fuji-II LC®	163 ±10	173 ±12
Fuji-Plus®	113 ±8	118 ±13

Data was presented in table form. Paired T test was used to find statistical difference between the commercial groups, keeping p value of  $\leq 0.05$  as significant.

## RESULT

Compressive strength at 24 °C: The average compressive strength of the samples in the various groups stored at 24 °C is given in Table 1. After 1-day storage, Chemifil-Rock showed the maximum compressive strength ( $161 \pm 12$  MPa), followed by Fuji-II LC ( $150 \pm 8$  MPa), conventional GIC Fuji-IX ( $144 \pm 16$  MPa) and Fuji-Plus ( $88 \pm 14$  MPa) respectively. Chemifil-rock GIC showed significantly higher compressive strength compared to RMGICs ( $P \leq 0.05$ ).

After 28 days, Fuji-IX showed the maximum compressive strength ( $191 \pm 26$  MPa) followed by Chemifil-rock ( $179 \pm 31$  MPa), Fuji-II LC ( $167 \pm 8$  MPa) and Fuji-Plus ( $109 \pm 9$  MPa) respectively. Furthermore, higher compressive strength was seen for conventional GICs and RMGICs at 28 days compared to day 1 ( $p > 0.05$ ).

Compressive test at 37 °C: After 1 day, the maximum compressive strength was observed for Chemifil-rock ( $179 \pm 20$  MPa) followed by Fuji IX ( $169 \pm 33$  MPa), RMGIC Fuji-II LC ( $163 \pm 10$  MPa) respectively. Minimum compressive strength was noted for Fuji-Plus ( $113 \pm 8$  MPa). Statistical analysis showed insignificant difference between the conventional GICs and RMGICs at 37 °C ( $P \geq 0.05$ ), apart from Fuji-Plus that differ significantly ( $P \leq 0.05$ ) from other GICs.

After 28 days, the maximum compressive strength was observed for Chemifil-rock ( $221 \pm 7$  MPa), followed by Fuji-IX ( $198 \pm 28$  MPa), RMGIC Fuji-II LC ( $173 \pm 12$  MPa). Furthermore, Fuji-Plus showed the lowest compressive strength ( $118 \pm 13$ ) among all other commercial materials. Statistical analysis at 28 days showed a significant variation between conventional GICs and RMGICs ( $P \leq 0.05$ ) and exhibited higher average compressive strength for conventional GICs compared to RMGICs ( $P \geq 0.05$ ).

## DISCUSSION

In this study, two types of materials (GIC and RMGIC) were tested in four groups depending upon the test conditions; time intervals (1 and 28 days) and testing temperatures (24 °C and 37 °C). Overall,

conventional GIC had higher compressive strength compared to RMGIC at 24 and 37 °C. Secondly, the testing variables such as storage time and temperature can significantly influence the mechanical properties of the material.

Amongst the four groups tested, conventional GIC marketed under the trade name Chemifil-rock® (Dentsply DeTrey GmbH Germany) showed the highest compressive strength at 37 °C and 4 weeks' time ( $221 \pm 7$  MPa). Although the RMGIC Fuji-Plus® (GC Corporation Tokyo Japan) had the lowest compressive strength at 24 °C and 24 hr. ( $88 \pm 14$  MPa), this value was well above 50 MPa which is the acceptable value for the lining cement according to ISO 9917-1<sup>3</sup>.

This study had observed low compressive strength of RMGIC compared to GIC, which is in agreement with work done by Xie et. al.<sup>14</sup>, Anstice et. al.<sup>17</sup> and Nicholos et. al.<sup>18</sup>. They also observed the degradation of compressive strength in RMGIC on storage in water medium. Moreover, during the primary setting, the values of compression displayed a rise mainly upon the utilization of ultrasonic and heat methodologies. As a result of these characteristics the materials durability in clinical practice would show an enhancement and even ultrasonic means would raise the properties of RMGIC by its command setting<sup>19</sup>.

High viscosity GIC in this experimentation displayed maximum average compression values ( $221 \pm 7$  MPa) in comparison to low light viscosity GIC and light and auto-cure RMGIC at 1 and 28 days. This can be contributed to the fact that Chemifil-rock® had high viscosity and faster setting reaction. Furthermore, the higher strength could be contributed to compositional zinc-reinforcement as mentioned by the manufacturer (Dentsply Detrey GmbH Germany). In comparison, an argument was made by Xu X et. al.<sup>20</sup> and reported that compression values of low viscosity GIC at 24 hours period were 168 MPa which were comparatively higher. This could be attributed to the different sample dimension and testing capacity<sup>21</sup>. Another study by Wu W et. al., Algera et. al., and Nomoto et. al.,<sup>21-23</sup> reported corresponding results to the present study where increase in the compressive strength of GIC was evident except for Fleming GJ<sup>24</sup> who mentioned low values of compression in commercial GIC and

## RMGIC.

In this study, compressive strength of commercial GIC and RMGIC were comparable to studies in literature. The average compression values in this study for low viscosity GIC at 24 hours and 37°C was about 168 MPa which were similar as reported by Xu X et. al,<sup>20</sup>. Whereas the average compression measurements of low viscosity GIC (168 MPa) and high viscosity GIC (179 MPa) at 1 day period and 37°C of this study was found to be of similar values as reported by Wu W et. al.<sup>21</sup>

However, light activated RMGIC displayed different compressive strength compared to study done by Wu W et. al. This could be due to different sample size or composition<sup>25</sup>. Dissimilar measurements were most probably related to difference in test specimen dimensions, mentioned dispensing ratio of powder and liquid around 2.7/1, different sample dimensions (4mm x 8mm) and keeping samples in deionized water as storing liquid for 1 week<sup>26</sup>.

In this study, all commercial materials showed a significant increase in compressive strength when stored at room temperature compared to storage at 37 °C. This could be due to higher solubility and wear at 37 °C.

## CONCLUSION

Conversional glass ionomer cement has higher compressive strength as compared to resin-modified glass ionomer cement. Furthermore, compressive strength value of all material reduced when immersed for a longer period of time and at a higher temperature. Among all the commercial GIC and RMGIC, Chemifil-rock material has achieved maximum compressive strength.

## REFERENCES

- Ahluwalia P, Chopra S, Thomas AM. Strength Characteristics and Marginal Sealing Ability of Chlorhexidine-Modified Glass Ionomer Cement: An In Vitro Study. *Journal of Indian Society of Pedodontics and Preventive Dentistry*. 2012 Jan 1;30(1):41.
- Wilson AD, Kent BE. A New Translucent Cement For Dentistry: The Glass-Ionomer Cement. *British Dental Journal*. 1972 Feb 15;132(4):133-5.
- Sidhu S, Nicholson J. A Review of Glass-Ionomer Cements for Clinical Dentistry. *Journal of Functional Biomaterials*. 2016 Jun 28;7(3):16.
- Palma-Dibb RG, de Castro CG, Ramos RP, Chimello DT, Chinelatti MA. Bond Strength of Glass-Ionomer Cements to Caries-Affected Dentin. *The Journal of Adhesive Dentistry*. 2003 Spring;5(1):57-62.
- Naasan M, Watson TJ. Conventional Glass Ionomers as Posterior Restorations. A Status Report for the American Journal of Dentistry. *American Journal of Dentistry* vol. 1998 Feb;11(1):36-45.
- Powers JM, Wataha JC. *Dental Materials-E-Book: Foundations and Applications*. Elsevier Health Sciences; 2015 Dec 27.
- Bücher K, Metz I, Pitchika V, Hickel R, Kühnisch J. Survival Characteristics of Composite Restorations in Primary Teeth. *Clinical Oral Investigations*. 2015 Sep;19(7):1653-62.
- Yap A, Lee CM. Water Sorption and Solubility of Resin-modified Polyalkenoate Cements. *Journal of Oral Rehabilitation*. 1997 Apr;24(4):310-4.
- Iwami Y, Yamamoto H, Sato W, Kawai K, Torii M, Ebisu S. Weight Change of Various Light-cured Restorative Materials After Water Immersion. *Operative Dentistry*. 1998 Mar 1;23:132-7.
- Jaidka S, Somani R, Singh DJ, Shafat S. Comparative Evaluation of Compressive Strength, Diametral Tensile Strength and Shear Bond Strength of GIC type IX, Chlorhexidine-incorporated GIC and Triclosan-incorporated GIC: An In Vitro Study. *Journal of International Society of Preventive & Community Dentistry*. 2016 Apr;6(Suppl 1):S64.
- Lim BS, Moon HJ, Baek KW, Hahn SH, Kim CW. Color Stability of Glass-Ionomers and Polyacid-modified Resin-based Composites in Various Environmental Solutions. *American Journal of Dentistry*. 2001 Aug 1;14(4):241-6.
- Mount GJ, Hume WR, Ngo HC, Wolff MS. *Preservation and Restoration of Tooth Structure*: John Wiley & Sons; 2016.
- Ellakuria J, Triana R, Minguez N, Soler I, Ibaseta G, Maza J, García-Godoy F. Effect of One-year Water Storage on the Surface Microhardness of Resin-modified Versus Conventional Glass-ionomer Cements. *Dental Materials*. 2003 Jun 1;19(4):286-90..
- Xie D, Brantley WA, Culbertson BM, Wang G. Mechanical Properties and Microstructures of Glass-ionomer Cements. *Dental Materials*. 2000 Mar 1;16(2):129-38..
- Yan Z, Sidhu SK, Carrick TE, McCabe JF. Response to Thermal Stimuli of Glass Ionomer Cements. *Dental Materials*. 2007 May 1;23(5):597-600..
- Chutinan S, Platt JA, Cochran MA, Moore BK. Volumetric Dimensional Change of Six Direct Core Materials. *Dental Materials*. 2004 May 1;20(4):345-51.
- Anstice HM, Nicholson JW. Studies on the Structure of Light-cured Glass-ionomer Cements. *Journal*

- of Materials Science: Materials in Medicine. 1992 Nov;3(6):447-51.
18. Nicholson JW, Anstice HM, McLean JW. A Preliminary Report on the Effect of Storage in Water on the Properties of Commercial Light-cured Glass-ionomer Cements. *British dental journal*. 1992 Aug;173(3):98-101.
  19. Kleverlaan CJ, Van Duinen RN, Feilzer AJ. Mechanical Properties of Glass Ionomer Cements Affected by Curing Methods. *Dental Materials*. 2004 Jan 1;20(1):45-50.
  20. Xu X, Burgess JO. Compressive Strength, Fluoride Release and Recharge of Fluoride-releasing Materials. *Biomaterials*. 2003 Jun 1;24(14):2451-61.
  21. Wu W, Xie D, Puckett A, Mays JW. Synthesis of Amino Acid-containing Polyacids and Their Application in Self-cured Glass-ionomer Cement. *European polymer journal*. 2003 May 1;39(5):959-68.
  22. Algera TJ, Kleverlaan CJ, Pahl-Andersen B, Feilzer AJ. The Influence of Environmental Conditions on the Material Properties of Setting Glass-ionomer Cements. *Dental Materials*. 2006 Sep 1;22(9):852-6.
  23. Nomoto R, McCabe JF. Effect of Mixing Methods on the Compressive Strength of Glass Ionomer Cements. *Journal of dentistry*. 2001 May 1;29(3):205-10.
  24. Fleming GJ, Farooq AA, Barralet JE. Influence of Powder/Liquid Mixing Ratio on the Performance of a Restorative Glass-ionomer Dental Cement. *Biomaterials*. 2003 Oct 1;24(23):4173-9.
  25. Wu W, Xie D, Puckett A, Mays JW. Synthesis and Formulation of Vinyl-containing Polyacids for Improved Light-cured Glass-ionomer Cements. *European polymer journal*. 2003 Apr 1;39(4):663-70.
  26. Zhao J, Xie D. A Novel Hyperbranched Poly (acrylic acid) for Improved Resin-modified Glass-ionomer Restoratives. *Dental Materials*. 2011 May 1;27(5):478-86.