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Original Article

Dentistry Section

Comparative Evaluation of Microleakage in Class V Cavities Restored with Glass Ionomer Cement Modified with Chicken Eggshell Powder and Cention N: An In-vitro Study

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ABSTRACT

Introduction: Glass Ionomer Cements (GIC) have been valued for their ease of use, fluoride release, and bonding. However, their microleakage can cause sensitivity and secondary caries. Adding Chicken Eggshell Powder (CESP) improves GIC's properties, while Cention N, an alkasite material, enhances wear resistance and sealing with fluoride and calcium release. The present study compares the microleakage of CESP-modified GIC and Cention N.

Aim: To evaluate and compare the microleakage of GIC modified with CESP and Cention N.

Materials and Methods: This in-vitro study was carried out in the Department of Conservative Dentistry and Endodontics, Bharati Vidyapeeth (Deemed to be) University Dental College and Hospital, Pune, Maharashtra, India and was carried out over three months from August 2024 to October 2024. For the present study, 14 healthy maxillary first premolar teeth that were extracted for orthodontic treatment, intact, had no carious lesions or restorations and were free of pulpal abnormalities were selected. Class V cavities were prepared on the buccal and palatal surfaces of premolars and divided into two groups. Group I where Cavities on the buccal surface were restored using GIC modified with 3% by weight CESP (GIC+CESP), and those on the palatal surface with Cention N being group II. After immersion of the teeth in 0.5% methylene blue dye and buccolingual sectioning, the microleakage assessment was done under a stereomicroscope. Intergroup comparison of microleakage between the two groups was performed using an Independent samples t-test, and the p-value less than 0.05 was considered statistically significant.

Results: The comparison showed statistically significant differences (p-value=0.029) between the two groups. Group I (GIC+CESP) and group II (Cention N) showed differences in the microleakage scores, and group I showed the lowest microleakage in comparison to group II.

Conclusion: GIC modified with CESP (GIC+CESP) exhibited significantly lower microleakage compared to Cention N in Class V cavities. This suggests that incorporating CESP into GIC enhances its sealing ability, making it a promising alternative for reducing microleakage in restorative dentistry.

Keywords: Calcium carbonate, Calcium compound, Dental marginal adaptation, Dentin permeability, Dental restoration failure

INTRODUCTION

Dental restorations are essential for maintaining oral health, especially in the treatment of Class V cavities, which are frequently associated with cervical caries or non carious cervical lesions. Dental restoration, success and longevity are significantly influenced by microleakage [1].When oral fluids, bacteria, and other materials pass through the interface between the tooth structure and restorative material, it is referred to as microleakage. This process can cause secondary caries, hypersensitivity, and restoration failure, posing a considerable challenge to restorative dentistry [1].

Class V cavities, located in the gingival third of teeth, are highly susceptible to microleakage due to their anatomical position, moisture exposure, and masticatory stresses [2]. Class V restorations are challenging due to the gingival margin often being on dentin or cementum, complicating marginal adaptation [1]. Isolation is difficult, especially with proximal or subgingival lesions, as cervical anatomy limits rubber dam placement and access, leading to difficulty in insertion of material [3]. Preventing gap formation at the gingival wall is a key challenge, with various restorative approaches aimed at minimising polymerisation shrinkage and enhancing marginal adaptation. Furthermore, the bond strength to enamel is usually stronger than to dentin, which affects the restoration’s longevity even more [4]. As a result, selecting a restorative material with superior sealing ability is critical for clinical success.

The GIC has long been a preferred material for Class V restorations since a long time due to its chemical adherence to tooth structure, fluoride release, and biocompatibility. However, its mechanical characteristics and resistance to microleakage are still areas of concern [5]. To solve these constraints, innovative modifications to standard restorative materials are being investigated. One such potential approach is to incorporate natural components, such as CESP into GIC [6]. Chicken eggshells, predominantly composed of calcium carbonate, exhibit potential as a biocompatible and cost-effective additive to improve the material’s physical and chemical properties, including remineralisation capacity and marginal adaptability [7].

The CESP, which is high in calcium carbonate, has been demonstrated to improve the mechanical characteristics and sealing ability of GIC by increasing its remineralisation capacity and marginal integrity [6].

Cention N, a newer restorative material, has also gained popularity as a potential option for Class V restorations because of its adhesive qualities, fluoride release, and aesthetic compatibility. This alkasite material combines the benefits of glass ionomers with composites, providing excellent compressive strength, fluoride release, and improved aesthetics [8].

Its self-curing and dual-curing capabilities make it an adaptable material for a variety of therapeutic application [8]. Preliminary tests indicate that Cention N has good sealing capabilities [8], however its performance against modified GIC in terms of microleakage needs to be investigated further.

The incorporation of bio-based materials like CESP into GIC, as well as the development of advanced restorative materials like Cention N, demonstrates continued efforts to solve the difficulties of microleakage in restorative dentistry.

Methylene blue dye penetration evaluated under a stereomicroscope remains one of the most widely used methods for assessing microleakage in restorative dentistry because it is sensitive, practical, and well established in the literature. Its low molecular weight allows it to diffuse into microscopic gaps at the tooth-restoration interface, and its intense colour enables clear visualisation and scoring under magnification [9]. Stereomicroscopic evaluation enhances reliability by allowing magnified, three-dimensional observation of sectioned specimens [10].

Although advanced techniques such as scanning electron microscopy and micro-CT offer high-resolution or three-dimensional analysis, dye penetration has been shown to provide comparable results for ranking restorative materials with lower cost and technical demands [9]. Despite limitations such as specimen sectioning and possible overestimation, methylene blue dye penetration remains a valid and widely accepted in-vitro method due to its sensitivity, affordability, and consistency with previous research.

Hence, the present study aimed to evaluate and compare the microleakage of cavities (Class V) restored using modified GIC (GIC + CESP) and Cention N. The objective of the study was to comparatively evaluate and analyse the microleakage in Class V cavities restored with GIC modified with CESP and Cention N using an in-vitro dye penetration method. By examining their sealing abilities under standardised conditions, this research seeks to provide insights into the potential advantages and clinical implications of these materials for restorative dentistry. The null hypothesis of the present study was that there is no statistically significant difference in the microleakage and between the two restorative materials tested. The alternate hypothesis was that there would be a statistically significant difference in microleakage between the two restorative materials.

MATERIALS AND METHODS

This in-vitro study was carried out in the Department of Conservative Dentistry and Endodontics, Bharati Vidyapeeth (Deemed to be) University Dental College and Hospital, Pune, Maharashtra, India and was carried out through three months from August 2024 to October 2024. The research protocol of the study was approved by the Institutional Ethics Committee (EC/NEW/INST/2021/MH/0029).

Sample size calculation: The sample size was calculated using data from a previous study conducted by Kumari A and Singh N (2022) [11]. In the referenced study, gingival scores were reported as a frequency distribution across a four-point ordinal scale. Since the mean and standard deviation were not directly reported, they were derived from the published frequency data using standard statistical methods for grouped data.

The sample size formulae used are as follows:

$$n=\frac{(\sigma_1^2+\sigma_2^2)/(z_{1-}\alpha_{/2}+z_{1-}\beta)^2}{\Delta^2}$$

The notation for the formulae are:

n= sample size to be determined

σ_1= standard deviation of Group 1

σ_2= standard deviation of Group 2

Δ= difference in group means

$z_{1-}\alpha_{/2}$=two-sided z value (e.g., z=1.96 for 95% confidence interval).

$z_{1-}\beta$ = power

Substituting the values from the previous study,

σ_1 = standard deviation of Group I = 1.25

σ_2 = standard deviation of Group II = 0.42

Δ = difference in group means = 1.5

k= ratio= n2/n1= 1

$z_{1-}\alpha_{/2}$= 1.96 at 95% confidence level

$z_{1-}\beta$= 2.325 at 90% power

Substituting these values in above mentioned formula, the total sample size estimated was 14 per group.

Materials used: Conventional GIC (GC Fuji 2 Gold Label Universal Restorative GIC), CESP, Ivoclar Cention N, etchant (Ivoclar Vivadent, Eco-Etch), and bonding agents (Te-Econom Bond, Ivoclar Vivadent) were the materials employed in this study.

Inclusion criteria: For this study, 14 healthy maxillary first premolar teeth that were extracted for orthodontic treatment, intact, had no carious lesions or restorations and free of pulpal abnormalities were selected [Table/Fig-1].

Exclusion criteria: Teeth with prior endodontic therapy, restorations, or root cracks were not included.

[Table/Fig-1]: Sample size (n=14, first maxillary premolars).

Study Procedure

To remove any remaining organic tissue, each tooth was cleaned using an ultrasonic instrument. Following that, the samples were kept in distilled water to prevent them from dehydrating.

A high-speed air rotor and water spray was used with No. 1 round bur to prepare Class V cavities buccally and palatally on 14 premolars keeping the margin 1 mm coronal to the Cemento-enamel Junction (CEJ) [Table/Fig-2,3]. Cavities were made on both buccal and palatal surfaces of 14 premolars. The standard measurements for the cavity were 3 mm mesiodistally, 2 mm cervico-occlusally and depth of 1.5 mm. These teeth were then divided into two groups [Table/Fig-4].

1. Cavities restored with modified Glass Ionomer Cement (GIC)

i) To prepare Chicken Eggshell Powder (CESP): The eggshell powder used in the present study was self-made by calcining eggshells in compliance with the guidelines provided by the World Property Intellectual Organisation [12]. Chicken eggs were procured from a local poultry shop, and the shells were carefully separated from the yolk and albumen. The shells were thoroughly washed with distilled water to remove adhering organic residues before further processing. The membrane of the eggshells was then removed

[Table/Fig-2]: Cavity preparation.

[Table/Fig-3]: Class V cavity.

Groups	Restorative material	Sample Size
Group I (Buccal)	GIC+CESP	14
Group II (Palatal)	Cention N	14

[Table/Fig-4]: Experimental groups according to the restorative material used.

after they had been kept for ten minutes at 100°C in a hot water bath. A sterilised mortar and pestle were then used to crush these eggshells. Following crushing, the particles were heated to 1200°C in a muffle furnace for two hours and then cooled to room temperature and a fine powder was obtained.

The calcination, cooling, and grinding steps followed in this experiment were done strictly in accordance with the protocol specified by the World Intellectual Property Organisation (WIPO), which offers standardised guidelines for the preparation of purified calcium-rich powder from eggshells. Following this standardised protocol ensured consistency and reproducibility of results and adherence to an internationally documented preparation protocol. The temperature used for calcination (1200°C for 2 hours) was chosen to ensure complete thermal decomposition of calcium carbonate and removal of any organic residue, thus preparing a stable and reactive calcium-based compound [12]. Cooling at a controlled rate in ambient conditions minimised the risk of thermal shock and structural instability.

While differences in calcination temperature and cooling rate may affect the particle size and reactivity, any deviation from the standardised protocol specified by WIPO may have resulted in variability and reduced the internal validity of the experiment. Since the experimental aim was to assess the microleakage properties and not to optimise the variables of material synthesis, it was methodologically sound to strictly follow the standardised protocol.

The physicochemical analysis of the final eggshell powder (particle size distribution, XRD analysis, BET surface area, and purity analysis) was not carried out in the present study, since the main aim was to assess the clinical performance parameter (microleakage) of GIC modified with CESP, rather than exploring its material science aspects. The preparation method was carried out according to established and previously published calcination methods, which have already described the composition and structure of the calcined eggshell powder [13]. Hence, further analysis was not necessary in the study.

Moreover, the study was designed in a way that it was a comparative in-vitro study, in which all the specimens were prepared from the same processed powder. Since the study aimed to investigate the impact of CESP addition on microleakage results, rather than exploring its chemical and crystalline changes, the use of advanced analytical methods such as XRD, BET, or particle size analysis was not necessary to complete the objectives of the study.

ii) Modified Glass Ionomer Cement (GIC+CESP) for cavity restoration: After being properly cleaned with an air/water spray, the prepared cavity was dried. The C-GIC-CESP hybrid (3%) was prepared under standardised conditions to ensure accuracy and reproducibility. Precisely 0.97 g of conventional GIC powder and 0.03 g of CESP were weighed using a portable weighing scale to achieve exact 3% weight modification. The powders were thoroughly mixed on a glass slab to ensure uniform distribution. An oil-impervious paper pad and agate spatula was used for mixing. Powder and liquid were dispensed immediately before mixing to prevent alteration of water content. One measuring scoop (provided by the manufacturer) of GIC powder and one full drop of liquid (dispensed by first holding the bottle horizontally, then vertically) were used to maintain the recommended powder-liquid ratio.

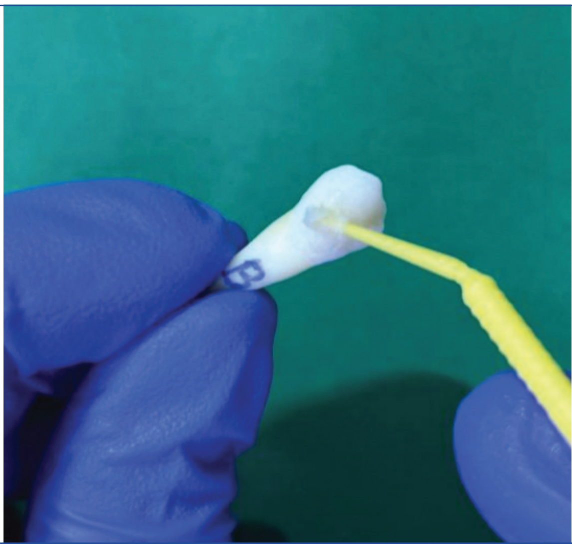
The powder was then portioned into two increments of equal proportions. The powder was not pre-wetted to prevent early moisture contamination of the matrix. The first portion was added to the liquid in the next five to 10 seconds without spreading the mix over the pad. The second portion was added to the mix using a folding motion in a small area in the next 15 seconds. The incremental mix was of a smooth, glossy consistency, which was an indication of proper particle distribution [Table/Fig-5]. This mix was then placed into the buccal cavity using a plastic filling instrument in bulk [Table/Fig-6]. After five minutes, petroleum jelly was applied and finishing burs were used to finish the restoration [Table/Fig-7]. Bulk placement was done because conventional GIC has minimal polymerisation shrinkage, and petroleum jelly was applied to prevent early moisture contamination of the restoration.

[Table/Fig-5]: Smooth, glossy mix obtained after mixing powder and liquid.

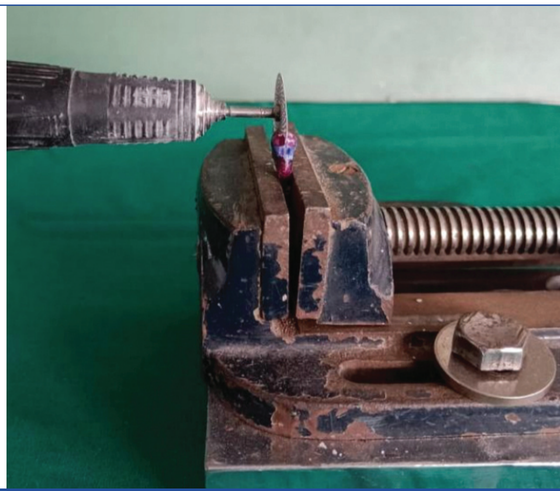
2. Cention N for Cavity Restoration

After being properly cleaned with an air spray/water spray, the prepared cavity was dried. Cavity surfaces were then etched for 15 seconds and bonding agent was applied for 10 seconds. The Cention N powder and liquid was then manipulated according to the recommendations by manufacturer and was placed into the palatal cavity using a plastic filling instrument. After 20 seconds of light curing with a visible light curing equipment, it was immediately completed and polished with burs.

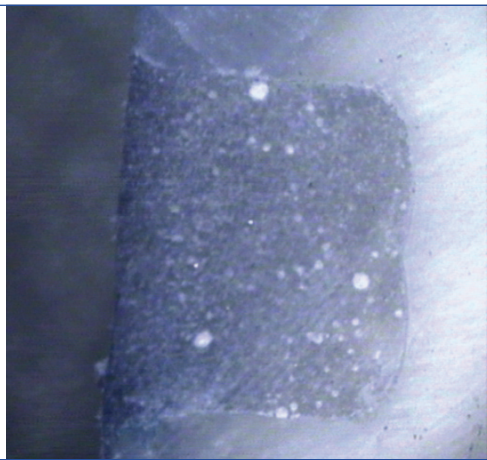
[Table/Fig-6]: Mix placed into buccal cavity.



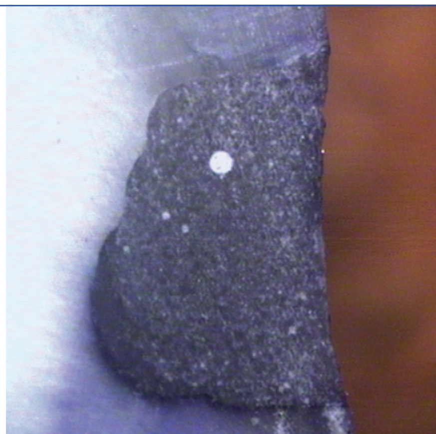
[Table/Fig-7]: Application of petroleum jelly.



[Table/Fig-8]: Buccolingual segmentation of teeth.



[Table/Fig-9]: Stereomicroscopic Image of microleakage of cavity restored with GIC+CESP (Group I).



[Table/Fig-10]: Stereomicroscopic Image of microleakage of cavity restored with Cention N (Group II).

Before conducting thermocycling (500 cycles of thermocycling at five and 55°C with a 5-second immersion period in each water bath), the restored teeth were kept in distilled water at room temperature for 24 hours after petroleum jelly application. After that, they were left undisturbed for a further 24 hours at room temperature and average humidity [11].

After sealing the root apices with sticky wax and painting two coats of nail varnish on all surfaces except the restoration and a 1 mm margin around it, the specimens were placed in 0.5% methylene blue dye solution for 24 hours to assess microleakage. The concentration of the dye was standardised to ensure that all specimens had the same concentration. The pH of the dye solution was maintained at a neutral level (pH≈ 6.8-7.0) to prevent demineralisation or changes to the tooth structure. The specimens were maintained at room temperature (approximately 25±2°C), which is standard laboratory conditions. The dye solution was not agitated during immersion to prevent artificially increasing the dye penetration; the specimens were left undisturbed to allow passive diffusion along potential margins. After immersion for 24 hours, the specimens were rinsed with running water to remove surface dye residues before sectioning and stereomicroscopic analysis. Teeth were segmented buccolingually using a micromotor with diamond disc, approximately at the restoration's centre after they had been secured at place vertically [Table/Fig-8]. A stereomicroscope with a 40x magnification was used to evaluate the extent of microleakage in both recovered tooth halves [Table/Fig-9,10].

Though the limitations of methylene blue dye penetration are well understood, the inclusion of further controls and regional analyses was not considered, as the main objective of the study was to have a standardised comparative assessment between two restorative materials under similar circumstances. Even if there was a possible overestimation due to tubular penetration or smear layer effect, it would have equally affected both groups, thus ensuring internal validity. The inclusion of a negative control group was not considered, as the main objective of the study was to compare materials and not to validate the dye technique. Similarly, regional analysis (occlusal, mid, and gingival regions) was also not considered, as it would have added complexity to the methodological design, and overall marginal leakage was assessed as a uniform screening criterion.

Scoring criteria [14]: 0) Penetration of dye not present; 1) Penetration of dye till one-third of the cavity depth; 2) Penetration of dye till two-thirds of the cavity depth, including the interface; 3) Penetration of dye till the axial wall, but not along it; 4) Penetration of dye till and along the axial wall.

In the present study, the microleakage was assessed using a single calibrated third examiner and a standardised scoring system to minimise subjective bias associated with stereomicroscopic scoring; however, examiner calibration and inter-/intra examiner reliability assessment were not performed.

STATISTICAL ANALYSIS

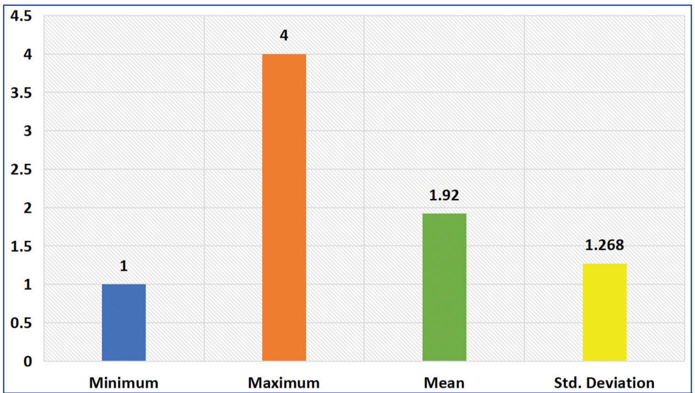
Statistical analysis was performed using Statistical package for Social Sciences (IBM, SPSS) IBM SPSS Statistics for Windows, version 21.0 (IBM Corp., Armonk, NY, USA). Descriptive and inferential statistics was performed for the parameter assessed in the study. Intergroup comparison of microleakage between two groups was performed using Independent samples t-test. All statistical tests were performed at 95% confidence intervals. A p-value of less than 0.05 was considered as statistically significant in the study.

RESULTS

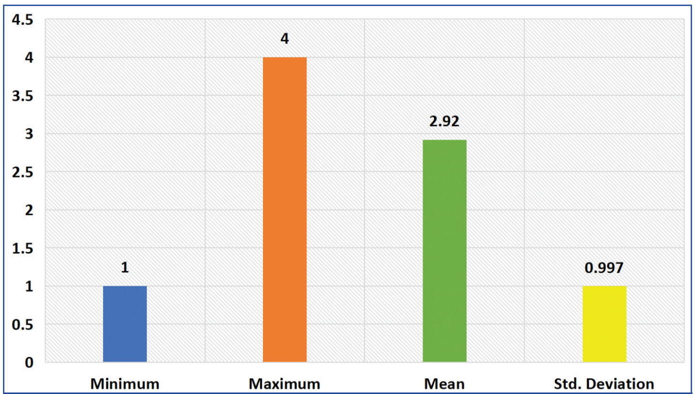
The descriptive statistics of microleakage scores among the two study groups are presented in [Table/Fig-11]. In group I (GIC modified with CESP), the scores ranged from 1.00 to 4.00, with a mean of 1.92 and a standard deviation of 1.268. In group II (Cention N), the scores also ranged from 1.00 to 4.00, with a higher mean of 2.92 and a standard deviation of 0.997. These findings indicate comparatively lower mean microleakage scores in group I than in group II [Table/Fig-11-13].

Groups	N	Minimum	Maximum	Mean±SD
Group I: GIC modified with CESP	14	1.00	4.00	1.92±1.268
Group II: Cention N	14	1.00	4.00	2.92±0.997

[Table/Fig-11]: Descriptive statistics of microleakage scores amongst 2 groups.



[Table/Fig-12]: Descriptive statistics of microleakage scores in group I: GIC modified with CESP.

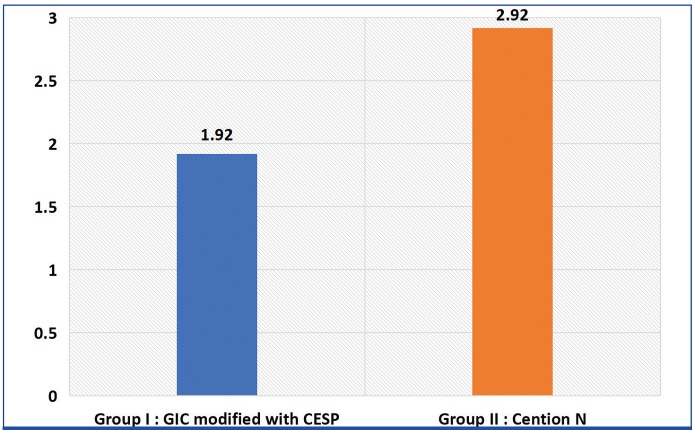


[Table/Fig-13]: Descriptive statistics of microleakage scores in group II: Cention N.

In the current study, intergroup comparison of microleakage between different groups was performed using independent samples t-test. This comparison showed statistically significant differences (p-value <0.05) between the two groups. Thus, it can be interpreted that group I and group II showed differences in the microleakage scores and group I showed lowest microleakage in comparison to group II [Table/Fig-14,15].

Comparison groups	t	df	p-value	Mean difference	Std. error difference	95% Confidence interval of the difference	
						Lower	Upper
Group I: GIC modified with CESP vs group II: Cention N	-2.31	26	0.029*	-1.000	0.43131	-1.886	-0.113

[Table/Fig-14]: Intergroup comparison of microleakage scores between 2 groups.



[Table/Fig-15]: Intergroup comparison of mean microleakage scores between 2 groups.

DISCUSSION

Microleakage is the penetration of fluids, ions and bacteria into the interface between a dental restoration and the surrounding tooth structure due to an inadequate seal [9]. Given that it directly affects the restorative materials' clinical performance and durability, it is a major problem in restorative dentistry [9]. Pulpal inflammation, staining, sensitivity, secondary caries, and eventually restorative failure can all result from microleakage [9]. Several factors influence microleakage, including the properties of the restorative material, cavity preparation techniques, polymerisation shrinkage, thermal cycling, and the challenging conditions of the oral environment [9].

The present study compared the microleakage of Cention N, a more recent alkasite restorative material, with that of GIC mixed with CESP. The findings revealed that GIC modified with CESP exhibited significantly less microleakage than Cention N. So the null hypothesis was rejected.

The GIC is a key material in combating dental caries due to its distinctive properties including fluoride release, anticariogenic effect, chemical adherence to enamel and dentin and biocompatibility [4,6]. Its ability to form a strong seal under challenging clinical conditions makes it highly valued in restorative dentistry. However, conventional GIC has some limitations, including insufficient strength, low toughness, poor wear resistance, limited aesthetics, and low bond and compressive strength all of which may jeopardise the marginal seal [4]. Furthermore, GICs are moisture-sensitive in the initial setting phase, making them susceptible to hydration or dehydration, which might aggravate microleakage [4]. To address these shortcomings, GIC has undergone various improvements over the years, resulting in enhanced strength, better handling, and improved wear resistance [6].

Eco-friendly material research is a result of growing interest in sustainable technology worldwide. The composition of eggshell, a usual by-product of homes and food businesses, makes it a concern for the environment [15]. However, with 98.2% calcium carbonate, along with calcium phosphate, magnesium carbonate, and organic content, eggshells provide a great supply of calcium

[6]. Using eggshell in dental materials could enhance its value while helping reduce environmental pollution.

Several studies have demonstrated that the incorporation of Eggshell Powder into GIC can enhance the physical properties of the cement. Allam G and Abd El-Geleel O reported that GIC modified with eggshell powder exhibited improved compressive strength and reduced solubility compared to unmodified GIC, which could correlate with a decrease in microleakage [6]. Similarly, other studies have found that the addition of natural bioactive fillers in dental cements can enhance their sealing ability by promoting better integration with the structure of tooth [16,17]. However, a study by Salem AM et al., found that incorporation of CESP increases solubility of GIC, which does not align with the results of the present study [18]. The difference in results can be ascribed to differences in methodology, such as differences in the concentration of CESP, incorporation of powder, and methods of mixing, which may have influenced the integrity and solubility of the matrix. The differences in materials, storage conditions, immersion fluids, and times of testing may also have played a part in the differing outcomes of the two studies.

Cention N (IvoclarVivadent) is a dual-cured urethane dimethacrylate alkasite restorative material that releases fluorides, calcium, hydroxide and acid neutralising ions [8]. It is designed to reduce microleakage and polymerisation shrinkage due to its low-modulus isofiller [8]. Kumari A and Singh N found that Cention N exhibited less microleakage compared to conventional GIC [11].

After the class V cavities were restored, microleakage was assessed using the straightforward and commonly used 0.5% methylene blue technique. The diameter of dye molecule is smaller than the diameter of dentinal tubules. The lower particle size and dentinal tubule permeability may lead to an overestimation of the significance of this penetration [11]. Thermocycling was used to replicate the thermal fluctuations seen in the oral cavity.

In the current study, results showed that microleakage in group I (GIC modified with CESP) was 1.92 and group II (Cention N) was 2.92. Microleakage was lower in group I than group II, which was statistically significant (p-value=0.029).

The $CaCO_3$, the main component of CESP, transforms into CaO upon sintering at 1200°C. In calcium silicate-based cements like GIC, CaO reacts with water, forming $Ca(OH)_2$, which dissociates into hydroxide and calcium ions, enhancing the alkaline environment and compressive strength. Adding CESP to GIC reduces setting time by filling pores, while improved hydration, interface density, crystallinity, and reduced porosity enhance mechanical properties [19]. This effect minimises the formation of microgaps, thus reducing the chances of secondary caries. Additionally, the incorporation of calcium from eggshell powder enhances the material's capacity for remineralisation, which is beneficial for maintaining marginal integrity of the restoration over a period of time [20].

In the present study, the modified GIC incorporating eggshell powder demonstrated significantly lower microleakage under simulated oral conditions. This effect is attributed to the increased mineral content of the eggshell powder, which not only enhances interfacial bonding between the tooth and restorative material but also promotes remineralisation at the interface [21]. The study carried out by Allam G and Abd El-Geleel O proved that the addition of CESP did not hamper the natural ion release properties of GIC but rather improved them, with higher values of fluoride and calcium ion release being recorded in the groups containing CESP compared to the control GIC. The enhanced release of calcium ions in eggshell-modified GIC may help in the restoration of small demineralised lesions at the interface between the tooth and the restoration [6].

Cention N is valued for its mechanical strength and fluoride release, which contribute to caries prevention. However, it may still show slight microleakage because of polymerisation shrinkage and thermal expansion, which are inherent to resin-based materials [22]. Although Cention N offers advantages in strength, the eggshell-modified GIC demonstrated superior resistance to microleakage due to enhanced marginal adaptation and remineralisation potential, suggesting it could serve as an effective option in cases where marginal integrity is prioritised over mechanical strength.

Eggshell powder modified GIC provides a cost-effective, eco-friendly solution by enhancing performance with a biological waste product. Its superior microleakage resistance makes it a valuable option for restorative dentistry. The preparation of CESP is cost-effective because eggshells are easily available biological waste, and the processing steps are mainly cleaning, drying, grinding, calcination, and sterilisation, which do not require much laboratory equipment. In fact, the cost is much lower compared to other bioactive fillers. Although CESP has potential advantages such as enhanced availability of calcium ions and potentially improved mechanical strength when added to GIC, most of the available evidence is restricted to in-vitro studies; hence, its actual cost-effectiveness has yet to be established.

Future research should also involve the quantitative analysis of calcium ion release by methods such as Inductively Coupled Plasma Mass Spectrometry (ICP-MS) or atomic absorption spectroscopy, as well as pH analysis to determine the alkalising effect. Chemical analysis of the interface between the tooth and the restoration by methods such as Scanning Electron Microscopy - Energy Dispersive X-ray Spectroscopy (SEM-EDX) analysis would also be valuable in directly determining the remineralisation effect. These analyses would serve to further verify the proposed mechanisms.

Limitation(s)

The methylene blue dye penetration test might give a higher value to microleakage because the dye can penetrate dentinal tubules and irregularities of the smear layer instead of being restricted to the restoration margins, and it gives indirect information about sealing rather than actual microleakage. The lack of a control group that did not receive cavity preparation makes it difficult to evaluate the dye diffusion artifacts, and the leakage test was not performed separately for the occlusal, middle, and gingival margins, although the latter are most important in Class V restorations. The sample size relatively small and might be prone to chance variation, and the statistical significance might be influenced by surface characteristics (buccal vs. palatal) instead of being material-related. The present study had a small sample size and was conducted under in-vitro conditions, which may not fully represent the oral environment. Therefore, the results cannot be directly extrapolated to clinical situations. Further studies with larger sample size and in-vivo evaluation are required to confirm these findings.

Although there were attempts to standardise the cavity preparation, material handling, and storage conditions, the possible confounding variables of natural tooth variations, slight variations in the size of the cavities, operator variability, and in-vitro storage conditions could not be completely ruled out.

CONCLUSION(S)

Conventional glass ionomer enhanced with CESP exhibited less microleakage than Cention N when the two materials were evaluated. This shows that CESP modified GIC provides an effective, durable and cost-effective alternative for clinical applications. With continued research, eggshell-modified GIC could serve as a key material in sustainable dental practices.

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