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A comparative evaluation of fracture toughness, flexural strength, and acid buffer capability of a bulk-fill alkasite with high-strength glass-ionomer cement: An *in vitro* study

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ABSTRACT

Background: Although glass-ionomer cement (GIC) has many unique properties and advantages, it still lacks favorable mechanical properties. Cention N is a recent alkasite material with excellent mechanical properties. The purpose of this study was to compare the mechanical properties (fracture toughness [FT] and flexural strength [FS]) and acid buffer capability of an alkasite material to GIC.
Materials and Methods: In this *in vitro* study, a total of 60 samples were prepared using Cention N or GIC. Twenty specimens (n = 10) were prepared using beam-shaped Teflon molds for FS, and twenty specimens (n = 10) were prepared with a similar mold with a notch for FT. These were evaluated on a universal testing machine using a three-point bend test. Twenty (n = 10) disk-shaped specimens were prepared for acid buffer capability. The samples were stored in distilled water for a week. This was followed by immersion in lactic acid with a pH of 4 for calculation of the materials acid buffering capacity at 30 and 60 min from exposure using a pH meter. The data obtained were tabulated and subjected to Kolmogorov–Smirnov test and Shapiro–Wilk test to assess the normal distribution and further analyzed using the Student's t-test to assess the level of significance, $P < 0.05$ was considered statistically significant.
Results: The mean FT, FS, and acid buffer capability of Cention N were significantly higher than GIC at $P < 0.05$.
Conclusion: The present study surmised that Cention N exhibited higher FT, FS, and acid buffer capability than GIC.

Key Words: Buffering capacity, Cention N, flexural strength, glass-ionomer cement, mechanical property

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INTRODUCTION

Wilson and Kent introduced the first glass-ionomer cement (GIC) in 1972 and called glass polyalkenoate cement.[1,2] It has anticaries properties, such as fluoride ion release and recharge abilities, and it prevents enamel decalcification. It also exhibits inhibition of bacterial acid metabolism. Other beneficial properties of GICs include adhesion to the tooth structure, a similar coefficient of thermal expansion as dentin, and biocompatibility.[3] However, the major disadvantages of the GIC are its poor mechanical properties

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such as poor fracture toughness (FT), low flexural strength (FS), brittleness, and low compressive strength.[3,4] Hence, it is not a suitable restorative material in load-bearing areas.

Cention N (Ivoclar Vivadent) is a new alkasite, tooth-colored, and bulk fill direct restorative material that resembles ormocer or compomer and is a subgroup of composite resin. This can be used with or without the application of an adhesive, depending on the retention features of the tooth preparation. It is a self-curing material whose setting can be expedited by light curing. This new material is effective in releasing acid neutralizing ions as it contains alkaline filler.[5] It is a urethane dimethacrylate (UDMA) based dual-curing restorative material. The powder contains various glass fillers, initiators, and pigments, while the liquid comprises dimethacrylates and initiators. It is radiopaque and contains alkaline glass fillers capable of releasing calcium, fluoride, and hydroxide ions.[5,6] It displays a high polymer network density and degree of polymerization over the complete depth of the restoration, due to the cross-linking methacrylate monomers in combination with a stable, efficient self-cure initiator.[7]

The success rate of restorative treatment depends on physical, biological, and pathophysiological principles and thorough knowledge of mechanical and chemical properties of dental tissues and materials.

An *in vitro* study concluded that Cention N could be used for Class V cavities, as it would prevent caries at restoration margins by releasing calcium and fluoride ions.[8] Various other studies also showed that Cention N has significantly higher compressive, tensile strength, and shear bond strength when compared with GIC.[4,9-13] However, there is limited data about FT, FS, and acid buffer capability.[5,12,14,15]

Thus, this study aimed to assess FT, FS, and acid buffer capability of Cention N and compare it to GIC (GC Corporation, Tokyo, Japan). The null hypothesis was that there is no difference in the FT, FS, and acid buffer capability of Cention N and GIC.

MATERIALS AND METHODS

In this *in vitro* study, test materials and their compositions used are provided in Table 1. The sample size was calculated using G Power software (version 3.1.9.4). Based on the previous studies[12,16] and keeping the standard values of alpha error at 0.05 and the power of the study at 80%, the minimum sample size of the study is 30 per group and 10 in each subgroup. Sixty Teflon mold samples were prepared as per the specifications of tests using GIC (N = 30) and Cention N (N = 30).

Table 1: Materials used for sample preparation

Item	Composition	Manufacturer
Cention N	Liquid: Urethane dimethacrylate, tricyclodecane dimethanol dimethacrtylate, polyethylene glycol dimethacrylate Powder: Inorganic fillers (Ba-Al-Ca-Ba-Al-F silicate glass, Ca-F-silicate glass, YtF3) and customized fillers	Ivoclar Vivadent, Schaan, Liechtenstein
GIC	Liquid: Polyacrylic acid, polybasic carboxylic acid Powder: Fluoroaluminosilicate along with strontium, polyacrylic acid powder	GC Corporation, Tokyo, Japan

GIC: Glass-ionomer cement

Flexural strength

Ten beam-shaped Teflon mold samples measuring 25 mm × 2 mm × 2 mm [Figure 1a] were prepared for each test material. The GIC and Cention N were mixed as per manufacturer instructions.[6] They were inserted into the mold, covered with a polyester strip at the top, and compressed with a glass plate under a constant load of 500 g for 10 min. The samples were then stored at 37°C with a relative humidity of 100% for 50 min. They were removed from the molds and stored for 24 h at 37°C in distilled water before being subjected to a three-point bending test at a crosshead speed of 0.5 mm/min using a universal testing machine (UTM) (AG 15, Shimadzu Co., Kyoto, Japan).

Fracture toughness

Teflon mold samples with dimensions 25 mm × 2.5 mm × 5 mm and a single knife-edge notch of 2.5 mm depth and 0.5 mm width [Figure 1b] were prepared for each test material. The FT was determined by subjecting the prepared specimens to transverse bending according to the method outlined in the American Society for Testing and Materials specification E-399-90[17] with a three-point bending test was carried out at a crosshead speed of 0.5 mm/min using a UTM. FT (K_{1C}) (MPa $m^{1/2}$), was calculated.

Acid buffer capability test

Disk-shaped Teflon mold samples measuring 10 mm × 2 mm [Figure 1c] were prepared for GIC (n = 10) and Cention N (n = 10). The samples

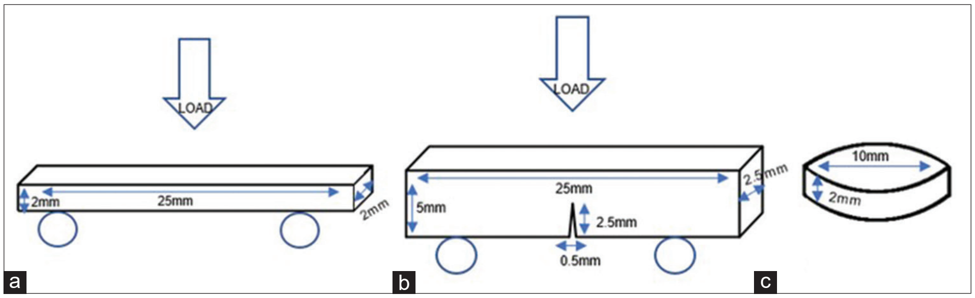

Figure 1: Schematic diagram of specimens showing (a) Flexural strength, (b) Fracture toughness, and (c) Acid Buffer Capability.

were kept at room temperature for 10 min and then stored in distilled water for a week. At the end of 1 week, the specimens were immersed in a 50 ml plastic tube with 5 ml of a lactic acid solution of pH 4.0.[16] A pH electrode (LI 120, ELICO Ltd) connected to a pH meter was placed at the center of the tube. The change in pH was noted 30 and 60 min after immersion.

Statistical analysis

Kolmogorov–Smirnov test and Shapiro–Wilk test were used to assess the normal distribution of the two groups. An insignificant value in each of the two tests with respect to each of the two groups in all the four parameters (FS, FT, and acid buffer capacity at 30 and 60 min) tells us that data follows normal distribution [Table 2]. In other words, it tells us that the data are normally distributed in the two groups and so we can now proceed for further evaluation of data using the parametric test of significance.

The data were then analyzed by the *t*-test using SPSS 20.0 (SPSS Inc., Chicago, Illinois, USA) and presented in the form of mean ± standard deviation (SD), standard error (SE); $P < 0.05$ was considered statistically significant with confidence interval set at 95%.

RESULTS

Table 3 depicts the mean FS and FT (with the corresponding SDs, SEs, and 95% confidence interval upper and lower values) obtained for the Cention N and GIC groups. In comparison between the same groups, the FS and FT of Cention N were statistically highly significant than GIC (Student's *t*-test; $P < 0.00001$).

The change in the pH of the lactic acid solution is shown in Table 3. There was a significant difference in the pH of the lactic acid solution at 30 and 60 min of sample immersion. The acid buffer capability of Cention N specimens was significantly higher than that of GIC.

Table 2: Tests of normality for the two groups on four parameters

Variable	Groups	Kolmogorov–Smirnov			Shapiro–Wilk		
		Statistic	df	*P*	Statistic	df	*P*
Flexural strength	Cention N	0.150	10	0.200	0.943	10	0.591
	GIC	0.156	10	0.200	0.924	10	0.395
Fracture toughness	Cention N	0.200	10	0.200	0.958	10	0.761
	GIC	0.137	10	0.200	0.979	10	0.960
Acid buffer capability 30 min	Cention N	0.225	10	0.163	0.872	10	0.104
	GIC	0.256	10	0.063	0.769	10	0.106
Acid buffer capability 60 min	Cention N	0.225	10	0.162	0.914	10	0.312
	GIC	0.160	10	0.200	0.942	10	0.575

P<0.05 is statistically significant. df: Degree of freedom; GIC: Glass-ionomer cement

DISCUSSION

The present study compared and evaluated the mechanical properties (fracture strength, FT) and acid buffer capability of Cention N with GIC. Cention N showed significantly higher and better properties than GIC. Hence, the null hypothesis was rejected.

The ability of restorative material to withstand the masticatory loads in stress-bearing areas of Class I, Class II, or IV restorations are crucial for their functional success.[15] The primary reason for failure in the restoration was fracture of restoration when placed in larger cavities over a period longer than 11 years.[18] According to Heintze *et al.*, FT and FS are two valuable tools to characterize the fracture resistance and durability of material under masticatory forces.[19] It is proven that the filler and level of filler weight are directly proportional to the strength of the material.[20] In the present study, Cention N shows a significantly higher FT and FS as compared to GIC. The higher strength can be due to higher filler loading. Cention N has four different dimethacrylates, namely

Table 3: Comparison of the flexural strength (MPa), fracture toughness (MPa·m$^{1/2}$), and acid buffer capacity (pH 4) at 30 min and 60 min between Cention N and glass-ionomer cement

Variable	Groups	*n*	Mean±SD	SE mean	*P*	95% CI of the difference	
						Lower	Upper
Flexural strength (MPa)	Cention-N	10	73.170±8.981	2.842	0.000**	48.610	64.149
	GIC	10	16.790±7.479	2.365			
Fracture toughness (MPa·m$^{1/2}$)	Cention-N	10	0.754±0.045	0.014	0.000**	0.537	0.610
	GIC	10	0.180±0.030	0.009			
Acid buffer capability for pH 4 at 30 min	Cention-N	10	4.096±0.026	0.008	0.000**	0.037	0.074
	GIC	10	4.040±0.009	0.002			
Acid buffer capability for pH 4 at 60 min	Cention-N	10	4.164±0.043	0.013	0.000**	0.051	0.112
	GIC	10	4.082±0.013	0.004			

P<0.05 is statistically significant; ***P*<0.01 is statistically highly significant, Student-*t* (Unpaired *t*) test applied. SD: Standard deviation; CI: Confidence interval; GIC: Glass-ionomer cement, SE: Standard error

UDMA the main component of the monomer matrix, aromatic aliphatic-UDMA, dicalcium phosphate, and polyethylene glycol 400 dimethacrylate (PEG-400 DMA), representing (PEGDA 400) 21.6% wt. of final mixed material. These filler particles attribute to the high FS and FT[17,18] and desired handling characteristics of mixed material.

Various techniques for measuring FT include double torsion, Chevron notch bend specimen, indentation strength, indentation crack length/fracture, double cantilever beam, fractography approach, single-edge precracked beam, single-edge notched (SEN) beam, and compression precracking. The short rod Chevron notch test and the SEN test using rectangular, cylindrical, and prismatic specimens are more common when determining FT of dental materials.[21] The SEN test method to determine the FT was used in this study, primarily because of its simplicity and low cost. FT measurements using a SEN beam use a three- or four-point bending apparatus. The limitations of this test are that the results are sensitive to the width and depth of the notch. This makes direct comparison of the different studies complex.[18]

The acid buffer capability of the Cention N and GIC group, 1 week after mixing, when immersed in lactic acid for 30 min and 60 min are depicted in Table 3. The results for Cention N were significantly higher when compared to GIC. This could be due to the regular elution of the fluoride ion from the Cention N compared to the calcium ion from the GIC.[12,22] This finding is clinically effective on the premise that Cention N has an acid buffering capacity for up to an hour while being subjected to changes during drinking or eating[16] Although the results obtained in this study suggest efficiency toward caries prevention and remineralization, there is no clinical evidence toward the same.

The results of our study were consistent with the results of studies by Mishra *et al*.,[14] Sadananda *et al*.,[9] Sujith *et al*.,[11] Chole *et al*.,[15] Bahari *et al*.,[5] and Balagopal *et al*.[12] They reported that Cention N exhibited FS more than GIC and could be used as alternative posterior restorative material.

Limitations of the study are that though we evaluated the acid buffer capability, we could not evaluate the direct effect on caries prevention and remineralization. This is an area for future research. Tribological and *ex vivo* simulated experiments could yield more exhaustive results for mechanical strength.

CONCLUSION

The present study showed that the mean FT, FS, and acid buffering capability of Cention N is higher than that of GIC.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, and financial or nonfinancial in this article.

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