ORIGINAL RESEARCH

Effect of Prolonged Water Aging on the Bond Strength and Marginal Seal of Three Novel Restorative Materials

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Abstract

Aim: To assess and contrast the shear bond strength (SBS) and microbial leakage of Cention-N, Fuji IX, and nanohybrid composite restorative materials after being exposed to prolonged water aging.

Materials and methods: A total of 30 self-curing acrylic blocks were prepared for SBS analysis. Extracted teeth were affixed on the acrylic resin to incorporate the root section. To expose the occlusal dentin, 3 mm of the midcoronal portion was sectioned. The sectioned samples were allocated into the following three groups: Group I: Fuji IX; group II: Filtek Z350; and group III: Cention-N. Cylindrical plastic tubing was used to place each material as directed by the manufacturer and water aging for 7, 14, and 28 days at 37°C. Also, a universal testing machine (UTM) was utilized for testing followed by a scanning electron microscope (SEM). For microleakage analysis, a total of 30 class-V cavities were prepared. The prepared samples were allotted to respective groups; Later, 200 thermocycles at 5°C and 55°C were applied for 30 seconds to mimic the oral environment. The root apices sealed with sticky wax and the exception of a 1-mm around the edges of the restorations were then painted twice with clear nail varnish and submerged in 0.5% basic fuchsin dye at 37°C. Samples were washed, dried, and sectioned longitudinally followed by stereomicroscopic evaluation.

Results: Groups I (0.083), group II (0.083), and group III (0.102) did not show significant variation in the SBS after water degradation. At the end of 28 days of water aging, group III showed 33.3% adhesive failure and 66.7% mixed failure mode. For marginal leakage in group III, the mean and standard deviation (SD) were 334.90 ± 418.454 with the $p = 0.001$ showing a significant difference compared to groups I and II.

Conclusion: Compared to nanohybrid composite and Fuji IX, Cention-N showed a superior SBS after being exposed to water aging and exhibited lesser marginal leakage.

Clinical significance: Cention-N outperformed in its marginal adaptation with superior shear resistance and can be considered as an alternative bulk filling material.

Keywords: Cention-N, Filtek Z350, GIC Fuji IX, Water aging.

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Introduction

In the realm of advanced dental practice, a variety of direct filling materials are accessible, ranging from amalgams to contemporary bulk-fill composites.[1] In pediatric dentistry, glass ionomer cement (GIC) is the most often utilized cement for restoring deciduous teeth. However, the major drawback is the fluoride release which is maximum at the first 24 hours and decreases exponentially.[2]

In addition to aluminum silicate polyacrylate (ASPA) cement, resin composites are the frequently utilized restorative materials due to their significantly superior structural and esthetic qualities.[3] The majority of advancements have been made in filler systems, thereby improving mechanical characteristics and wear resistance.[4] A significant influence of nanotechnology on restorative dentistry has led to the creation of nanohybrid composites with novel filler patterns. Numerous benefits, including enhanced mechanical and better optical qualities, can be obtained by changing the organic resin component.[5]

Cention-N, a novel filling material delivers great flexural strength together with tooth-colored esthetics and belongs to the family of alkasite materials. A special alkaline filler present in the Cention-N speeds up the release of hydroxide ions, which helps maintain pH during acidic assaults. Additionally, the massive release of calcium and fluoride ions provides a strong foundation for the remineralization of tooth enamel. Good chemical self-curing and light curing properties are made possible by the initiator mechanism, providing dual cure properties. The liquid comprises methacrylate monomers, initiators, and various organic fillers. It exhibits high mechanical qualities and has a modest degree of viscosity.[6]

The resilience of the restorative materials to withstand masticatory forces and exhibit less microleakage determines the longevity of the restoration.[7] Any force applied to the filling material results in compressive, tensile, and shear stresses.[8] The term "shear bond strength (SBS)" refers to the "material's ability to resist these shearing forces without being detached from the tooth or suffering an adhesion or cohesion fracture."

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Additionally crucial to the effectiveness of restoration is the marginal seal. "The movement of bacteria, fluid, chemicals, or ions in clinically undetectable amounts *via* tiny gaps (10^{-6} m) between the cavity wall and the applied restorative material" is known as microleakage. The lesser the microleakage, the longer the restoration will last in the oral cavity.[7] Because of the ions, enzymes, bacteria, pH variations, temperature fluctuations, and other components present in the complex oral environment, any restorative material is constantly challenged. This might cause the filler materials to deteriorate, resulting in an increase in wear and roughness and a gradual loss of mechanical qualities.[9] It is necessary to assess dental restorative materials to see if they are likely to degrade over time.[10]

Several aging-related biodegradation models were used in past studies to assess these restorative compounds. To replicate the oral environment, for instance, agents such as alcohol, clean water, and synthetic saliva (free of salivary bacteria) were used;[11] Thermocycling was utilized to imitate the thermal fluctuations that restorative materials encounter in the mouth when used clinically;[12] ultraviolet (UV)-accelerated aging simulated exposure to UV light while engaging in outdoor activities.[13]

Long-term water storage is the method of artificial aging that is most frequently utilized. Water may also enter and impair the structural constituents of the resin matrix by "expanding and lowering the friction that occurs in the polymer chains, a process known as plasticization."[14] It degrades the interface between the matrix and filler and shows that silanization agents have a major impact on the mechanical characteristics of restorative material.[15]

Since then, there has not been a lot of research on the SBS, marginal seal qualities, durability, and water aging resistance of Cention-N. For this reason, the current research was undertaken to assess and contrast the SBS and microbial leakage of Cention-N, Fuji Type IX, and nanohybrid composite restorative materials after being exposed to water aging.

Materials and Methods

The study was undertaken in the Department of Pediatric and Preventive Dentistry, Amrita School of Dentistry, Kochi from June 2022 to February 2023. The Ethical Clearance was obtained from the Ethics Committee of Amrita School of Medicine (ECASM-AIMS-2021-182). Based on the results observed in a study by Naz et al., with 80% power and 95% confidence, the minimum sample size was increased to 10 in each group, thus adding up to a total of 30 for each analysis.

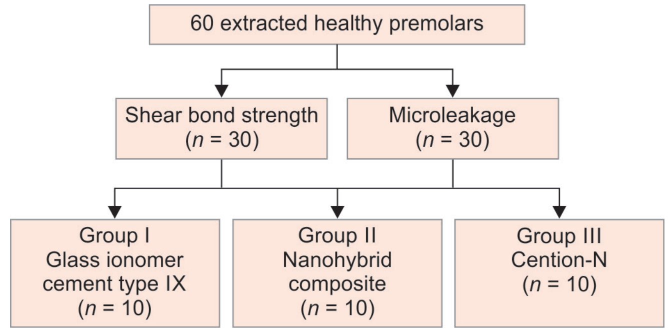
A total of 60 human premolar teeth were obtained from patients who reported for orthodontic reasons and stored for this study. Freshly extracted healthy premolars with intact crowns, closed apices, and no signs of caries, fracture, or visible morphological alterations in the enamel are included and the teeth with enamel defects, dental caries, restoration, and periodontal diseases are excluded.

Randomization was done by randomly assigning the specimens into two groups, based on the property assessment; 30 in each group. Further into three subgroups group I (GIC type IX), group II (nanohybrid composite), and group III (Cention-N) based on the type of restorative material used (Flowchart 1). Blinding was done through a single investigator.

Shear Bond Strength Analysis

Thirty caries-free human premolars were extracted and kept in sterile saline before being examined. On self-curing acrylic blocks (2 cm × 2 cm), the extracted tooth specimens were mounted so that the root portion was incorporated. The midcoronal tooth structure was sectioned using cutting burs to remove 3 mm, exposing the occlusal dentin of the embedded teeth. Using the size 600 grit carbide sandpaper, the exposed dentin surface was smoothened with the use of grinding and polishing equipment. All the restorations were placed on the occlusal surface using cylindrical plastic tubing (4 mm × 4 mm), in accordance to the manufacturer's instructions. Following the placement of restorative material on the occlusal surface using the mold, group II (Filtek Z350) and group III (Cention-N) underwent polymerization using a light-emitting diode (LED) curing device for 40 seconds. Using finishing and polishing burs, the rough surface of the restoration was smoothed once they had set in order to eliminate any surface imperfections. The prepared teeth samples were then aged in deionized water for a dwell period of 7, 14, and 28 days at 37°C. To keep the samples in a dynamic oral state, they were put in a digital shaker incubator (JSR shaking incubator).

Flowchart 1: Sample grouping



Using an Instron universal testing machine (UTM) (electronic type; UTE-40; 400 kN, 50 Hz AC), a load cell of 1 kN, a crosshead speed of 0.5 mm/minute, and a crosshead speed of 0.5 mm/minute the SBS was analyzed. The results were represented in MPa after the mean and standard deviation (SD) were calculated. After the debonding process, the dentin surface was examined using a scanning electron microscope (SEM) (JEOL JSM-6490LA). Under sputter, samples were gold-plated for 90 seconds prior to SEM analysis. For each sample, images were captured at 1000× magnification. For each sample, five scans were performed at various locations to identify the failure modes, that is, "According to the research done by Yahya and Shekh[16] and Naz et al.,[3] the mode of failure was categorized as

- Type I: Adhesive failure – defects at the contact between the adhesive and the dentin or the adhesive and the composite.
- Type II: Cohesive failure – defects develop inside the substance or composite.
- Type III: Mixed failure – a hybrid of cohesive and adhesive failure.
- Type IV: Cohesive dentin failure – the dentin itself fails.

Microleakage Analysis

A total of 30 premolars were collected and stored in 0.9% normal saline solution till use. Class V cavities with dimensions of 2 mm × 3 mm × 2 mm in the occlusogingival direction were prepared on the buccal surface of premolar teeth using a flat-end straight diamond bur with water coolant. All the tooth preparations were restored using the appropriate materials after being equally distributed into three groups of 10 samples each. In order to imitate changes in oral thermal state, they were then put through 200 thermocycles lasting 30 seconds at 5°C and 55°C. With the exception of the 1 mm

Table 1: Multiple group comparison of mean and SD of SBS after 7, 14, and 28 days of water aging

	Group I		*Group II*		*Group III*		
Time interval	*Mean ± SD*	*p-value*	*Mean ± SD*	*p-value*	*Mean ± SD*	*p-value*$^{+}$	*p-value**
SBS – 7 days	2 ± 0	–	32.25 ± 0.5	–	5 ± 0	–	0.002
SBS – 14 days	5 ± 0	NA[a]	5 ± 0	<0.001	5 ± 0	1.00	NA[a]
SBS – 28 days	3 ± 0	NA[a]	14.33 ± 0.57	NA[a]	16.33 ± 0.57	1.00	0.004

One-way ANOVA to test the normality; *Between group comparison; $^{+}$Within group comparison; [a]The correlation cannot be computed because the standard error of the difference is 0; NA, not applicable

border around the margins of the restorations, the root and crown surfaces of the teeth were painted with the clear nail varnish in two coats to prevent any dye from leaking through the root apex. These samples were submerged in 0.5% basic fuchsin dye for 24 hours at 37°C. Then, they were thoroughly cleaned with tap water before being dried. Each tooth was then longitudinally sectioned in the center of the restoration using a diamond disc under water coolant. Using a stereomicroscope with a 20× magnification, all sections were examined. A sectioned portion of a tooth with more microleakage was selected for scoring after each longitudinal segment was examined. Using Image J software, the depth of the leakage between the margins and the calculated limit was measured in millimeters. The mean leakage score for each group was computed and assessed.

The dye penetration was scored utilizing the "Munro, Hilton, and Hermesch scoring system.

- Score 0 shows no signs of dye penetration.
- Score I shows that the dye penetrates the cavity to a depth of half.
- Score II shows dye penetration of more than 50% of cavity wall depth.
- Score III shows the dye penetration involving the axial wall.

The IBM® statistical package for the social sciences (SPSS®) software, version 20.0, software was used to perform the statistical analysis. Using mean, SD, and median [interquartile range (IQR)], SBS and microleakage were demonstrated.

Results

To test the statistical significance of the comparison of the SBS and microleakage property of Cention-N, GIC (Type IX), and nanohybrid composite, a one-way analysis of variance (ANOVA) variance test was used for normality followed by *post hoc* test and Kruskal–Wallis test for non-normality. The significance level was considered at $p \leq 0.05$ for all tests.

For SBS, groups I, II, and III showed that there was no statistically significant difference between the groups. Groups I (0.083), II (0.083), and III (0.102) did not show significant variation from one another when compared among all three groups at the end of 7 and 28 days, respectively. Intergroup comparison of all three groups at the end of 14 and 28 days reveals no statistically significant difference with $p > 0.05$ for group I (0.083), II (0.102), and III (0102) (Table 1; Fig. 1). No significant difference was observed between the groups at the end of 7, 14, and 28 days.

At the end of 7 days of water aging, group I (GIC) showed 100% of type 3 failure mode; group II (nanohybrid composite) showed 75% of type 2 failure and 25% of type 3 failure; group III (Cention-N) showed 25% of type 2 failure mode and 75% of type 3 failure mode. By the end of 14 days, group I (GIC) showed 66.7% type 3 failure mode and 33.3% type 4 failure mode; group II (nanohybrid composite) showed 33.3% type 1 failure and 66.7% type 2 failure; group III (Cention-N) showed 100% of type 3 failure mode. At 28 days, group I (GIC) showed 66.7% type 1 failure and 33.3% of type 3 failure mode; group II (nanohybrid composite) showed 100% of type 3 failure; group III (Cention-N) showed 33.3% type 1 failure and 66.7% of type 3 failure mode (Fig. 2).

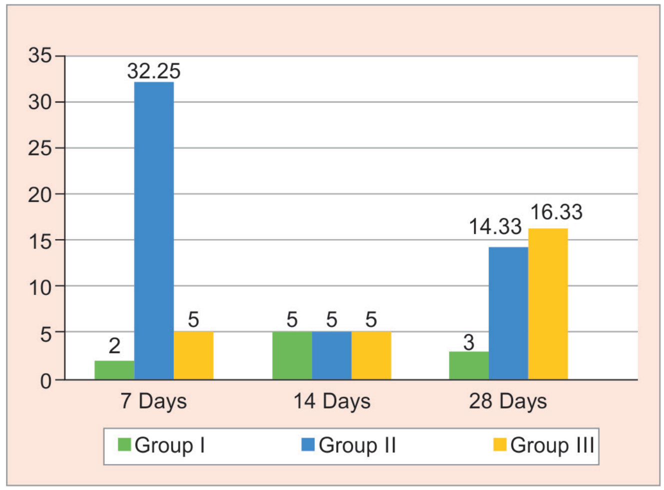
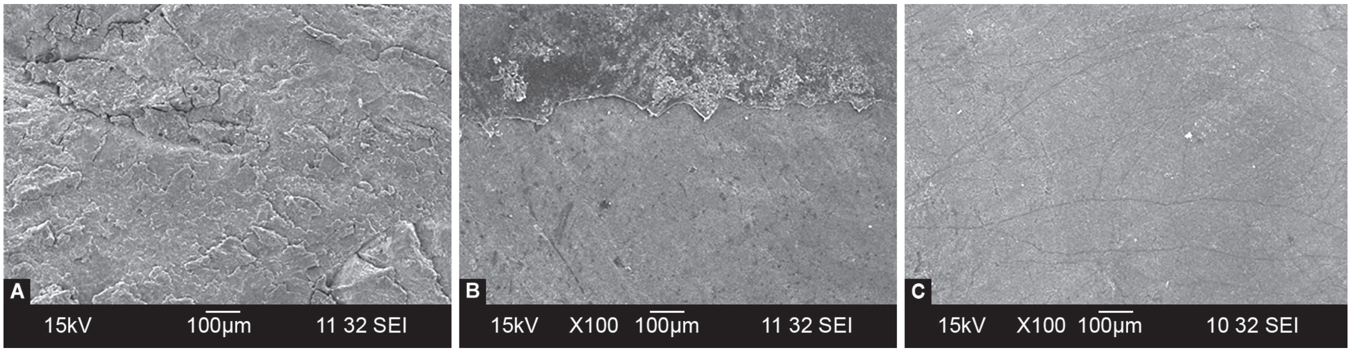


Fig. 1: Three-dimensional column diagram representing the SBS of the three restorative groups

For microleakage analysis, the mean and SD of group I were 1402.40 ± 525.587, with $p = 0.001$ indicating a significant difference when compared with group II (525.587 ± 542.128). However, there was no statistically significant difference between groups I and II in the intergroup comparison with a p 0.001. Group I (1402.40 ± 525.587) indicated a significant variation when compared with group III (334.90 ± 418.454). Groups II and III exhibit significant difference. Cention-N showed a least microleakge score when compared with the GIC IX and nanohybrid composite (Table 2; Fig. 3).

Discussion

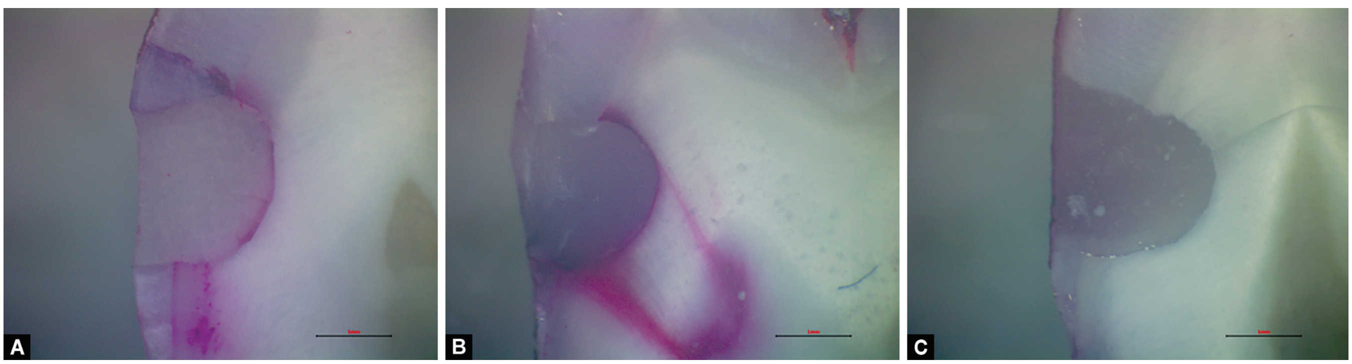
In the current investigation, prior to the placement of restorative materials, the dentin surface was pretreated to eliminate the smear layer and improve adherence. Additionally, it has been shown that the etching of dental hard tissue can improve the cohesive strength of the restoration. The suggested etching time with 37% phosphoric acid gels frequently used with etch-and-rinse systems has been 15 seconds for both enamel and dentin. Ustunkol et al.[17] found that the etching procedure used prior to the restoration had a substantial influence on the cohesive strength of a composite resin.[18]



Figs 2A to C: The SEM image exhibiting the failure mode of different restorative materials at the end of 28 days of water aging. (A) Fuji IX; (B) Nanohybrid composite; (C) Cention-N

Table 2: Multiple group comparison of dye penetration

Group	*Mean ± SD*	*Median (Q1–Q3)*	*p-value*	*Multiple comparison*
I	1402.40 ± 525.587	1155.50 (1005.25–1979.25)	<0.001	Group I vs Group II = 1.000
II	525.587 ± 542.128	1469.50 (1073.25–2120.0)		Group I vs Group III = 0.001
III	334.90 ± 418.454	165.50 (81.25–454.5)		Group II vs Group III = 0.001



Figs 3A to C: (A and B) Fuji IX and nanohybrid composite show dye penetration to axial wall; (C) Cention-N shows no evidence of microleakage

Some studies claim that the storage agent had little impact on the mechanical characteristics; storage duration was considered to be more crucial. According to a study by Ugurlu M,[19] water aging can have a negative impact on GIC based on water sorption because it erodes the material's surface and causes the hydrolysis and dissolution of the GICs' constituent parts. Due to the hydrogel structure and wide micropores on the surface of typical GIC, water absorbs quickly; as a result, the material's strength and elasticity may be significantly reduced. There is a dearth of studies on the impacts of water aging on the recently released material Cention-N, despite the possibility that these effects are related to the components of composite resins and GICs.

In terms of specimen preparation, dimensions, temperature, time intervals, and testing methods, measures were taken to make testing conditions almost identical to the intraoral environment. In the present study, it was shown that, after 7 days of water aging, the nanohybrid composite (Filtek Z350) showed a highly significant difference of mean ± SD (32.25 ± 0.5 MPa) when compared with the GIC Type IX (2 ± 0 MPa) and Cention-N (5 ± 0 MPa). After 14 days of aging, the test restorative groups exhibited no discernible variations in the shear values, but the mechanical strength of the nanohybrid composite gradually decreased. This could be because of the process of hygroscopicity which occurs between the polymer chains, causing a swelling that could weaken the bonds between the chains, or it could be because these materials undergo hydrolysis, which would cause the leaching of unreacted monomers.[20]

The hypothesis that water aging weakens the bonding strength of restorative materials was affirmed by a modest body of research by Hoshika et al.[21] Parallel to our findings, Alzraikat et al.[22] found that the porous nanoclusters' inability to sufficiently penetrate the silane caused the nanohybrid composite to have reduced SBS. Consequently, the nanohybrid composite was vulnerable to deterioration when kept in deionized water for storage. According to Khalid et al.[23] by entering *via* the polymer-filler interface and rupturing the chemical interactions, water molecules begin the process of hydrolytic degradation, which limits the lifetime and cohesive strength of the filling material. Additionally, Awad et al.[24] demonstrated that the stress caused by contraction and expansion during the thermocycling procedure might affect the resin-dentin bond strength.

After 28 days of water aging, Cention-N exhibited a superior SBS, followed by nanohybrid composite and GIC Type IX. It has been asserted that the presence of isofiller, a high network density of polymers, and a high level of polymerization were responsible for the extraordinary strength of Cention-N. The SBS on the GIC Type

IX was the lowest. This could be as a result of its innate brittleness. It is expected to get stronger and mature over the course of several months.[25]

In our study, we discovered that the type of adhesive used and the pretreatment of the dentin surface also affect the type of failure. This outcome was consistent with the research by Dugar et al.,[26] who discovered that composites treated with phosphoric acid had material adhered to the surface of the dentin more firmly compared to composites that are polyacrylic acid treated. Perhaps it is because the dentinal surface was treated with phosphoric acid, which induced the composite material to penetrate deeper and form a micromechanical interlock.

Cention-N displayed a mixed type of failure in all phases of water degradation (adhesive and cohesive). However, after 28 days of water degradation, Cention-N showed more SBS than the other restorative materials. The possible reason could be that Cention-N contains urethane dimethacrylate (UDMA), which are higher molecular weight monomers that withstand the leaching process.

A good marginal seal tends to increase the life span of the restorative components.[27] Since intact non-carious class V cavities have a low configuration factor, are simple to prepare and repair, and have reduced method sensitivity, they were chosen for this investigation. Research by Alsagob et al.[28] claimed that the gingival surface's marginal microleakage was statistically greater than the occlusal surface's marginal microleakage.

Of the methods that are now available, using colored agents to show microleakage continues to be the most common. However, because of the high technique sensitivity, thorough standardization is needed when evaluating the data.[29]

To find the microleakage in the current investigation, 0.5% basic fuchsin dye was used. Utilizing an organic dye as a tracer is a tried-and-true method of detecting leaks *in vitro*. The amount of dye that is employed varies from 0.5 to 10%, and the period that the specimen is immersed in dye ranges from 4 to 72 hours or more. In all *in vitro* leakage experiments, the majority of researchers have employed basic fuchsin at a standard concentration of 0.5%.[30]

To simulate an oral environment, thermocycling was used.[31] All research samples underwent 200 sessions between 5 and 55°C with an elapsed time of 30 seconds, which is regarded as an appropriate artificial aging test since it is comparable to twelve months of clinical evaluation.

The nanohybrid composite showed a higher microleakage score when compared to Cention-N, this might be a result of insufficient resin polymerization, which negatively impacts the physical characteristics of RBC, weakens the bond to the tooth, and promotes marginal wear and breakdown.[28] When compared to the other groups in our investigation, Cention-N demonstrated the least amount of microleakage. Perhaps the reason for Cention-N's excellent behavior is the isofiller present in the powder component that relieves shrinking stress. The stress from shrinking is allegedly kept to a minimum by the inclusion of a unique, patent filler. Additionally, reduced volumetric shrinkage is caused by the material's organic/inorganic ratio and monomer composition.

Sujith et al.[7] and Sardana et al.,[32] who reported a comparable result of Cention-N, which demonstrated a reduced microleakage, confirmed our findings. According to different research by Dennis et al.,[33] the interface is substantially sealed as an acid-resistant and resin-dentin inter-diffusion zone, which found that using adhesive before the restoration showed less leakage between the restoration and tooth structure than those restored without adhesive. Bhullar et al.[34] revealed data in contrast to our investigation, exhibits higher microbial leakage in Cention-N compared to GIC Type IX as well as Biodentin. The disparity between our study's findings and those of Bhullar et al. may be attributable to the various kinds of materials employed.

However, there is not much research currently accessible to support the findings of the present investigation. Therefore, more investigation is needed to determine if this material is an effective substitute for GIC and Composite material when subjected to different forms of aging. The main limitation of the current study was that only two parameters were examined following water degradation; hence, future studies should consider other mechanical parameters as well. Additionally, this investigation was conducted under *in vitro* circumstances; hence, future research should concentrate on using *in vivo* conditions to assess the exact clinical behavior of the evaluated restorative materials.

Conclusion

Within the constraints of this research, it can be concluded that Cention-N has a substantially superior SBS when compared to nanohybrid composite and GIC Type IX. Following 7, 14, and 28 days of exposure to water deterioration, it outperformed the other materials in terms of mechanical strength. It has been shown to present with a lesser degree of dye penetration particularly when utilized in conjunction with an adhesive.

Clinical Significance

The recently introduced tooth-colored restorative material Cention-N outperformed in its marginal adaptation with superior shear resistance when compared with the novel Fuji IX and nanohybrid composite material after being subjected to prolonged water deterioration and hence can be considered as an alternative bulk filling material.

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