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Impact of Moisture Exposure on Surface Hardness of Conventional Glass Ionomer Cements: An In Vitro Study

[1]Dr. Sudeep H.M, Professor, Triveni Institute of Dental Sciences, Hospital and Research Centre (Affiliated to Pt. Deendayal Upadhyay Memorial Health Sciences and Ayush University of Chhattisgarh), Vidya Sthali, Bodri, Bilaspur, 495220

Corresponding Author: Dr. Sudeep H.M, Professor, Triveni Institute of Dental Sciences, Hospital and Research Centre (Affiliated to Pt. Deendayal Upadhyay Memorial Health Sciences and Ayush University of Chhattisgarh), Vidya Sthali, Bodri, Bilaspur, 495220

Conflict of interest: Nil

Abstract

Objective: This in vitro study aimed to evaluate the effect of moisture exposure on the surface microhardness of four commercially available conventional glass ionomer cements (GICs): Micron Superior, GC Gold Label 2, Prime Restorite 2 and Neo Cem 2.

Materials and Methods: Eighty cylindrical specimens (n=20 per material) were prepared and divided into two groups based on storage conditions: dry (stored in a desiccator at 37°C) and wet (immersed in distilled water at 37°C). After 24 hours, Vickers microhardness testing was performed using a 490.3 mN load for 10 seconds. Mean hardness values were compared using two-way ANOVA and Tukey's post hoc test.

Results: All materials showed significantly higher microhardness when stored in wet conditions compared to dry ($p < 0.05$). GC Gold Label 2 had the highest hardness under dry storage (62.0 ± 1.93 HV). GC Gold Label 2 and Micron Superior showed the highest values in wet storage (84.6 ± 3.35 HV, 83.7± 7.29 HV). Prime Restorite 2 exhibited the most pronounced improvement with moisture.

Conclusion: Moisture positively influences the maturation and surface hardness of GICs, emphasizing the importance of controlled hydration during the setting phase. Variations among materials suggest differences in composition affect their response to environmental conditions.

Keywords: Glass ionomer cement, microhardness, moisture, surface hardness, wet storage, dry storage

Introduction

Glass ionomer cements (GICs) are widely used in restorative dentistry owing to their desirable properties such as chemical adhesion to tooth structure, biocompatibility, and sustained fluoride release [1,2]. Their clinical versatility includes use as restorative materials, liners, bases, and luting agents, particularly in pediatric and geriatric dentistry [3]. The mechanical performance of GICs, especially surface hardness, plays a crucial role in their long-term clinical success and wear resistance[4].Surface microhardness is considered an indirect measure of the degree of setting and material strength, directly correlating with resistance to masticatory forces and abrasion [5]. However, the setting reaction and subsequent maturation of GICs are influenced by environmental conditions, particularly moisture exposure during the early stages [6]. While initial hydration supports ion exchange and matrix formation, premature exposure to water can disrupt setting, whereas dehydration may lead to surface crazing or incomplete maturation [7,8]. Hence, the surrounding moisture environment—whether dry or wet—significantly impacts the physical properties of GICs, including microhardness. Recent advancements in GIC formulations have focused on enhancing mechanical properties through modifications in powder particle size, glass composition, and incorporation of resin components [9]. Among contemporary GICs available, Micron Superior (Prevest DenPro, India), GC Gold Label 2 (GC Corporation, Japan), Prime Restorite 2 (Prime Dental, India), and Neocem 2 (Orikam, India) are frequently used products that differ in their filler content, particle reactivity, and powder-liquid ratios. Comparative evaluation of their microhardness under varying storage conditions can provide insight into their clinical durability and material behavior in the oral environment[10]. Despite several studies assessing GIC performance, limited data are available comparing these four specific formulations under both dry and wet conditions over a defined period. Understanding the interaction between hydration states and mechanical performance is essential for informed material selection and optimal clinical outcomes. Therefore, this study aims to compare the surface microhardness of four commercially available glass ionomer cements under dry and wet storage conditions, to determine the influence of environmental factors on their maturation and performance.

Materials and Methods

Study Design

This in vitro experimental study was conducted to evaluate and compare the surface microhardness of four commercially available conventional glass ionomer cements (GICs) when stored under dry and wet conditions. The study design was structured to assess the effect of environmental storage condition on the material hardness after a standard setting period. Four different GIC formulations were selected based on their widespread clinical use and availability:

Table 1:

Material	Manufacturer	Type
Micron Superior	Prevest DenPro, India	Conventional GIC
GC Gold Label 2	GC Corporation, Japan	Conventional GIC
Prime Restorite 2	Prime Dental, India	Conventional GIC
Neocem 2	Orikam, India	Conventional GIC

Each material was used in its original packaging and manipulated strictly following the manufacturer's recommendations regarding mixing ratios and setting times. A total of 80 specimens were prepared-10 specimens per material per storage condition, resulting in 20 specimens for each GIC (10 dry + 10 wet). The samples were fabricated using a cylindrical Teflon mold measuring 5 mm in diameter and 2 mm in height. The powder and liquid components were mixed manually on a glass slab using a plastic spatula for approximately 30 seconds or as per manufacturer's instructions. The mixed cement was immediately packed into the Teflon mold, placed over a glass slide lined with a Mylar strip to prevent moisture loss and obtain a smooth surface. A second Mylar strip and glass slide were placed over the top and slight pressure was applied to ensure a flat surface and to extrude excess material. The material was allowed to set undisturbed for 10 minutes at room temperature (23 ± 1°C) to ensure adequate initial setting. After setting, the specimens were removed carefully from the molds using plastic instruments to avoid surface damage.

Grouping and Storage Protocol

The specimens were randomly divided into two major groups based on storage conditions: Group A (Dry Condition): Specimens were stored in a desiccator containing silica gel at 37°C to simulate a dehydrated environment. Group B (Wet Condition): Specimens were immersed in distilled water at 37°C in a sealed container. All specimens were stored for 24 hours before hardness testing to allow for initial maturation and avoid early testing variability. After 24 hours of storage, the specimens were gently blotted dry (for wet-stored samples) and tested for microhardness using a Vickers microhardness tester (Model: HMV-G31-ST, Shimadzu Corporation, Japan). The procedure was as follows: Each specimen was placed on the tester platform with the top (Mylar-finished) surface facing upward. A Vickers diamond indenter was applied vertically onto the specimen surface with a load of 490.3mN for 10 seconds. Three indentations were made on each sample surface, spaced at least 1 mm apart and away from the edges to avoid boundary effects. The diagonal lengths of each indentation were measured using the built-in microscope, and the Vickers Hardness Number (VHN) was calculated using the standard formula: $VHN = 0.1891F/d^2$. The mean of the three readings was recorded as the microhardness value for each specimen.

HV= Vickers Hardness

f= Test load (n)

d= Mean of the indentation diagonal length (mm)

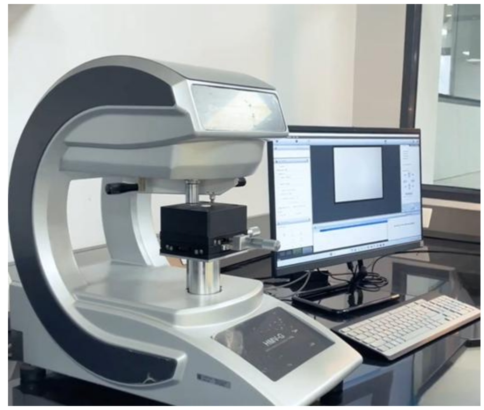


Figure 1: Vickers Microhardness Testing Machine used in the study

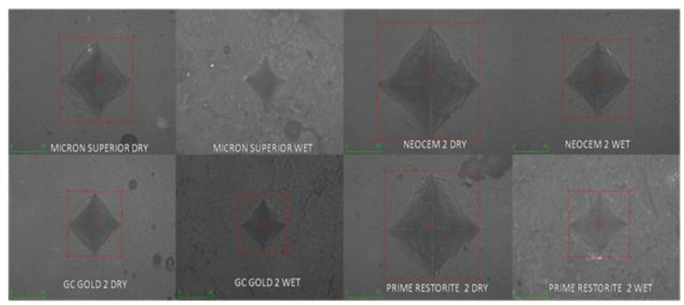


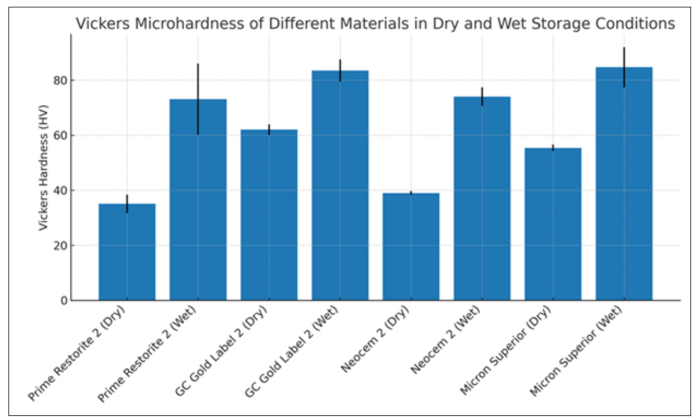
Figure 2: Vickers Hardness Indentation Made By Microhardness Tester For Different GIC's

Statistical Analysis

The collected data was entered into Microsoft Excel and analyzed using IBM SPSS Statistics (Version XX). The Shapiro–Wilk test was used to assess the normality of the data distribution. Two-way Analysis of Variance (ANOVA) was performed to evaluate the interaction between material type and storage condition on microhardness values. Tukey's post hoc test was used for pairwise comparison among groups. A p-value < 0.05 was considered statistically significant.

Results

Vickers microhardness values were assessed for four different glass ionomer cements (GICs)—Prime Restorite 2, GC Gold Label 2, Neo Cem 2, and Micron Superior- under both dry and wet storage conditions. Under dry storage conditions, GC Gold Label 2 exhibited the highest microhardness with a mean value of 62.0 ± 1.93 HV, followed by Micron Superior (55.4 ± 1.19 HV). Neo Cem 2 demonstrated a comparatively lower value of 39.2 ± 0.67 HV, while Prime Restorite 2 recorded the lowest hardness (34.3 ± 3.36 HV), and also showed the highest variability among the dry-stored materials, with a coefficient of variation of 9.57%. When stored in wet conditions, all materials exhibited a significant increase in microhardness. Prime Restorite 2 showed a substantial increase, reaching a mean hardness of 73.1 ± 12.9 HV. Micron Superior showed the second highest hardness in wet storage (83.7 ± 7.29 HV). Neo Cem 2 followed closely, exhibiting a mean value of 75.2 ± 4.05 HV. GC Gold Label 2 also showed an increase in hardness under wet storage (mean HV = 84.6 ± 3.35), maintaining its performance with low variability (CV = 4.53%). Within each material group, comparison between dry and wet storage conditions revealed a consistent trend of increased microhardness in the presence of moisture. Prime Restorite 2 showed the most pronounced enhancement, rising from 34.3 HV in dry storage to 73.1 HV in wet storage. Neo Cem 2 also showed a marked increase from 39.2 HV to 75.2 HV. Micron Superior increased from 55.4 HV to 83.7 HV, while GC Gold Label 2 improved from 62.0 HV to 84.6 HV. These observations suggest that water storage may promote continued acid-base reactions and matrix maturation, thereby improving surface hardness. Across the four materials under similar conditions, GC Gold Label 2 and Micron Superior performed better under dry storage. While in wet storage, Prime Restorite 2, Neo Cem 2, and Micron Superior all exhibited comparable and elevated microhardness values. Notably, GC Gold Label 2 maintained consistent mechanical performance with low variation, whereas Prime Restorite 2 showed the highest variability in wet storage (CV=17.7%), despite its improvement in hardness. These findings indicate material-dependent responses to moisture exposure, possibly linked to their composition and setting mechanisms.



Graph 1: Comparison of Vickers Microhardness Values under Dry and Wet Storage Conditions

Discussion

The present study evaluated the effect of moisture exposure on the surface microhardness of four conventional glass ionomer cements (GICs) under controlled in vitro conditions. The results clearly demonstrated that specimens stored in a wet environment exhibited significantly higher microhardness values compared to those stored under dry conditions. This finding underscores the critical role of moisture in promoting the maturation of GICs through ongoing acid-base reactions, which enhance the mechanical properties of these materials.

Effect of Moisture on GIC Maturation

The data indicated that moisture exposure leads to an increase in surface microhardness for all tested materials. For instance, Prime Restorite 2 and Neo Cem 2 showed a marked increase from 34.3 HV and 39.2 HV in dry conditions to 73.1 HV and 75.2 HV in wet storage, respectively. This enhancement can be attributed to the continued ionic cross-linking and further development of the polysalt matrix when water is available to facilitate the acid-base reaction that governs the setting of these cements [11]. Such findings are in agreement with earlier studies which have reported that appropriate hydration accelerates the maturation process, leading to improved mechanical properties [12,13].

Comparative Analysis of GIC Formulations

Despite the uniform trend of increased hardness under wet conditions, differences among the individual GIC formulations were apparent. GC Gold Label 2 and Micron Superior demonstrated superior performance under dry storage, suggesting that their composition may favor a more robust initial set even in the absence of additional moisture [14]. Conversely, the lower initial hardness values observed for Prime Restorite 2 and Neo Cem 2 in dry conditions indicate that these formulations may rely more heavily on moisture for optimum maturation. The variability (as indicated by the coefficients of variation) observed in Prime Restorite 2 further suggests that formulation-specific factors such as powder particle size and the powder-liquid ratio might influence not only the rate of maturation but also the consistency of the final set [15,16].

Mechanisms Underpinning Improved Hardness in Wet Storage

The improvement in microhardness upon water immersion could be linked to the facilitation of continued acid-base reactions. Moisture acts as a medium for ion exchange, allowing the polyacids and fluoroaluminosilicate glass to interact more completely, forming a denser and more homogeneous matrix [17]. This phenomenon is supported by previous literature where controlled exposure to moisture enhanced the physical properties of GICs through improved matrix formation and decreased porosity [18,19]. In addition, water may help in reducing internal stresses by mitigating dehydration shrinkage, thereby minimizing the formation of microcracks or surface crazing—a frequent issue observed in dry-stored specimens [20].

Clinical Implications

From a clinical perspective, the results of the present study have significant implications. While the improved microhardness in moist conditions suggests that proper hydration immediately after placement could benefit the longevity and wear resistance of GIC restorations, practitioners must also be cautious. Excessive moisture exposure during the critical early stages of setting could potentially lead to dissolution or washout phenomena if not managed correctly [21]. Thus, a balance must be achieved to harness the benefits of moisture while avoiding detrimental overexposure. Furthermore, the relative performance of the various formulations under different storage conditions may guide clinicians in material selection based on specific clinical scenarios, such as areas with varying moisture exposure [22,23].

Limitations and Future Directions

Although this in vitro study provides valuable insights, several limitations should be noted. The experiment simulated only two extremes of moisture exposure (dry versus wet), which may not fully represent the dynamic environment of the oral cavity. Clinical conditions involve a fluctuating moisture level, including intermittent exposure to saliva and temperature variations that were not reproduced in the current study [24]. Future research should focus on long-term studies that mimic the clinical environment more closely, considering factors such as cyclic loading, pH fluctuations, and thermal stresses. Moreover, additional comparative studies with newer GIC formulations and resin-modified glass ionomers could offer a broader perspective on the performance of these materials under various environmental conditions [25].

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