RESEARCH ARTICLE

Comparative Evaluation of Compressive Strength and Diametral Tensile Strength of Conventional Glass Ionomer Cement and a Glass Hybrid Glass Ionomer Cement

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Abstract

Aim: The aim of this study is to compare and evaluate compressive strength (CS) and diametral tensile strength (DTS) of a conventional glass ionomer cement (GIC) and a glass hybrid GIC.

Materials and methods: Five samples each were prepared of GC Fuji IX and EQUIA Forte cements for CS testing and five samples of each material for tensile strength testing. Specimens were subjected to a universal testing machine. Comparison of CS and DTS among two study groups was made using an independent *t*-test for each. Level of significance was set at $p \leq 0.05$.

Results: Both test values were on the higher side for EQUIA Forte cement as compared to conventional GIC ($p \geq 0.05$). However, the differences in values were not statistically significant.

Conclusion: EQUIA Forte can serve as an alternative to conventional GIC in stress-bearing primary teeth areas. Considering several factors like cost-effectiveness, surface to be restored, moisture contamination, and time considerations, the material of choice can be tailored to one's needs.

Clinical significance: EQUIA Forte can serve as a viable alternative to conventional GIC because of its improved qualities.

Keywords: Compressive strength, Diametral tensile strength, Glass hybrid, Glass ionomer cement.

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Introduction

A pathological process of dental caries dates its occurrence since ancient times. It is one of the most common chronic diseases experienced globally.[1] The damage caused to hard tissues by caries affects its form and functions.[2] Hence, conservation of its remaining tooth structure is imperative in maintaining the longevity of the tooth. Subsequently, first therapeutic approach must thereby inculcate techniques causing minimal loss of enamel and dentin during caries removal and use of fluoride-releasing restorations.[3,4]

The world has witnessed a paradigm shift in the use of restorative materials ranging from traditional opaque metal alloys, amalgam, gold, and ceramics to much newer tooth-colored dental cement.[2] The silicate/phosphate-based cement was compromised in terms of biocompatibility with dental tissues,[5] and this was overcome by the use of alternative polyacids.[6] So, they were gradually replaced by a more translucent material in the form of GIC developed by Wilson and Kent in 1971.[6,7] It is a product of ion leachable calcium aluminofluorosilicate glass and aqueous solution of polyacrylic acid.

The invention of GIC gained attraction from dental practitioners all over the world.[8] Properties like adhesion to the moist tooth structure and base metals, anticariogenicity, thermal compatibility, biocompatibility, and low toxicity make it a unique cement.[9–11] Its ease of application without the use of adhesive systems makes it clinically attractive.[4,12] Albeit, conventional GICs are plagued by their limitations which include brittleness, poor fracture toughness,[10] prolonged setting time, sensitivity to moisture, dehydration, etc.[8]

To overcome these shortcomings, advancements were made in the past and are continually being so by incorporating filler components in powder such as silver-amalgam particles, zirconia, glass fibers, and hydroxyapatite.[13] Liquids have inclusions of more polyacids along with pretreatment of the glass surface and modified glass compositions.[9]

Development of high viscosity GICs as Fuji IX (by GC manufacturers) is one such potential development in conventional GICs.[7,14] In this, optimization of the particle size distribution of glass particles and concentrations and molecular weight of polyacid is done. EQUIA Forte, a new member of EQUIA family (by GC manufacturers), is believed to have improved mechanical properties due to the addition of ultrafine glass particles to create a stronger matrix.[15,16]

Whenever a newer material is introduced, a thorough knowledge of its physical/mechanical properties, along with clinical trials, is crucial before including it in clinical practice.[17] As these restorative materials replace missing tooth structures, they need to be strong enough to withstand compressive and tensile

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forces/stresses created during mastication.[2,12] Performing these mechanical strength tests would be important in understanding the durability of the cement, which enters into a dynamic state as soon as they enter the oral cavity.[3,17]

The most commonly used tests to determine the mechanical properties of the newer cement are the CS test and the DTS test.[9,18,19] Hence the aim of this study was the compare and evaluated the CS and DTS of a conventional GIC (here, Fuji IX) and glass hybrid GIC (EQUIA Forte).

Materials and Methods

Two types of cement used in this study are listed in Table 1.

In accordance with American National Standards Institute/American Dental Association (ADA) specifications,[20] five samples each were prepared for two materials for two tests. The cylinder dimensions for CS tests were 6.0 mm diameter × 12.0 mm, and for the DTS test were 6.0 mm diameter × 3.0 mm made in aluminum.

The powder/liquid ratios were used according to the manufacturer's instructions for all materials. GIC type IX was mixed with a plastic spatula on impermeable paper. EQUIA Forte capsules were activated by GC Applier (0409-140) and mixed in an amalgamator (HL-AH G5, Zoneray, manufactured by Shanghai Dynamic Industry Co., Ltd.). The mixed material was inserted into the molds, which were previously coated with petroleum jelly, using a cement carrier in increments. Excess material was removed, and the specimens were again coated with petroleum jelly during the initial setting.

The specimens were made at room temperature 37 ± 1°C and 95 ± 5% relative air humidity, as recommended by ADA, and then thermocycled (×500 cycles, 5–55°C dwell time: 30 seconds in LG model: 051SA, Mahavir, India). Further, the tests were carried out in a universal testing machine (computerized software by Acme Engineers, India, Model no. UNITEST-10, accuracy of the machine: ±1%) at a crosshead speed of 1 mm/min for the CS test and 0.5 mm/min for the DTS test.

Testings

For the CS test, the cylindrical specimen was placed in a position where the force was introduced on the long axis (Figs 1A and B). For the DTS test, the specimens were diametrically compressed, introducing tensile stress in the plane of force of action of the specimen, as shown in Figures 2A and B.

Statistical Analysis

Comparison of CS and DTS among two study groups was made using an independent *t*-test for each. Level of significance was set at $p \leq 0.05$.

Table 1: Commercially available GIC, manufacturers, samples used

Materials	*Manufactures*	*Classification*	*Number of samples*
GC FUJI IX	GC Corporation, Tokyo, Japan	Restorative Conventional High viscosity	CS 5 DTS 5
EQUIA Forte	GC Corporation, Tokyo, Japan	Bulk Fill Fluoride release Rapid restorative	CS 5 DTS 5

Results

The CS value of EQUIA Forte (mean value: 112.48 MPa) was slightly higher than that of Fuji IX (mean value: 108.59 MPa), but the difference was not statistically significant. Similarly, the DTS value of EQUIA Forte was on a higher side (mean value: 12.43 MPa) than Fuji IX (mean value: 10.09 MPa), with no statistically significant difference between the two (Table 2).

Discussion

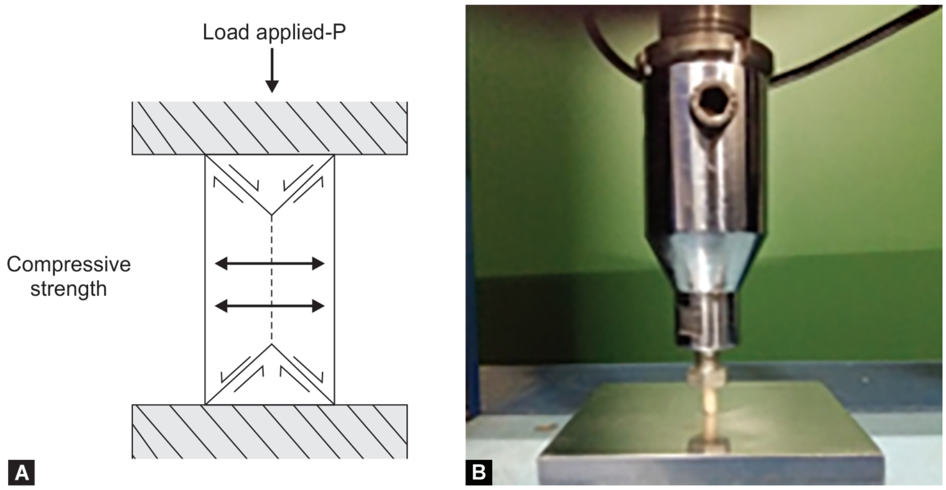
The physical science dealing with forces that act on bodies and the resultant motion, deformation, or stresses that those bodies experience are the laws of mechanics that govern the mechanical properties of any material. The knowledge about these attributes allows us to differentiate between the potential causes of clinical failures that may be due to material deficiencies, design features, dentist errors, technician errors, or patient factors such as diet, biting force magnitude, and force orientation.[21]

Fracture stress determines the fracture inside a restorative material, and the resistance to it is referred to as the "strength of the material".[19] During the process of mastication, various intraoral compressive (vertical compressive force and lingual side compression force)[2] and tensile forces are produced.[17] The DTS test measures the cohesive strength of the material. These cohesive forces within the material influence the load that is necessary to produce fracture in the material when subjected to masticatory load. Such forces are independent of the deformation values. Thus more brittle the material, the faster will be the occurrence of the fracture. In this way, the DTS values are important for material pertaining to the daily chewing action.[7,17] With respect to this, any cement that is to be used as bulk fill, restorative and core buildup must have properties that will withstand these forces.[7,22] Hence, two mechanical strength tests were undertaken in this study—CS and DTS.

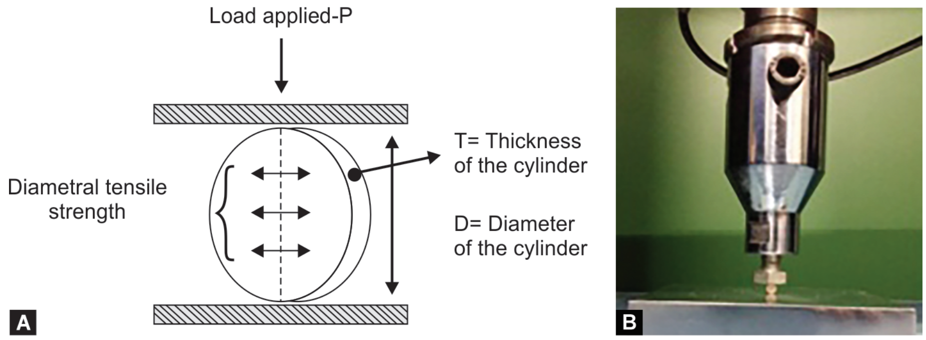
Compressive strength is tested, wherein two axial sets of forces are applied to a sample but in opposite directions. In this way, it brings about an approximation of the structures of the material. The DTS is again one of the critical tests as most of the clinical failures of material occur due to tensile stress. Due to a lack of methods to determine the DTS of GICs directly, British Standards Institution adopted the DTS test.[23] Herein, a compressive force is directed onto a cylindrical specimen across the diameter of the compression plates. While the stresses in the contact regions are indeterminate, there is evidence of a compressive component that hinders the propagation of the tensile crack.[10] Large shear stresses that exist locally under the contact area may also induce a shear failure before tensile fracture at the center of the specimen.[10,18]

Fuji IX was a development that came into the GC family of restorative cement along with collaboration by the World Health Organization.[14] It is indicated for use in geriatric as well as pediatric restorations, core buildup, interim restorations etc. *In vitro* studies[24] had given better results in favor of Fuji IX when compared for mechanical properties with Miracle Mix. Hence, it became the material of choice for various restorations.

EQUIA Forte was a new take of GC manufacturers who took glass ionomers to the next level. The company reports that this cement has improved physical properties, wear and acid erosion resistance, and fluoride release. They have attributed the reason to an innovative glass hybrid technology. Ultrafine and highly reactive glass particles dispersed evenly in its structure increase the ion



Figs 1A and B: (A) Schematic illustration of CS adapted from Darvell.[10] The stress and causes of failure in a cylindrical specimen loaded axially have a radially symmetrical pattern; (B) Pictorial representation of CS testing



Figs 2A and B: (A) Schematic illustration of DTS adapted from Darvell.[10] The diametral tensile stress is envisaged ideally with tension acting smoothly over the entire diameter, peak at its center; (B) Pictorial representation of DTS testing

Table 2: Mean CS and DTS values of both materials in MPa, standard deviation (SD), and *p*-value *(p)*

Tests	*Cement*	*Mean value (in MPa)*	*Standard deviation (SD)*	*p-value*
CS	EQUIA Forte	112.48	5.15	0.214
	Fuji IX GP	108.59	2.30	
DTS	EQUIA Forte	12.32	4.98	0.454
	Fuji IX GP	10.09	3.92	

availability and build a stronger matrix, even in the presence of saliva.[16] To the best of our knowledge, fewer studies have tested the mechanical properties of the cement compared with other restorative cement commonly used in dentistry. Thus, a comparison between the mechanical properties of EQUIA Forte and Fuji IX was made in this study.[15]

The CS of group I—Fuji IX was 112.48 MPa, and of group II—EQUIA Forte was 108.59 MPa. The difference between the groups was not statistically significant. This result was in accordance with a study done by Barretto et al.[1] The study compared CS of Ketac Molar, Fuji IX, and EQUIA Forte, to which he concluded that although Ketac Molar had significantly higher values for the CS as compared to the other two, there was no statistically significant difference in CS values of Fuji IX and EQUIA Forte group. Another study by Poornima et al.[12] compared the CS and microhardness of EQUIA Forte with conventional GIC and resin-modified GIC. The results were in favor of the newly developed glass hybrid cement, that is, EQUIA Forte, for both parameters.

For all the dental cement, the CS values are 8–13 times higher than the DTS values. This can be explained because the cohesive forces between the material are identical both in CS and DTS tests; however, their direction of force is different.[24] The DTS value (mean) for group I was 12.43 MPa and for group II was 10.09 MPa. Again the difference in values between the two specimens was not statistically significant. This was in conjunction with one of the studies by Moshaverinia et al.,[25] who evaluated and compared the compressive, diametral tensile, and flexural strengths of EQUIA Forte Fil with Fuji IX GP and ChemFil Rock. He concluded that the differences in values were not significant on the day of testing. However, immersion in distilled water for 1 week improved their mechanical properties. It was attributed to the more pronounced maturation of the cement matrix due to the availability of more carboxylic acid groups like polyacrylic acid, which allows reactions with Al^{3+} and Ca^{2+} ions to form the glass ionomer particles.[25] Nevertheless, the differences in the values after a week were not statistically significant.

On the contrary, certain studies showed no difference in the CS and DTS values after 1-hour and 24-hour immersion period.[13,24] Busanello et al.[4] evaluated CS values of five GIC after 1-hour and 24-hour storage period and observed that Fuji IX had the best results after 1 hour. Following 24-hour storage period, Ketac Molar and Vitro Molar, along with Fuji IX, showed similar performance.

Limitations of the Study

The study involves a relatively smaller sample size for comparison with the other cement. Also, the testing of the samples was done at a single time interval. Certain studies have shown that there is a difference in the strength of restorative cement after 1 hour, 24 hours, and 1 week.[7,25] Whereas few other studies have observed relatively contrasting results.[8,13] Hence these discrepancies need to be confirmed by testing the samples of both materials at different time intervals, with immersion into a storage medium.

The disparity in conclusions obtained from various studies can be appertaining to variability in the testing conditions and available material, variability in composition, manufacturing process, size of the powder particles, type, concentrations, and molecular weight of liquid and powder to liquid ratios.

Conclusion

- The differences in the values of CS and DTS between the two materials were not found to be statistically significant.
- Nonetheless, considering several factors like cost-effectiveness, surface to be restored, moisture contamination, and time considerations, the material of choice can be tailored to one's needs.
- Further, more clinical studies need to be carried out to determine different parameters of mechanical strength testing, including a larger sample, to evaluate the success rate of the materials when used *in vivo*.

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