Comparative Evaluation of Flexural Strength of Glass Ionomer Cement and Cention N in Artificial Medium Over Time Intervals - An In-Vitro Study

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ABSTRACT

BACKGROUND
Glass ionomer cement (GIC) is a versatile restorative cement in paediatric dentistry. Due to its less flexural strength, alternative materials have been developed. Cention N is one such material, but since it's a new material evidence is lacking regarding its physical properties, especially flexural strength for evaluating its clinical outcome. We wanted to compare the flexural strength of glass ionomer cement and Cention N stored in artificial saliva and its variation over different time intervals, i.e., after 24 hours, 1 week and 4 weeks.

METHODS
A total of 30 specimens were prepared for GIC (Fuji IX) and Cention N and were further categorized according to the duration of storage time of 24 hours, 1 week and 4 weeks (N = 10). A 3 - point bending test using a universal testing machine was used to evaluate the flexural strength.

RESULTS
GIC Fuji IX showed a mean flexural strength of 35.296 ± 1.61 Mpa at the end of 24 hours, 47.234 ± 4.12 after 1 week and 66.039 ± 11.05 Mpa at the end of 4 weeks. GIC showed a statistically significant increase of flexural strength from 24 hours to one week and a further increase after 4 weeks of storage. The flexural strength of Cention N at 24 hours was 175.985 ± 22.11 Mpa, at the end of one week was 163.486 ± 17.55 MPa, and after 4 weeks was 175.437 ± 27.22 Mpa. Cention N did not show any statistically significant change in flexural strength value from 24 hours to 4 weeks. Cention N showed highly significant difference between flexural strength compared to GIC at all - time intervals.

CONCLUSIONS
Cention N has a superior flexural strength compared to GIC at all - time intervals.

KEY WORDS
Cention N, Flexural Strength, Glass Ionomer Cement

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BACKGROUND

Glass ionomer cement is a tooth-coloured dental restorative material invented by Wilson and Kent in the early 1970s. It is also known as polyalkenoate cement and is a water-based cement. There are three essential ingredients to a glass ionomer cement, namely polymeric water-soluble acid, basic (ion - leachable) glass, and water. It is commonly presented as an aqueous solution of polymeric acid and a finely divided glass powder, which is mixed by an appropriate method to form a viscous paste that sets rapidly. Alternative formulations exist ranging from both the acid and the glass being present in the powder, and pure water being added to cause setting.1 The polymers used in glass ionomer cement are polyalkenoic acids, either homopolymer (acrylic acid) or the 2:1 copolymer of acrylic acid and maleic acid.

The glasses for ionomer cement are basic, which include alumina-silicate glasses, with fluoride and phosphate additions. They are clinically attractive dental materials with certain unique properties like biocompatibility to dental tissues, physicochemical bonding to enamel and dentin, fluoride release thus promoting remineralization of tooth. They have coefficient of thermal expansion similar to that of tooth structure and bonds to non-precious metals.[1] The use of GICs in a mechanically loaded situation, however, has been hampered by their low mechanical performance, thus limiting their extensive use as a filling material in stress- bearing applications.[2] Numerous newer restorative materials have been introduced in dentistry with higher mechanical properties.

Cention N (Ivoclar Vivadent; Liechtenstein) is a recently introduced tooth-coloured, restorative material for bulk placement in retentive preparations with or without the application of an adhesive.[3] Cention N is a UDMA based, self - curing powder / liquid restorative material. The liquid comprises of dimethacrylates and initiators, whilst the powder contains various glass fillers, initiators and pigments. It is radiopaque and contains patented alkaline glass fillers capable of releasing fluoride, calcium and hydroxide ions. Cention N exhibits high polymer network density and degree of polymerization over the complete depth of the restoration. The special patented filler (Isofiller) acts as a shrinkage stress reliever and thus Cention N reduces polymerization shrinkage and microleakage.[4] Cention N has additional light curing options which marks its excellent handling properties. Glass ionomer cement is a tooth-coloured dental restorative material invented by Wilson and Kent in the early 1970s

Flexural strength is a fracture-related mechanical property and is a measure of the resistance of restorations to with stand tensile forces. Posterior restorations done with materials of low flexural strength are liable for fracture resulting in clinical failure. Restorations with materials of high flexural strength are less susceptible to fracture. Such restorations will undergo only a minimal deformation when subjected to forces during mastication.

The ability of restorative dental materials to withstand the functional force under masticatory forces is an important requirement for their clinical performance for a considerable period of time. Physical property of any restorative material will be different from a laboratory condition due to the dynamic environment by ever changing saliva and temperature. Various complex tensile, compressive, shear and bending forces tend to deform the material, thus the knowledge and interpretation of how materials behave under such forces are relevant in understanding the clinical performance.

Many studies have been conducted with regards to GIC on its flexural strength when stored in different media at different time intervals. But since Cention N is a newer material, there are no studies regarding the influence of storage media at different time intervals on its flexural strength.

Objectives

To study and compare the flexural strength of Glass ionomer cement and Cention N stored in artificial saliva at different time intervals of 24 hours, one week and 4 weeks.

METHODS

This is an invitro experimental study done following the CRIS guidelines for in-vitro studies as discussed in the 2014 concept note. The study was conducted at KMCT dental college, Calicut, Mukkam, Kerala from November 2020 to December 2021.

Sample Size Calculation

Sample size for the study was calculated using this equation

$$\frac{(Z_{\alpha/2} + Z_{1-\beta})^2 \times 2(\sigma)^2}{d^2}$$

Where,
σ = pooled standard deviation obtained from previous study
d = accuracy of the estimate
$Z_{\alpha/2}$ = Normal deviate for two tailed hypothesis = 1.96
$Z_{1-\beta}$ = 0.84 (Type II Error) - Substituting the values
N = 50.

Sample size is determined as a minimum of 50 but to achieve uniform and even number distribution into different groups sample size is taken as 60 in this study. For sample preparation customized silicone moulds were fabricated with dimensions of 4 mm × 4 mm ×50 mm.

Figure 1 GIC (Fuji IX GC International Corp, Japan) and Cention N (Ivoclar vivaldent, Liechtenstein) were manipulated according to the manufacturer's instructions and transferred to the mould, followed by placement of mylar strips and were pressed with glass microscope slides. The material was allowed to set for 160s and the samples were removed from the mould with plastic instrument and tweezer. The samples were inspected visually for imperfections. Defective samples were discarded. All the specimens were polished using 600 grit sandpaper to remove surface imperfections and were transferred to beakers containing artificial saliva and samples were maintained at a temperature of 37°C in incubator until the time of testing.

Total of thirty specimens were prepared for GIC and Cention N (N = 30) each. The samples were further subdivided based upon the time the samples tested i.e., 24 hours, 1 week and 4 weeks. Ten samples were allocated for each subgroup to be tested. (Figure 3)

Figure 1. Custom Fabricated Silicone Mould

Figure 2. Samples in Incubator

Figure 3. Total Prepared Samples

Flexural strength was measured with universal testing machine with a load of 1 kN, using a 3 - point bending test (I = 20 mm) at a cross head speed of 1 mm / min till fracture of the specimen. This procedure was repeated for all the samples as planned at 24 hours, 1 week and 4 weeks. 10 samples each were tested at 24 hours, 1 week and 4 - week interval.

Flexural strength was calculated by the equation.

$$\frac{\sigma 3FL}{2bh2}$$

Where F is the maximum load (N), l is the distance between the supports on which the sample is placed (20 mm), b is the width of the specimen (4 mm), and h is the height of the specimen (4 mm).

Statistical Analysis

Data was analysed with SPSS version 20.0 software. Paired t test was used for within the group's comparison and independent t test for comparison between the groups. P value less than 0.05 was considered statistically significant.

RESULTS

The mean flexural strength of glass ionomer cement at the end of 24 hours was 35.29 ± 1.61 Mpa, at the end of 1 week was 47.23 ± 4.12 Mpa and after 4 weeks was 66.03 ± 11.05 Mpa. When intragroup comparison was made, there was statistically significant difference for variation of flexural strength at different time intervals ($P < 0.001$). The mean flexural strength of Cention N after 24 hours was 175.98 ± 22.11 Mpa, at the end of one week was 163.48 ± 17.55 MPa, and at the end of 4 weeks was 175.43 ± 27.22 Mpa. Intragroup comparison revealed no statistically significant difference in variation of flexural strength at different time intervals for Cention N. When comparison was made there was statistically significant difference between mean flexural strength values of glass ionomer cement and Cention N at 24 hours (GIC - 35.29 ± 1.61 Mpa, Cention N - 175.98 ± 22.11 Mpa) at the end of 1 week (GIC - 47.23 ± 4.12 Mpa, Cention N 163.48 ± 17.55 Mpa) and at the end of 4 weeks. (GIC - 66.03 ± 11.05 Mpa, Cention N - 175.98 ± 22.11 Mpa)

DISCUSSION

Glass ionomer cements combine the technologies and chemistry of silicate and zinc polycarboxylate materials to incorporate the desirable characteristics of both. Even though GIC is a versatile restorative material in paediatric dentistry, low flexural strength is a major drawback which limits its usage only to minimal stress bearing areas. Cention N is an "alkasite" which comes as a subgroup of the composite material. It is a basic full volume bulk replacement material, designed to be applied quickly and conveniently. It is intended for restoring Class I, II or V cavities of deciduous teeth and permanent dentition.

The presence of 78.4 % wt. of a patented alkaline inorganic filler which provides the higher flexural strength and imparts adequate strength to withstand the stresses and strains of the oral cavity. Dental materials typically fail in flexure.[5] This is because of the multitude of stresses to which it is subjected in the oral cavity. Flexural strength is a commonly evaluated mechanical property of the dental materials as it is more susceptible to showing subtle changes in the substructure than compressive strength tests. According to studies by Xie D et al.[6] a strong explanatory power existed between the flexural strength and the long-term wear and hence suggested that it is possible to forecast the long-term wear of any materials by measuring the flexural strength. Moreover, the flexural strength produces an appropriate estimate of the tensile strength of the material, thus mimicking the clinical situation. Materials with high flexural strength provide restorations with less susceptibility to fracture at the margins or in bulk, thus are recommended in cases where they are subjected to heavy load as in cases of class II cavities. The ISO specifications for sample dimensions for flexural strength testing was 25 mm × 2 mm × 2 mm. Antonio Muench et al.[7] stated that there was no effect of specimen dimensions on the flexural strength and thus the dimensions of the samples in this study were taken as 50 mm × 4mm × 4 mm to aid in ease of the sample preparation, manipulation, and testing. Storage regimen may have an impact on various mechanical properties of dental materials. In the previous in-vitro studies, conflicting reports emerged when comparisons were made for flexural strength of GIC when stored in different storage media. Some have used distilled water, deionized water, saline, petroleum jelly, stimulated saliva and artificial saliva. Artificial saliva used for this study had a composition similar to natural saliva and pH of 6.8 which mimics the conditions of the oral cavity and was the most appropriate for in vitro studies.[8] In the present study, measures were taken to make testing conditions almost identical to the intraoral environment in terms of handling, specimen dimensions, storage media, temperature, time intervals and testing methods. In the present study the mean flexural strength of GIC specimens at the end of 24 hours was 35.296 ± 1.614 Mpa, at the end of one week it was 47.234 ± 4.128 Mpa and at the end of 4 weeks showed 66.039 ± 11.059 Mpa. So, it has been observed that this material is having a statistically significant increase in flexural strength from 24 hours to 4 weeks which is most desirable in the clinical situations. (Table 1) (Graph 1)

Similar results were observed in other studies by Abhishek Mishra et al.[9] (31.49 Mpa), Karin Sunnergardh et al.[10] (32 ± 8 Mpa), Piwowarcyzk et al. [11] (35.8 Mpa) and Frankel et al.[12] (37.8 Mpa) for glass ionomer cement at 24 hours. Meanwhile, flexural strength of GIC evaluated by Andree Piwowarcyzk et al.[13] (22.2 ± 3.5 Mpa), Iazetti et al.[14] (22.6 Mpa), Seung et al.[15] (24.5 ± 4.2 Mpa) and Tamara et al.[16] (28.5 Mpa) after 24 hours was lesser than the values of the current study. This difference could be attributed to the specimen's storage in water which might have had a negative influence of the mechanical property. While studying the variation of flexural strength over time Mckenzie et al.[17] with 0.9 % saline as a storage media observed no change in the strength from 24 hours to one week (33.1 Mpa). Storage in deionised water by Khouw et al.[18] reported an increase of flexural strength from 33 Mpa at 24 hours to 37 Mpa at the end of 1 week. The increase in strength was attributed to the completion of the first two stages of the setting reaction (dissolution and gelation) and the maturation of the cement matrix due to additional cross-linking. But contrary to previous studies which showed an increase of flexural strength till 4 weeks Khouw et al. reported a decrease in flexural strength at the end of 4 weeks (36.5 Mpa) which was not statistically significant. Flexural strength values for GIC at the end of 24 hours of storage in distilled water evaluated by Andree Piwowoarcyzk[13] were 35.8 Mpa. When GIC was aged in distilled water Karin et al.[10] reported a steady increase from 32 ± 8 Mpa at 24 hours to 40 ± 10 Mpa at the end of 1 week. Frankel et al.[12] extended the duration of study till 4 weeks and reported an increase of flexural strength values from 37.8 Mpa at 24 hours to 41.5 Mpa after one week with a further increase to 47.4 Mpa after 4 weeks. As reported by Crisp et al.[19] this increase in strength was a result of the continued formation of aluminium salt which was responsible for the final hardening of the cement. The more recent critically reviewed hypothesis by Wasson et al. suggests that maturation of GIC is the result of continuous formation of poly salt complexes involving several ionic species and not exclusively aluminium ions. Contrary to the above studies, Mckenzie et al.[17] reported an increase in flexural strength values from 24 hours (29.8 Mpa) to one week (44.1 Mpa) and a decrease in values at the end of 4 weeks (31.8 Mpa) when stored in distilled water. Similar results were observed by Faridi et al.[20] who also reported an increase of flexural strength values from 24 hours (23.1 Mpa) to one week (24.4 Mpa) and further reduction at the end of four weeks (14.5 Mpa) on storing in artificial saliva. It was stated that water as a storage medium for GIC is not ideal as it can lead to diminished physical properties due to absorption of water molecules by the cement and the susceptibility of the cement for chemical erosion caused by hydrolysis when stored in distilled water. Also, matrix - forming ions are released in the medium to help the process of buffering, thus affecting the strength of the material. Glass-ionomers release ions into the aqueous solution which eventually become incorporated into the cement matrix thus contributing to the final structure. The ability of ions to dissolve depends on the number of ionic species already in solution.[21] So, the dissolution into pure water is more extensive than into artificial saliva, which already contains dissolved ions. So, in artificial saliva, the dissolution of ions would be hindered and get retained as the structure - forming ion thus making the material stronger. Though conflicting reports have been reported about the effects of water storage on mechanical properties as most of the researchers opined that water storage produces a small initial decrease in strength but has little long term effects.

Mckenzie et al.[17] had used unstimulated and stimulated whole saliva as a storage media. The variation in flexural strength in unstimulated saliva over 24 hours to one month showed a similar pattern of strength variation like distilled water with an increase in flexural strength from 24 hours (26.4 Mpa) to one week (30.4 Mpa) and then a tremendous decrease by the end of 4 weeks (21.7 Mpa). But there was a steady decrease of flexural strength from 24 hours (32.8 Mpa) through 2 weeks (28.0 Mpa) to 4 weeks (26.2 Mpa) for unstimulated saliva. Even though it is suggested that in saliva GIC undergoes a surface reaction that leads to the precipitation of calcium and phosphate ions into the outermost layer, according to Mckenzie et al. the flexural strength values at all the intervals in unstimulated saliva were much lesser compared to the present study.

The adverse effects of the surrounding environment on the properties of GIC have been known for years and for that reason GIC is coated with varnish, petroleum jelly or other commercially available materials soon after placement into the cavity. Authors suggest that coating with petroleum jelly and varnish gave specimens higher mechanical strengths attributed to the fact that surface coating reduces ion release and dissolution of ions into the surrounding aqueous medium thus contributing to the strength of set cement[21]

In the present study the mean flexural strength of Cention N at the end of 24 hours was 175.98 ± 22.11 Mpa, at the end of one week it was 163.48 ± 17.55 Mpa and at the end of 4 weeks showed 175.43 ± 27.22 Mpa. (Table1) (Graph 1) It has been observed that this material was showing slight decrease in flexural strength from 24 hours to 4 weeks but was not statistically significant. This observation was in striking contrast with the previous studies conducted by different researchers.

Mishra et al.[9] have shown that flexural strength of Cention N at the end of 24 hours of storage in water was 87.27 Mpa which was far below the present study (175.98 Mpa). This could be explained by the fact that specimens were stored in distilled water. In another study, Chole et al.[22] observed higher values of 133.2 Mpa for Cention N stored in distilled water at the end of 24 hours in comparison with the current study but nonetheless the values were lower than the ones that were observed in the current study.

Flexural strength of Cention - N can be attributed to higher filler loading. Fillers are responsible for imparting restorative materials with adequate strength to withstand stresses and strains of the oral cavity and to achieve acceptable clinical longevity. The patented filler composition of Cention N achieve strength and also obtain desired handling characteristics of mixed material. All the fillers, therefore (except ytterbium trifluoride) are surface modified to ensure wettability by liquid and incorporation into the polymer matrix. The inorganic fillers comprise a barium aluminium silicate glass filler, ytterbium trifluoride, an isofiller, calcium barium aluminium fluorosilicate glass filler and a calcium fluorosilicate (alkaline) glass filler, with a particle size of between 0.1 µm and 35 µm.

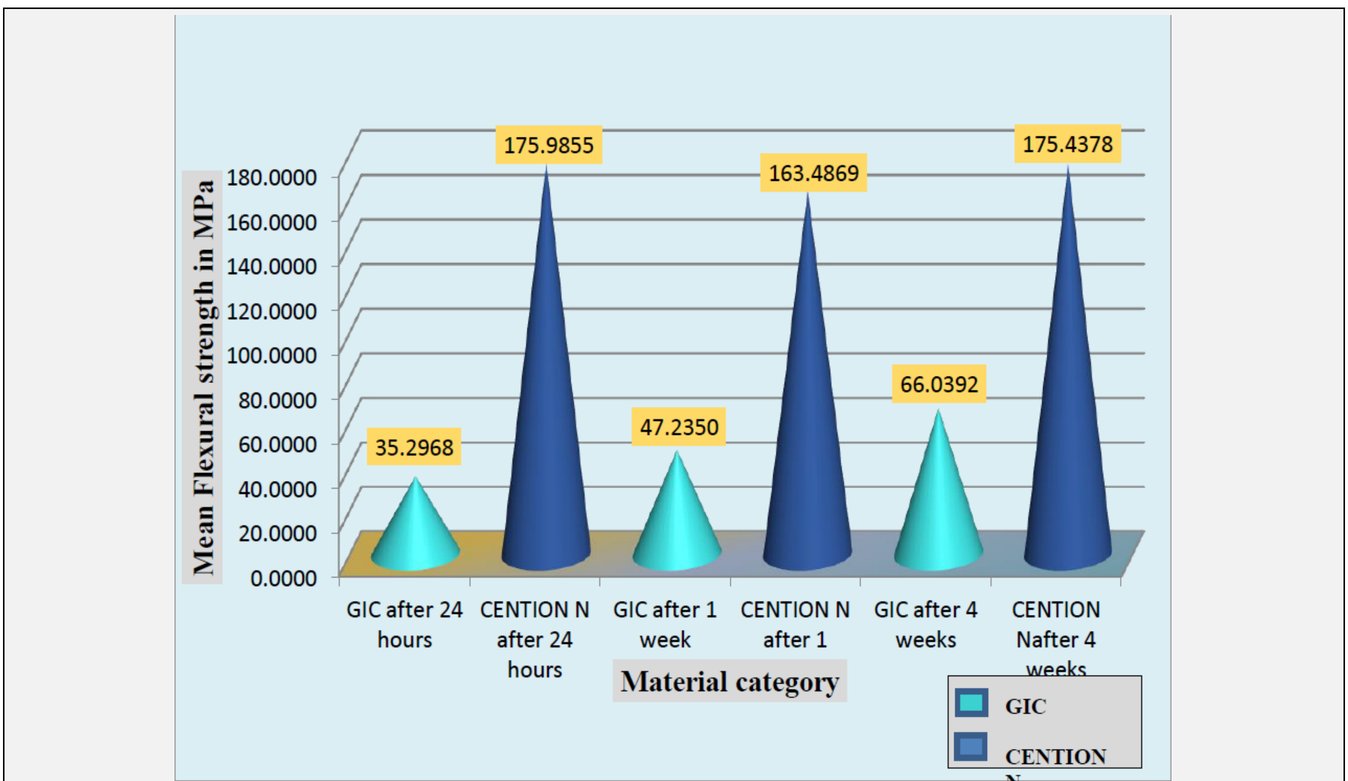
When the flexural strength of Cention N was compared to GIC, remarkably higher values were noticed for Cention N. (Table 1) (Graph 1). The flexural strength values after storage in artificial saliva for Cention N at the end of 24 hours was 175.98 ± 22.11Mpa while GIC reported 35.29 ± 1.61Mpa. The difference was statistically significant. (P value 0.001). After 1 week of storage in artificial saliva flexural strength value for Cention N was 163.48 ± 17.5 Mpa and of GIC was 47.23 ± 4.12Mpa. The difference was statistically significant. (P value 0.001) (Table 1) (Graph 1) At the end of 4 weeks of storage in artificial saliva the flexural strength of Cention N was 175.43 ± .22Mpa and for GIC it was 66.03 ± 11.05Mpa. Statistically significant difference was noticed. (P value 0.001) (Table 1) (Graph 1)

Category 1 Mean Flexural Strength	Category 2 Mean Flexural Strength	Student's t Test Value	Significance (2 Tailed P - Value)
GIC after 24 hrs (35.29 ± 1.61 Mpa)	Cention 24 hrs (175.99 ± 22.11 Mpa)	20.06	0.001***
GIC after 1 week (47.23 ± 4.122 Mpa)	Cention after 1 week (163.48 ± 17.55 Mpa)	20.383	0.001***
GIC after 4 weeks (66.03 ± 11.05 Mpa)	Cention 24 hrs (175.99 ± 22.11 Mpa)	11.772	0.001***
GIC after 24 hrs (35.29 ± 1.61 Mpa)	GIC after 1 week (47.23 ± 4.122 Mpa)	8.516	0.001***
GIC after 1 week (47.23 ± 4.122 Mpa)	GIC after 4 weeks (66.03 ± 11.05 Mpa)	5.037	0.001***
GIC after 24 hrs (35.29 ± 1.61 Mpa)	GIC after 4 weeks (66.03 ± 11.05 Mpa)	8.698	0.001***
Cention 24 hrs (175.99 ± 22.11 Mpa)	Cention after 1 week (163.48 ± 17.55 Mpa)	- 1.40	0.179
Cention after 1 week (163.48 ± 17.55 Mpa)	Cention after 4 weeks (175.43 ± 27.22 Mpa)	1.167	0.259
Cention 24 hrs (175.99 ± 22.11 Mpa)	Cention 24 hrs (175.99 ± 22.11 Mpa)	0.049	0.961

Table 1. Comparison of Mean Flexural Strength of Different Categories

*P value less than 0.05 is significant.

The published data revealed that only two studies were conducted on flexural strength of Cention N and the limitations of these studies were that evaluation of flexural strength was done only at the end of 24 hours and longer periods of observation was not included. But the current study explains that flexural strength does not alter significantly after long storage times. Within the limitation of the study, an attempt has been made to assess the flexural strength after 24 hours, end of one week and at the end of 4 weeks.



Graph 1. Distribution of Mean Flexural Strength of Glass Ionomer Cement and Cention N at Various Time Intervals

CONCLUSIONS

When comparisons were made Cention N showed superior performance than GIC in terms of flexural strength. GIC exhibited very low flexural strength at the end of 24 hours and increased steadily to one week and 4 weeks. The variation between each interval was statistically significant. Flexural strength of Cention N did not exhibit statistically significant changes from 24 hours to 4 weeks.

Limitations

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Data sharing statement provided by the authors is available with the full text of this article at jemds.com.
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