ORIGINAL RESEARCH

Comparative Evaluation of Compressive Strength of Self-cure, Dual-cure, and Light-cure Glass Ionomer Cements in a Simulated Oral Environment: An *In Vitro* Study

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Abstract

Background: In primary dentition, glass ionomer cements (GICs) have unique benefits as a restorative material. Various types of GICs are available in the market. In pediatric dentistry, the choice of GI materials is generally focused on handling convenience with adequate consideration for mechanical qualities, including compressive strength to withstand occlusal stresses in the oral environment.

Aim of the study: To evaluate the compressive strength of self-cure, dual-cure, and light-cure GI-based cements using a universal testing machine.

Materials and methods: The study population comprised 30 cylindrical restorative blocks for compressive strength assessment. The restorative materials used for the studies were self-cure GIC (ChemFil Rock and GC Fuji IX GP Fast GIC), dual-cure GIC (Equia Forte and Ionolux GIC), and light-cure GIC (GC Fuji II LC and Ketac N 100 GIC). The cylindrical blocks were prepared using prefabricated Teflon mold measuring 4 mm diameter and 6 mm height from respective restorative materials and divided into three major groups and were subdivided into six groups comprising two materials in each group. Using an Instron universal testing machine, compressive strength was assessed. Data obtained were tabulated, and statistical analysis was done using Statistical Package for the Social Sciences (SPSS v22.0) software.

Results: On individual comparison of GI-based types of cement, Ketac N100 GIC showed the highest compressive strength, and Fuji IX GP Fast GIC showed the least compressive strength.

Conclusion: Light-cure GIC exhibited the highest compressive strength in comparison to dual-cure and self-cure GICs with regard to the nature of curing.

Keywords: Artifical saliva, Glass ionomer cement, Instron universal testing machine.

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Introduction

In the field of pediatric dentistry, glass ionomer cements (GICs) have several advantages as restorative materials, especially in primary dentition. It stands out from other restorative materials due to its unique chemical composition, which enables chemical adhesion to both enamel and dentin, caries-protective fluoride release, and the capacity to have the fluoride particles in their matrix to recharge through external exposure from other sources of fluoride.[1]

The research in material sciences has brought about modifications in the composition of GICs, thereby improving their mechanical properties and clinical success. Conventional GIC has undergone several modifications to address shortcomings in its mechanical integrity and capacity to bear fracture stresses.[2] As a result, novel GIC formulations have been developed, such as resin-modified GI and GIC strengthened with metal. GIC with metal reinforcement was first created in 1977 in order to strengthen and make them adequately radiopaque. Silver tin metal alloys were either sintered with glass to create glass cermet, or they were combined with glass powder to create a silver alloy admix. These cement varieties have quick setting periods and are opaque in nature. High-viscosity GICs and resin-modified GICs have been created in an effort to address the physical drawbacks of standard GIC.[3]

With the developments in nanoscience, the incorporation of nanoparticles has improved the physicochemical properties of GICs, resulting in material strength and high-viscosity ionomer types of cement.[4] These modifications were made to accommodate unique clinical requirements. Present-day restorative materials are well-established in pediatric dental treatment, and several clinical studies have shown that they are durable enough to be used as permanent restorations in primary teeth.[3] According to recent studies, adding nanoparticles or "nanoclusters" to glass powder or GIs increased the particle size distribution and enhanced the mechanical characteristics of dental restorative materials.[5]

In pediatric dentistry, the choice of GI materials is focused largely on handling convenience, with adequate consideration for mechanical attributes such as compressive strength to withstand occlusal stresses in the oral environment.[6] It is essential to identify the materials that have a higher compressive strength given the

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plethora of new GI materials that are now on the market. Only a small number of comparison studies based on compressive strength have been documented in the literature regarding recent GIC materials. Therefore, research was done to determine the compressive strength of six various kinds of self-curing, dual-curing, and light-curing GI types of cement.

Materials and Methods

An *in vitro* study was conducted in the postgraduate Department of Pediatric and Preventive Dentistry of a Dental college in Kerala, India. G*Power version 3.1 software was used to calculate the sample size (80% power and level of significance was set at 5%). The minimum sample size required was 30. The permission to conduct the study was given by the Institutional Review Board (KDC/IRBPED3). Simple random sampling was done.

A total of 30 cylindrical blocks were prepared using prefabricated Teflon mold measuring 4 mm diameter and 6 mm height from respective restorative materials and were divided into three major groups based on their nature of curing; namely, group A (self-cure), group B (dual-cure), and group C (light-cure), these major groups were again divided into six subgroups comprising of two materials with five samples in each group, namely group A1 (ChemFil Rock), group A2 (GC FUJI IX GP Fast), group B1 (Equia Forte), group B2 (Ionolux), group C1 (GC Fuji II LC), and group C2 (Ketac N100). For easy removal, petroleum jelly was added to the inside of the Teflon mold before any material was placed inside. After the preparation of the restorative material cylindrical blocks, the specimens were immersed in commercially available artificial saliva for 2 weeks in order to simulate the oral environment.

Determination of Compressive Strength

Utilizing an Instron universal testing machine (M/S Shimadzu company, Japan) with a cross-head speed of 1.0 mm/minute, compression strength testing was performed. The load was delivered along the specimens' long axes after each sample was positioned with its flat ends between the universal testing machine's plates. The greatest force that may have caused the specimens to shatter was noted.

The compressive strength was calculated in MPa using the following formula: $C = (4p)/(\pi d^2)$

Where d is the average measured diameter of the specimen in mm, p was the highest force applied, expressed in Newton, and π, with a constant value of 3.1. The collected results were collated and put through statistical analysis. Standard deviation and mean were used to represent the data. The analysis is performed using the Statistical Package for Social Sciences (SPSS v22.0 version). To determine the statistically significant difference between the groups, a one-way analysis of variance (ANOVA) (*post hoc*) was used, followed by an independent *t*-test. A *p*-value of 0.05 or less is regarded statistically significant.

Results

Table 1 shows the intercomparison of compressive strength between the groups. One-way ANOVA with Tukey's *post hoc* test was used to compare compressive strength between the groups, and it was observed that there was a significant difference in compressive strength between the groups. Group A demonstrated the least compressive strength with a mean value of 173.7780 ± 11.8118, group B demonstrated moderate compressive strength with a mean value of 317.6400 ± 55.44453, whereas group C demonstrated the maximum compressive strength with a mean value of 467.4780 ± 37.79072.

Table 2 shows the intragroup comparison of compressive strength using a one-way ANOVA with Tukey's *post hoc* test, and it was found that there was a significant difference between the groups. Group C2 showed the highest compressive strength, followed by groups C1, B1, and B2, whereas group A1 showed moderate compressive strength, and it was observed that group A2 showed the least compressive strength. Group A1 demonstrated a mean value of 178.30 ± 13.30, group A2 demonstrated the least compressive strength with a value of 169.25 ± 9.25, group B1 demonstrated a mean value of 363.99 ± 34.21, group B2 demonstrated a mean value of 271.28 ± 19.33, group C1 demonstrated with a mean value of 450.93 ± 37.34, whereas group C2 demonstrated with highest compressive strength of 484.02 ± 33.68.

Table 3 shows the mean comparison of compressive strength between groups A1 (ChemFil Rock GIC) and A2 (GC Fuji IX GP Fast GIC). Group A1 demonstrated a mean value of 178.30 ± 13.30, whereas group A2 demonstrated a mean value of 169.25 ± 9.25. An independent *t*-test was used to compare the compressive strength between groups A1 and A2, and it was observed that there was no significant difference between the groups with $p > 0.05$, indicating that the compressive strength of A1 was more compared to A2.

Table 4 shows the mean comparison of compressive strength between the groups B1 (Equia Forte GIC) and B2 (Ionolux GIC). Group B1 demonstrated a mean value of 363.99 ± 34.21, whereas group B2 demonstrated a mean value of 271.28 ± 19.33. An independent *t*-test was used to compare compressive strength between groups B1 and B2, and it was observed that there was a significant difference between the groups with $p < 0.05$, indicating that the compressive strength of B1 was more compared to B2.

Table 5 shows the mean comparison of compressive strength between groups C1 (GC Fuji II LC GIC) and C2 (Ketac N 100 GIC). Group C1 demonstrated a mean value of 450.93 ± 37.34, whereas group C2 demonstrated a mean value of 484.02 ± 33.68. An

Table 1: Intercomparison of compressive strength between groups

	N	*Mean*	*Standard deviation*	*p-value*
A	10	173.7780	11.81188	<0.001
B	10	317.6400	55.44453	
C	10	467.4780	37.79072	

Table 2: Intragroup comparison of compressive strength between the groups

	N	*Mean*	*Standard deviation*	*p-value*
A1	5	178.3020	13.30528	<0.001
A2	5	169.2540	9.25875	
B1	5	363.9960	34.21309	
B2	5	271.2840	19.33868	
C1	5	450.9340	37.34550	
C2	5	484.0220	33.68033	

Table 3: Comparison of compressive strength between groups A1 (ChemFil Rock GIC) and A2 (GC Fuji IX GP Fast GIC)

	G	*N*	*Mean*	*Standard deviation*	*p-value*
Strength	A1	5	178.3020	13.30528	0.255
	A2	5	169.2540	9.25875	

Table 4: Comparison of compressive strength between groups B1 (Equia Forte GIC) and B2 (Ionolux GIC)

	G	*N*	*Mean*	*Standard deviation*	*p-value*
Strength	B1	5	363.9960	34.21309	0.001
	B2	5	271.2840	19.33868	

Table 5: Comparison of compressive strength between groups C1 (GC Fuji II LC GIC) and C2 (Ketac N 100 GIC)

	G	*N*	*Mean*	*Standard deviation*	*p-value*
Strength	C1	5	450.9340	37.34550	0.172
	C2	5	484.0220	33.68033	

independent *t*-test was used to compare compressive strength between groups C1 and C2, and it was observed that there was a significant difference between the groups with $p > 0.05$, indicating that the compressive strength of C2 was more compared to C1.

Discussion

The present study used six glass ionomer-based restorative materials, namely ChemFil Rock GIC, GC Fuji IX GP fast GIC, Equia Forte GIC, Ionolux GIC, Ketac N 100 GIC, and GC Fuji II LC GIC. On the evaluation of the compressive strength of all these types of cement, it was observed that Ketac N 100 GIC showed the maximum compressive strength followed by GC Fuji II LC GIC, Equia Forte GIC, Ionolux GIC, ChemFil Rock GIC, and the least compressive strength was observed in GC Fuji IX GP fast GIC.

The compressive strength of the materials was assessed by an Instron universal testing machine, which is considered a standard method of estimation. Several similar previous studies also used Instron machines to check for compressive strength.[6–8] The study was conducted in a simulated oral environment in accordance with the study done by Baby et al.[6]

Ketac N 100 is a new-generation resin-modified GIC that was first marketed in 2007. The wear resistance, polishability, and aesthetics are improved by the inclusion of nanotechnology.[9] When compared to the other glass ionomer-based types of cement utilized in this study, the Ketac N 100 GIC had the highest compressive strength. The inclusion of nanofiller particles in resin-modified GICs may be the reason for the maximum compressive strength of this GIC.

The radiopaque light-cured reinforced GIC known as GC Fuji II LC has better abrasion resistance and great esthetics. It has a quicker set, better esthetics, translucency, longer working periods, and greater strength.[10] On intragroup comparison of GC Fuji II LC GIC and Equia Forte GIC, the compressive strength of GC Fuji II LC GIC is superior. This is because of the polysalt matrix produced by the acid-base reaction in the GC Fuji II LC GIC. Similar outcomes were seen in the research by Shah et al.[11] The light-cured GICs have superior performance due to the resin content, which enhanced the physical property, in addition to the light-curing property, which provided the immediate setting.

Equia Forte is a combination of a chemically cured, highly filled GIC with a filled resin surface sealant, which is self-adhesive.[12] When Equia Forte GIC and Ionolux GIC were compared, superior compressive strength was demonstrated using Equia Forte cement. It might be because the Equia system's surface coating agent is made of a nanofilled resin, which greatly increases the material's resistance to mechanical forces. Additionally, Equia bonds to enamel and dentin through a combination of chemical and micromechanical interactions with the hydroxyapatite.[13] The current research was in agreement with that of Kutuk et al.[14] Similar research conducted by Poornima et al.[15] found that EQUIA Forte's compressive strength was much higher than that of the other groups.

Ionolux is a highly durable resin-modified GIC.[16] When compared to ChemFil Rock GIC, Ionolux GIC has greater compressive strength. This may be a result of their dual adhesion mechanism and the improved mechanical qualities of Ionolux GIC. Most likely, a dynamic ion exchange process and a micromechanical bonding mechanism work together to create the adhesion. According to studies, the resin's role as reinforcing its ingredients results in noticeably increased initial properties, fracture toughness during desiccation, and lower solubility, all of which contribute to improved mechanical characteristics. Ionolux quickly hardens under the influence of visible light and has a shorter setting time, less early moisture sensitivity, and increased strength.[11]

ChemFil Rock is a glass Ionomer restorative material with zinc reinforcement. The material has increased hardness, wear resistance, and fracture toughness qualities.[17] On intracomparison of ChemFil Rock GIC and GC Fuji IX GP Fast GIC, the compressive strength of ChemFil Rock GIC shows superior compressive strength. The reason attributed to the superior compressive strength of ChemFil Rock could be due to the improved setting reaction in the new GIC. The zinc as a constituent of glass particles may help in having higher strength.[18] The studies about the compressive strength of ChemFil Rock are very scarce because this material is relatively new. Our result was in accordance with the study by Dowling et al.,[19] which compared the compressive strength between zinc-reinforced GIC (ZRGI) and types of high-viscosity GIC (HVGI) cement and found that there was no significant statistical difference. Another study done by Molina et al.[20] showed that the compressive strength of ZRGI was higher than that of HVGI. Similarly, a study by Gjorgievska et al.[21] also shows the high compressive strength of ChemFil Rock.

GC IX GP fast is a self-curing HVGI. It has a nonsticky, dough-like consistency and a simple placement technique, which is suitable for minimally invasive restorations.[17] GC Fuji IX GP fast GIC was found to have the least compressive strength when compared to other types of GIC that were used in the study. This may be due to the presence of larger glass particles and larger voids seen in GC Fuji IX GP Fast GIC.[22] This result was in accordance with the studies conducted by Seirawan et al.[17] and Arjomand et al.,[23] which show the least compressive strength of GC Fuji IX GP fast GIC.

The limitations of this study were that it was done under an *in vitro* scenario; hence, several factors that can affect the physical properties of dental materials cannot be reproduced or simulated in total. Future studies should be focused on and conducted in an *in vivo* condition such that the evaluation of the clinical behavior of the tested restorative materials can be done over a longer period of time by taking into consideration storage temperature, storage media, resin systems, and other brands of restorative materials.

Conclusion

It may be inferred that:

- Light-cure GI types of cement exhibited the highest compressive strength in comparison to dual-cure GI types of cement and self-cure GI with regard to the nature of curing.
- On individual comparison of glass ionomer-based cements, Ketac N100 GIC showed the highest compressive strength, and Fuji IX GP Fast GIC had the least compressive strength.

- Intragroup comparison of self-curing glass ionomer-based cements, ChemFil Rock GIC showed the highest compressive strength than GC Fuji IX GP Fast GIC.
- In the intragroup comparison of dual-curing glass Ionomer-based cements, Equia Forte GIC showed higher compressive strength than Ionolux GIC.
- Intragroup comparison of light-curing glass ionomer-based cements, Ketac N 100 GIC showed higher compressive strength than GC Fuji II LC GIC.

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