ORIGINAL RESEARCH

An *In Vitro* Evaluation of the Mechanical Properties and Fluoride-releasing Ability of a New Self-cure Filling Material

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Abstract

Aim: The aim of this study was to examine and compare the flexural strength, shear bond strength, and fluoride-releasing ability of glass ionomer cement (GIC), Fuji IX GIC®, and a new alkasite filling material, Cention N®.

Material and methods: The materials were divided into two groups, Fuji IX GIC® ($n = 30$) and Cention N® ($n = 30$) and further divided ($n = 10$) to test three parameters, the fluoride releasing ability, flexural strength, and shear bond strength. Fluoride release was checked using fluoride ion-selective electrode, and flexural strength and shear bond strength were tested using universal testing machine (Intron 3366, UK).

Results: Fluoride release of Fuji IX GIC® was significantly higher compared to that of control Cention N® over a period of 21 days. Flexural strength of Cention N® was significantly higher compared to Fuji IX GIC® and there were no significant differences in shear bond strength of both the materials.

Conclusion: From the results of the study, it can be concluded that Cention N® is an alkasite filling material for the complete and permanent replacement of tooth structure in posterior teeth and can be a good alternative when compared to GICs on the basis of their superior mechanical properties.

Clinical significance: Cention N® is an innovative filling material for the complete and permanent replacement of tooth structure in posterior teeth and can be a good alternative when compared to GICs on the basis of their superior mechanical properties.

Keywords: Flexural strength, Fluoride release, Glass ionomer cement, *In vitro* observational study, Restorative materials, Shear bond strength.

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Introduction

Dental caries are an infectious bacterial disease that has affected humans for several years. Dental caries are prevalent amongst all age-groups. Excavation of caries and eventually restoring them with a suitable restorative material are the ultimate treatment goal. Restorative dentistry is governed by the principle of conservation and rehabilitation of normal occlusion and function of the dentition. Over the past 100 years, innumerable changes have been developed in the field of dentistry and the growth is accelerating rapidly. In the current era of restorative dentistry, minimal tooth preparation is predominantly necessary. Earlier we emphasized on "extension for prevention" as a treatment guideline which has now gradually shifted to "restriction with conviction". The integrity and durability of the marginal seal are essential for any restorative system to maintain pulpal health and to increase the longevity of the restoration.[1]

Glass ionomer cement (GIC) has been widely used worldwide as luting, base, liners, and restorative materials as they possess certain qualities like adhesiveness, biocompatibility, and fluoride releasing ability. However, the major disadvantages of the material are fracture toughness, low wear resistance, and high dissolution in water sorption resulting in restoration failure leading to secondary caries or teeth fracture.[2]

Fluoride is an anticariogenic agent which has a number of mechanisms like anticariogenic capability that includes the formation of fluorapatite which is less soluble when compared to original hydroxyapatite crystals, the enhancement of remineralization, interference in the formation of ionic bonds during pellicle and plaque formation, and also inhibition of growth and metabolism of microbes.[3,4]

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The acid–base reaction of the GIC cement leads to fluoride ion release and the fluoride ions are not an essential part of the matrix formation. Hence, fluoride ions move freely in and out of the cement.[5] That is why GIC is a reservoir of fluoride ions, which maintains a steady release of fluoride into the near vicinity of the tooth which eventually enhances the caries attack resistance throughout the life of restoration.[6]

GC Fuji IX GIC® was introduced into clinical practice in the late 1990s and was developed mainly for geriatric and pediatric patients. It is highly viscous, condensable, and has better aesthetics. This improvement was due to a reduction in the size of the glass particles in the matrix, allowing a faster speed of reaction between the silica particles and polyacrylic acid. An ideal restorative material is one that can resist various dislodging forces within the oral cavity by showing good adhesion with the dentinal surface. These forces are measured in terms of compressive strength, tensile strength, and shear strength.

Shear bond strength is defined as the resistance to forces that slides restorative material past tooth structure. Therefore, the higher the shear bond strength, the better will be the bonding of the material to the tooth. The flexural strength is a measure of fracture resistance of the material which indicates the flaws within the material that may possess the potential to bring about failure once subjected to loading. Flexural forces are generated under clinical situations, and the dental materials need to withstand the repeated flexing, bending, and twisting forces. The powder/liquid ratio of GIC influences the mechanical properties and bond strength of the material.

Cention N® is a tooth-colored, basic filling material for direct restorations. It is self-curing with optional additional light-curing. Cention N® redefines the basic filling, combining bulk placement, ion release, and durability in a dual-curing, esthetic product satisfying the demands of both dentists and patients.

For over a long period of time, GICs and amalgams have been used successfully within their indications as filling materials. In recent years, there has been a considerable demand for alternative filling materials mainly because of the reasons that include low flexural strength of GICs, the intrinsic grey color of amalgam, and the fact that amalgam contains mercury as one of its components. Therefore, to overcome certain drawbacks of conventional filling materials, the alkasite material, Cention N® offers tooth-colored aesthetics together with high flexural strength. This patented alkaline filler increases the release of hydroxide ions to regulate the pH value during acid attacks. As a result, demineralization can be prevented. Cention N® is available as powder and liquid of which liquid consists of dimethacrylates and initiators and powder is composed of various glass fillers, initiators, and pigments.

Several clinical studies have confirmed that flexural strength of more than or equal to 100 MPa is an important factor for maintaining durable restorations. This is where Cention N® differs from GICs. At values more than 100 MPa, Cention N® offers very good flexural strength for the stress-bearing regions in the oral cavity especially the posterior region.[7]

Various studies have been conducted testing the fluoride releasing ability and flexural strength of Fuji IX GIC® and Cention N®; however, there is no proven literature stating the shear bond strength of this material, and therefore, this study was designed to study the various mechanical properties (shear bond strength and flexural strength) and fluoride releasing ability of this material which can be of use in making a decision to choose the right esthetic restorative material in pediatric dentistry. We hypothesize that there is no difference in the fluoride release, flexural strength, and shear bond strength between the two groups.

Materials and Methods

This study was conducted in the Department of Pediatrics and Preventive Dentistry, Manipal College of Dental Sciences, Manipal, Karnataka, with the parameters analyzed at the Department of Dental Materials, Manipal College of Dental Sciences, Manipal, Karnataka, and at the Department of Civil Engineering, National Institute of Technology Karnataka, Suratkal. This study was approved by the Kasturba Hospital Institutional Ethics Committee, Kasturba Hospital, Manipal. (IEC 871/2017). This was an experimental type of *in vitro* study.

After consulting with a statistician at the Department of Statistics, Manipal Academy of Higher Education, Manipal, a sample size of 30 per group was determined, at a confidence level of 95%, with a power of 80. The study included 60 samples, out of which 20 were healthy human deciduous teeth in order to test the shear bond strength, 20 bar-shaped molds for testing the flexural strength, and 20 disk-shaped molds for testing the fluoride releasing ability. The materials used in the study are listed below: Fuji IX GP® (GC Corporation, Tokyo, Japan) and Cention N® (Ivoclar Vivadent AG Liechtenstein).

A total number of 20 disk-shaped specimens (6 mm in diameter and 2 mm thickness) for each group (Fuji IX GP® and Cention N®) had been fabricated according to the manufacturer's instructions. The preparation of samples with GIC type IX® for the testing of shear bond strength was mixed, as per the manufacturer's instructions. The standard powder liquid ratio was 3.6/1.0 gm which is 1 level scoop of powder, to one drop of liquid, were mixed individually, for the preparation of each sample. Using the plastic spatula, the mix was introduced into the prefabricated molds. After filling of the molds, the specimen's top surface was covered by a mylar strip and glass slides and allowed to set at a room temperature for 2 minutes and 20 seconds, and then the excess material was removed, using a lacron's carver. Cention N® (Ivoclar Vivadent AG Liechtenstein) was then mixed and poured into the molds in a similar manner. The powder liquid ratio was 4.6/1.0 gm which corresponded to one measuring scoop of powder with one drop of liquid. For standardization, all the specimens were premeasured with a digital weighing balance and noted. Then the specimens of group A (Fuji IX GIC®) and group B (Cention N®) were immersed in 1 mL deionized water and left undisturbed in an incubator set at 37°C. After 24 hours of incubation, the containers were shaken, and then the samples were removed, dried, and returned into a new vial containing 1 mL of deionized water. The procedure was then repeated daily and then the cumulative fluoride release measurement was recorded during the first week and at the end of the second and third weeks.

Fluoride Ion Release

A fluoride ion selective electrode with a combination of ion analyzers had been used to measure fluoride release (ORION™ Thermo Scientific™, USA). The prime element in the fluoride electrode is the laser-type doped lanthanum fluoride crystal across which is established by fluoride solutions of different concentrations. The crystal contacts the sample solution at one face and an internal reference solution at the other. The reference electrode used is Ag/AgCl. Fluoride forms complexes with several polyvalent cations, notably aluminum and iron. The fluoride release had been estimated by adding a quantity of total ionic strength adjustment buffer (TISAB) to the test solution to provide constant ionic strength, decomplex fluoride, and adjust pH. The use of TISAB provides uniform ionic strength background, adjusts pH, and breaks up such complexes. Cyclohexylenediaxninetetraacetic acid, a component present in TISAB, preferentially will complex with interfering cations and release free fluoride ions. By maintaining pH above 5, complex formation of hydrogen fluoride is avoided and interference of hydroxide ion is avoided by maintaining the pH below 5.5. The results obtained were recorded in ppm. The test solution was changed every 24 hours and fluoride release from each test solution was measured every day for 21 days following which the cumulative values were calculated. All the tests were conducted by an examiner who was blinded for the groups.

Shear Bond Strength

An acrylic block with dimensions of 50 mm height, 20 mm width, and 15 mm thickness was prepared using cold cure methyl methacrylate resin and polished with 400 number silicon carbide polishing paper. An impression of this block was taken using silicone elastomeric impression material, which was used as a mold for the fabrication of the acrylic blocks ($n = 20$) to maintain uniformity between all the blocks. The acrylic blocks were then randomly distributed into two groups of 10 blocks each. For the purpose of this study, 20 extracted primary molars were included. The following inclusion and exclusion criteria were followed: Healthy human deciduous teeth were extracted due to preshedding mobility. Teeth with caries, developmental defects like hypoplasia and fluorosis were excluded from the study. The teeth were collected, cleaned, and stored in distilled water for not more than three months. Using a low-speed handpiece, and a diamond disk, any remaining root structures were removed, and the buccal surfaces of each tooth were then flattened, to obtain a uniform enamel surface. Each tooth was embedded in one block, such that the flattened enamel surface was exposed, and lay 2 mm above and parallel to the adjoining acrylic surface. After placing the tooth in the window, the remaining space was filled with freshly mixed self-cure polymethylmethacrylate. On setting, this surface of the acrylic block was again polished and care was taken to not contact the tooth surface. The teeth were then mounted in a custom-made mold (size 25 × 10 × 10 mm) by autopolymerizing pink orthodontic resin, with the coronal portion of the tooth exposed. A plastic tube with an internal diameter 3 mm and height 4 mm was placed on the specimen through which the material had to be poured. The teeth were randomly allocated to study groups (group A—Fuji IX GIC® and group B—Cention N®).

These were then mounted on the universal testing machine (Instron 3366, UK), such that the chisel tip of the machine was perpendicular to the surface of the cylinder on the mounted block; and shear loading was applied to the adhesive interface at 0.5 mm/minute until debonding occurred (Fig. 1). Shear bond strength in MPa was calculated by dividing the peak load at failure with the specimen surface area (F/nr^2). The results displayed on the computerized readout were then recorded for statistical analysis.

Flexural Strength

For the testing of flexural strength, a split mold, with two parts, held together by two screws, was fabricated especially for the purpose of this study. A bar-shaped split mold of dimensions 25 × 2 × 2 mm was fabricated. The mold was made of an inert metal, which did not bond with either of the materials being tested. As it was a split mold, after the setting, or curing of the sample, the two parts could be separated, by releasing the joining screws, to facilitate easy removal of the samples. Fuji IX GP® (GC Corporation, Tokyo, Japan) was mixed, as per the manufacturer's instructions. Cention N® (Ivoclar Vivadent AG Liechtenstein) was dispensed directly by mixing and pouring into the split mold. The excess material was removed using a lacron's carver. The prepared bars were removed from the distilled water and dried. These were then mounted on the universal testing machine (Instron 3366, UK), such that the chisel of the machine was perpendicular to the bar, and contacted the bar at its midpoint. These were then loaded at 0.5 mm/minute until they fractured (Fig. 2).

Flexural strength in MPa was calculated as the highest load recorded before failure, divided by the area of a sample. The results displayed on the computerized readout were then recorded for statistical analysis.

Results

A fluoride ion selective electrode with a combination of ion analyzers had been used to measure the fluoride release of both the groups which had a sample size of 10 each (n = 20). The results obtained were recorded in mg/L/ppm and the test solution was changed every 24 hours and the fluoride release was measured every day for 21 days. As p value is <0.05 when compared between both the groups, it can be concluded that the fluoride release in Fuji IX GIC® and Cention N® showed statistically significant difference. Analyzing the data, significant differences in cumulative fluoride release between different days and both the materials ($p < 0.05$) were observed. The maximum cumulative fluoride release calculated for days 1–7 was more in group A (Fuji IX GIC®) and this remained the same until the 21st day when compared to group B (Cention N®). Both the materials continued to release fluoride, but a greater increase in fluoride release was seen in group A (Fuji IX GIC®) compared to group B (Cention N®) by the end of 21 days. The fluoride releasing

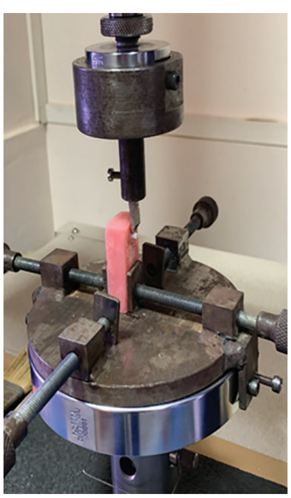

Fig. 1: Shear bond testing

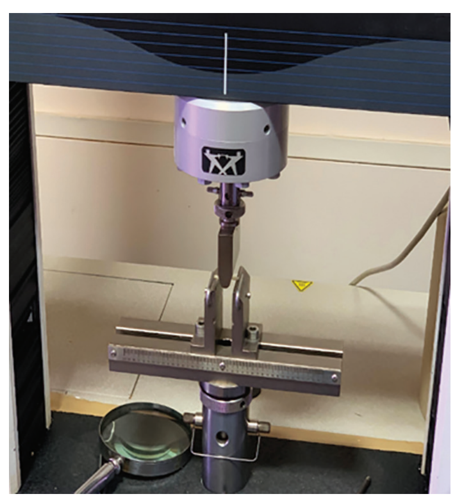

Fig. 2: Flexural strength testing

ability of group A was significantly higher (p <0.05) than control (p <0.05). Statistical analysis was done using SPSS version 22.0. A p value of <0.05 was considered statistically significant. Comparison of mean values was done using the Shapiro–Wilkinson test to test the fluoride release between the two groups. Therefore, the null hypothesis was rejected and it was proved that group A (Fuji IX GIC®) showed higher fluoride releasing ability than group B (Cention N®). The difference in fluoride releasing ability attained between two groups was statistically significant (*p* <0.001) (Figs. 3 and 4).

Flexural strength of the control group (group A) showed a mean value of 30.34 ± 3.77MPa and the test group (group B) showed a mean value of 98.169 ± 17.21 MPa. The flexural strength of group B was significantly higher (*p* <0.05) than control (*p* <0.05) (Table 1). Statistical analysis was done using SPSS version 22.0. A *p* value of <0.05 was considered statistically significant. Comparison of mean values was done using independent sample *t* test and the Shapiro–Wilkinson test was used to determine the variation in flexural strength between the two groups. Therefore, the null hypothesis was rejected and it was proved that group B (Cention N®) showed higher flexural strength than group A (Fuji IX GIC®). The difference in flexural strength attained between the two groups was statistically significant (*p* <0.001).

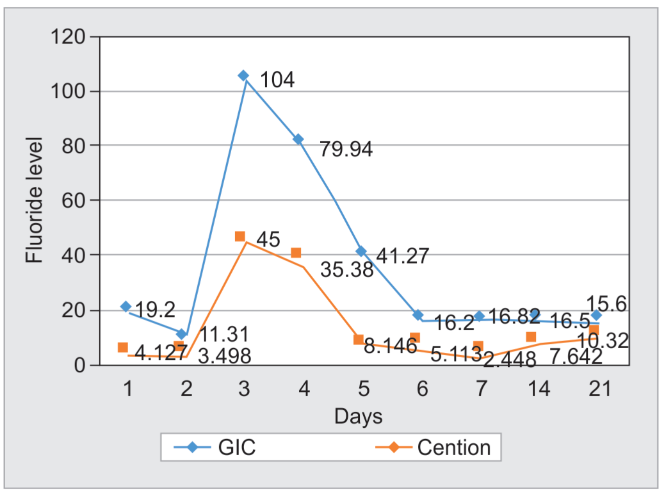

Fig. 3: Fluoride release per day

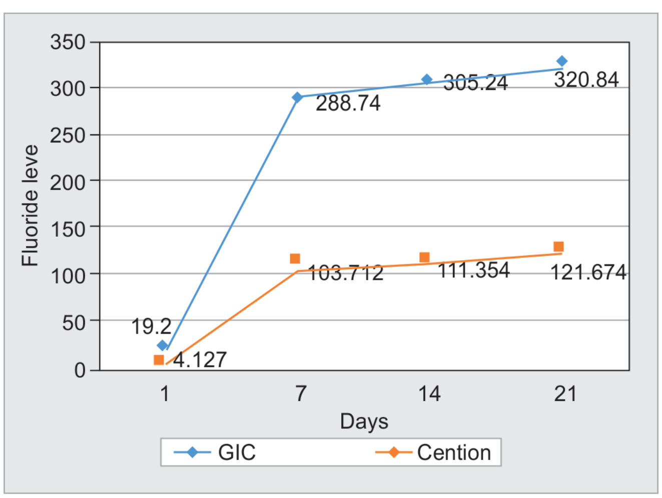

Fig. 4: Cumulative fluoride level at day 1, day 7, day 14, and day 21

Shear bond strength of the control group (group A) showed a mean value of 8.47 ± 1.08 MPa. Group B showed a shear bond strength of a mean value of 7.13 ± 2.13 MPa. Shear bond strength of group A and group B did not show any significant difference as (*p* >0.05) (Table 2). Statistical analysis was done using SPSS version 22.0. A *p* value of >0.05 was considered statistically insignificant. Comparison of mean values was done using independent sample *t* test and the Shapiro–Wilkinson test was used to determine the variation in shear bond strength between the two groups. Therefore, the null hypothesis was accepted and it was proved that group A (Fuji IX GIC®) and group B (Cention N®) did not show any significant differences. The difference in shear bond strength attained between the two groups was statistically insignificant (*p* >0.001).

Discussion

In this experimental *in vitro* study the shear bond strength, flexural strength, and fluoride releasing ability of a new alkasite filling material, Cention N®, and conventional GIC (Fuji IX GIC®) were calculated.

The results of our study were statistically significant as Fuji IX GIC® showed greater fluoride releasing ability than Cention N® over a period of 21 days. The maximum cumulative fluoride release calculated for days 1–7 was more in group A (Fuji IX GIC®) and this remained the same until the 21st day when compared to group B (Cention N®). Both the materials continued to release fluoride, but a greater increase in fluoride release was seen in group A (Fuji IX GIC®) compared to group B (Cention N®) by the end of 21 days (Figs. 3 and 4). Thus, the null hypothesis was rejected as there was a significant difference between the two groups.

These results were consistent with the study done by Gupta[7] who evaluated and compared fluoride ion release by Cention N® (self-cure and light-cure) and conventional GIC at different pH and time intervals. The results of this study showed higher

Table 1: Comparison of flexural strength between Fuji IX GIC® and Cention N®

	Fuji IX GIC®		*Cention N®*	
	Mean	*SD*	*Mean*	*SD*
	30.33	3.74	98.16	17.21
Minimum	24.39		73.70	
Maximum	36.57		136.20	
95% confidence interval	27.64–33.03		85.85–110.48	
p value	0.001*			
t value	12.17			

Table 2: Comparison of shear bond strength between Fuji IX GIC® and Cention N®

	Fuji IX GIC®		*Cention N®*	
	Mean	*SD*	*Mean*	*SD*
	8.46	1.074	7.13	2.134
Minimum	7		4.83	
Maximum	11.040		12.77	
95% confidence interval	7.70–9.23		5.60–8.25	
p value	0.09			
t value	1.76			

fluoride ion release in acidic pH as compared to neutral pH in all the groups, indicating that when conditions become acidic due to cariogenic challenges, GIC and Cention N® would release relatively more fluoride ion and these results were consistent with studies conducted by Gandolfi[8] and Mungara,[9] which tested fluoride ion release in GIC in similar conditions. This may be because a decrease in pH of solvent may lead to an increase in the surface dissolution of the materials, thus increasing fluoride ion release.

Also, in the same study done by Gupta,[7] Cention N®, in self-cure mode released significantly higher fluoride ions as compared to that of light-cure mode which is contradictory to the results of our study. The decline in the capacity of light cure to release fluoride ions may be due to a tightly bound or a less hydrophilic matrix due to photopolymerization of the alkasite restorative material. The same reason could be valid for a better alkalizing ability in self-cure as compared to the light-cure mode of Cention N®. Cention N® showed a significantly high alkalizing potential in acidic pH.

In our study, the flexural strength tests performed showed that the difference achieved between the two restorative materials, Fuji IX GIC® and Cention N®, were statistically significant. The flexural strength of Fuji IX GIC® (30.34 $\pm$ 3.77 Mpa) was less compared to Cention N® (98.16 $\pm$ 17.21 Mpa). The highly crosslinked polymer structure is responsible for the high flexural strength. The initiator system enables good chemical self-curing. The liquid comprises dimethacrylates and initiators, while the powder contains various glass fillers, initiators, and pigments. In our study, the shear bond strength tests performed showed that the difference in bond strengths achieved between the two restorative materials to the underlying tooth surface was statistically insignificant. Our results show that the Shear bond strength (SBS) obtained between Fuji IX GIC® (8.47 $\pm$ 1.08 Mpa) and Cention N® (7.13 $\pm$ 2.13 Mpa) does not vary significantly.

Cention N® showed a significantly high alkalizing potential in acidic pH. This may be due to the hydroxyl and calcium ions released by alkaline glass fillers from Cention N®, which are able to have a direct effect on the pH levels in the oral cavity, thus creating conditions whereby excess acidity due to bacterial activity could be neutralized.[10]

There are no studies reported in the literature stating the shear bond strength of the novel alkasite material, Cention N® and therefore this study is one of its kind. The results of our study pertaining to Fuji IX GIC® were consistent with the results of the study done by Somani[11] in which the mean value of shear bond strength was found to be highest for Light cure glass ionomer cement (LC GIC), followed by type IX GIC, and was lowest for conventional GIC.

In a study done by Manuja,[12] they evaluated the shear bond strength of tooth-colored restorative materials to dentin. The results of the study concluded that chemically cured GIC, Fuji IX GIC®, depicted the least mean shear bond strength value (7.76 $\pm$ 1.07 MPa) among all the groups tested. Various studies have also consistently shown the inferior bonding performance of GIC when compared to composite-based restorative materials.

Till date, glass ionomers remain as the only material that is self-adhesive to tooth tissue, without any surface pretreatment. This material bonds chemically to the tooth rather than a micromechanical bond, which is a weak bond. The mechanism of bonding of GICs involves wetting of the tooth surface by the cement and subsequent formation of ionic bonds with the conditioned tooth substrate. It is generally believed that the adhesion of conventional GICs might be the result of an ion-exchange mechanism, polyacrylate ions replacing phosphate ions in the surface of hydroxyapatite.[12] In a study by Mazumdar et al.,[13] Cention N® resulted in higher (p <0.01) hardness compared to nanohybrid composite. On the contrary in a study by Feiz et al.,[14] the microtensile bond strength in primary teeth dentin, giomer showed better results than Cention N®, Resin modified glass ionomer cement (RM GIC), and Zirconomer.

Conventional glass ionomers do not perform well in the SBS tests because of their weakness, which leads to their cohesive failure under these conditions. However, conventional GICs have other desirable properties like limited setting shrinkage, good elasticity, and the ability to show self-repair mechanisms once cracks appear within them. All these factors help in the survival of restorations in the oral environment.[15]

Hence, we can say that Cention N® can be used in various restorative procedures in daily dental practice as a basic filling material that has good aesthetic results and mechanical properties.

Conclusion

Within the limitations of this *in vitro* experimental study, the following conclusions were drawn:

- There is a significant increase in fluoride releasing ability of conventional Fuji IX GIC® over Cention N®; however, the flexural strength of Cention N® proves to be higher than that of Fuji IX GIC®.
- Also, this is the first study to evaluate the shear bond strength of Cention N®, and it was concluded that the shear bond strength of both conventional Fuji IX GIC® and Cention N® are almost comparable.

Clinical Significance

Cention N® is an alkasite filling material for the complete and permanent replacement of tooth structure in posterior teeth and can be a good alternative when compared to GICs on the basis of their superior mechanical properties.

However, further research is required, using more strictly controlled environmental parameters, and *in vivo* comparisons between Fuji IX GIC® and Cention N® before we can arrive at a definitive conclusion regarding this material.

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