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ASSESSMENT OF THE MECHANICAL PROPERTIES OF SMART DENTINE REPLACEMENT, BIODENTINE AND FUJI LINERS IN RESTORING PERMANENT TEETH: AN INVITRO STUDY

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ABSTRACT

Aim of the study: assessment of the microhardness of Smart Dentine Replacement, Biodentine and Fuji liners in restoring permanent teeth.

Methodology: For each test 27 samples were done for the vicker hardness test using circular split teflon mold with outer metallic ring (with outer ring 20mm diameter and 2 mm thickness was used to prepare the samples). Surface microhardness was measured using digital display Vickers micro-hardness tester. A load of 100g was applied to the surface of the specimens for a duration of 15 seconds. The indentations were spaced at least 0.5 mm apart. The diagonal lengths of these indentations were measured using built-in scaled microscope, and the Vickers values were converted into micro-hardness values.

Results: For vicker hardness there was a significant difference between different groups, The highest value was found in SDR (79.99±4.10A) followed by Fuji II (60.80±1.87^{B}) while the lowest value was found at Biodentine (51.73±2.78C).

Conclusions: Smart dentine replacement has the highest value in vicker test.

KEYWORDS: Smart Dentine Replacement (SDR), Microhardness, Vickers hardness, Biodentine, Fuji II.

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INTRODUCTION

Dental caries is a widespread condition affecting people across all age groups, from infants to adults. It arises from a complex interplay of factors, including fermentable sugars, acidogenic bacteria, saliva, and the tooth surface, resulting in progressive decay and weakening of tooth structure. The risk of developing caries is heightened by contributing factors like insufficient oral hygiene, low fluoride exposure, high levels of cariogenic bacteria, and unfavorable socio-economic circumstances. [1] If left untreated, early-stage caries can advance to significant tooth decay, especially in children's newly erupted first permanent molars, potentially causing irreversible harm. Additionally, the rise of Molar-Incisor Hypomineralization (MIH) in recent years has led to an increase in enamel defects affecting the first permanent molars and incisors. This condition requires prompt treatment to safeguard the natural tooth structure from further deterioration. [2]

With the progress of modern dentistry, minimally invasive methods for managing caries have become increasingly important, especially for treating deep carious lesions where maintaining tooth vitality is essential. Techniques like indirect pulp capping (IPC) and selective carious-tissue removal focus on avoiding pulp exposure and encouraging dentine remineralization. Historically, materials such as calcium hydroxide have been regarded as the "gold standard" for pulp capping in these procedures. [3] However, newer materials such as glass ionomer cements (GIC), resin-modified GIC, Smart Dentine Replacement (SDR), and bioactive tricalcium silicate-based cements like Biodentine have demonstrated superior clinical performance. These materials offer enhanced mechanical properties, greater biocompatibility, and improved durability compared to traditional options. [4]

Materials such as Biodentine, Smart Dentin Replacement (SDR), and glass ionomer-based liners like GC Fuji II LC are increasingly noted for their restorative capabilities. Biodentine, a tricalcium silicate-based cement, is particularly valued for its excellent biocompatibility, ease of handling, and effective bonding to dentine. [5] SDR, a flowable bulk-fill material, provides benefits such as reduced polymerization shrinkage and lower stress, making it an ideal choice for posterior restorations. [6] GC Fuji II LC, a light-cured glass ionomer, offers robust bonding and fluoride release, which aids in tooth remineralization and enhances durability in areas subject to high stress. [7]

Although these materials are widely used in clinical practice, their mechanical properties, particularly hardness and durability, continue to be studied. Vickers microhardness testing is a crucial method for evaluating the resistance of restorative materials to indentation and wear. This study seeks to assess and compare the Vickers microhardness of Smart Dentine Replacement, Biodentine, and GC Fuji II LC liners used for restoring permanent teeth, aiming to enhance our understanding of their performance and long-term effectiveness in restorative dentistry.

PATIENTS AND METHODS

First, The Research Ethics Committee Faculty of Dentistry, Cairo University (CREC) evaluated the study proposal, with approval Research number: pedo3-3-1.

Mold description

In the study, circular split Teflon molds were employed to create samples for. These molds featured an outer metallic ring with a diameter of 20 mm and a thickness of 2 mm, along with a split Teflon insert measuring 19 mm in diameter and 2 mm in thickness. The Teflon insert contained a central cavity, precisely 4 mm in diameter and 2 mm thick, designed for sample preparation.

Sample preparation

The material was mixed according to the manufacturer's guidelines. The mold was positioned on a larger glass plate and lined with polyester film.

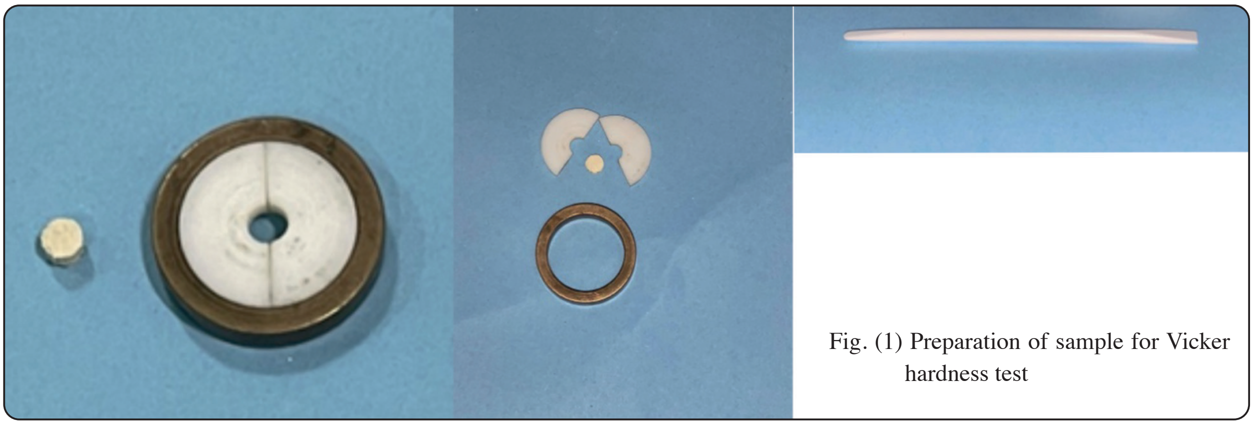

Fig. (1) Preparation of sample for Vicker hardness test

The prepared material was then packed into the mold using a plastic spatula to ensure proper compaction. A second glass plate, also covered with polyester film, was placed on top to ensure even distribution and uniform contact across the mold as shown in **Fig. (1).**

The assemblies were subsequently placed in an incubator set to 37°C with 95% relative humidity for a period equal to three times the material's setting time. After curing, the samples were carefully removed from the molds, and any excess material was trimmed with a sharp No. 15 blade to eliminate loose particles. The final dimensions of each sample were then accurately measured using a digital micrometer (Mitutoyo MTI Corporation, Tokyo, Japan) to ensure precision.

Measuring the microhardness:

After the samples were set, one side was polished with a 600-grit paper disc to achieve a smooth surface. The surface microhardness was measured using a Digital Display Vickers Micro-hardness Tester (Model HVS-50, Laizhou Huayin Testing Instrument Co., Ltd., China) fitted with a Vickers diamond indenter and a 20X objective lens. A 100g load was applied to each specimen for 15 seconds. Three indentations were made on each sample, evenly spaced in a circular pattern, with a minimum distance of 0.5 mm between them. The indentation diagonals were measured using the tester's integrated scaled microscope, and the Vickers hardness numbers were then converted into microhardness values. as illustrated in **Fig. (2).**

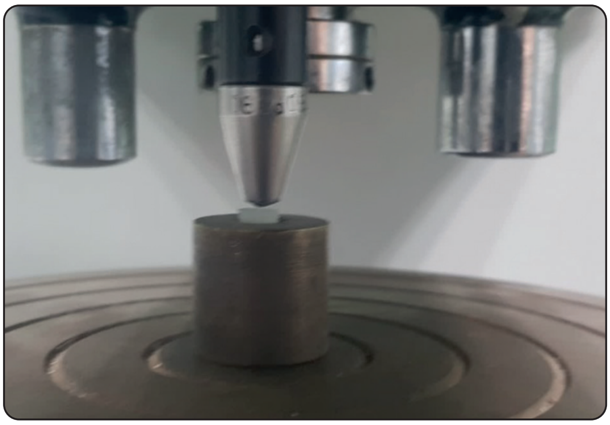

Fig. (2) Vicker hardness test for measuring microhardness

Micro-hardness calculation;

Micro-hardness was calculated using the formula:

$$HV=1.854\ P/d^2$$

where, HV is Vickers hardness in Kgf/mm^2, P is the load in Kgf and d is the length of the diagonals in mm

Statistical analysis

Numerical data was explored for normality by checking the data distribution, calculating the mean and median values and using Kolmogorov-Smirnov and Shapiro-Wilk tests. The data was found to be normally distributed; it was presented as mean and standard deviation; one way ANOVA was used for the analysis followed by Tukey post-hoc test. The assumption of normality was found to be violated; the data was presented as median and range values and was analyzed using Kruskal–Wallis test followed by Dunn's post hoc test with Bonferroni correction. The significance level was set at $p \leq 0.05$ for all tests. Statistical analysis was performed with IBM® SPSS® Statistics Version 26 for Windows, the estimated sample size (n) required was determined to be (27) samples in total (9 samples per group). The calculation was done using G*Power version 3.1.9.7.

RESULTS

Surface micro-hardness (Kgf/mm²)

Intergroup comparisons, mean and standard deviation values of surface micro-hardness (Vickers test) (Kgf/mm²) for different groups.

There was a significant difference between different groups ($p<0.001$). The highest value was found in SDR (79.99±4.10), followed by Fuji II (60.80±1.87), while the lowest value was found at Biodentine (51.73±2.78). All post hoc pairwise comparisons were statistically significant ($p<0.001$). Results are shown in **Table (1)** and **Fig. (3).**

TABLE (1) Intergroup comparisons, mean and standard deviation values of Vickers micro-hardness (Kgf/mm²) for different groups

Vickers micro-hardness (Kgf/mm²) (mean±SD)			***P*-value**
SDR	**Biodentine**	**Fuji II**	
79.99±4.10^{A}	51.73±2.78^{C}	60.80±1.87^{B}	**<0.001*** **

: Significant at P ≤ 0.05; **: highly Significant at P ≤ 0.01; ***: extremely Significant at P ≤ 0.001.

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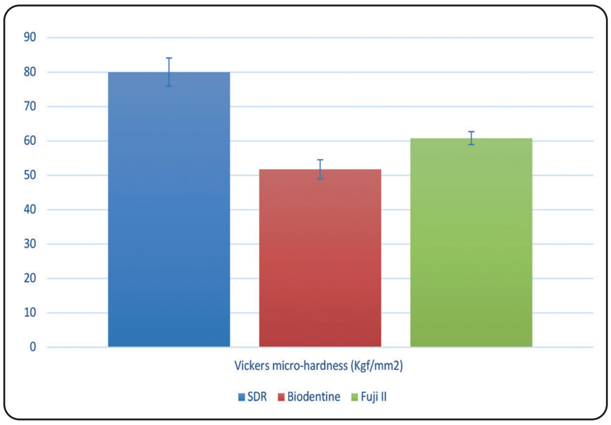

Fig. (3) Bar chart showing mean and standard deviation (error bars) values for Vickers micro-hardness (Kgf/mm²) for different groups

DISCUSSION

The findings of the current study provide critical insights into the mechanical properties of Smart Dentine Replacement (SDR), Biodentine, and Fuji II glass ionomer cement (GIC) liners, particularly in terms of their Vickers microhardness (VHN). Microhardness is a key determinant of a material's resistance to indentation and plastic deformation, which directly impacts the material's long-term performance in restorative dentistry. Given the importance of preserving tooth structure, especially in minimally invasive procedures, the mechanical robustness of these materials is of significant clinical relevance. [8]

The results demonstrated that SDR exhibited the highest microhardness value (79.99 ± 4.10), followed by Fuji II GIC (60.80 ± 1.87), while Biodentine had the lowest microhardness (51.73 ± 2.78). These findings are consistent with previous research suggesting that SDR's high filler content and modulated polymer network contribute to its superior mechanical properties, including greater resistance to shrinkage and enhanced adaptability to cavity walls. The ability of SDR to be placed in bulk layers (up to 4 mm) without compromising its mechanical integrity makes it particularly advantageous for posterior restorations, where speed and durability are crucial, especially in pediatric dentistry where quick procedures are essential for managing patient behavior. [9]

On the other hand, Fuji II GIC showed a commendable VHN value, reflecting its ability to sustain adequate hardness over time. The continuous fluoride release from Fuji II not only enhances remineralization but also improves mechanical properties, as demonstrated in this study. The increase in hardness of GICs over time is well-documented, and the material's water absorption properties further enhance its mechanical strength when stored in humid conditions, which was confirmed in our investigation. This makes Fuji II GIC a reliable option for minimally invasive dentistry, where maintaining both mechanical strength and biocompatibility is critical. [10]

Interestingly, the lower microhardness values recorded for Biodentine raise important questions regarding its performance as a restorative material. While Biodentine is recognized for its biocompatibility and its use in vital pulp therapy, its lower hardness in this study suggests potential limitations in its ability to withstand masticatory forces, particularly in high-load areas such as posterior teeth. The decreased microhardness observed in this study may be attributed to the shorter setting time used in the experimental design. Previous studies have indicated that Biodentine's hardness increases significantly with longer maturation periods, reaching higher VHN values after two weeks. This maturation process is essential for optimal crystallization of the calcium silicate hydrate gel, which forms the material's bulk. The short setting time used in this study may have limited this maturation process, leading to lower microhardness values compared to other studies where Biodentine was allowed to set for longer periods. [11]

It is also worth noting that the current study's methodology, which involved storage of samples in 100% humidity at 37°C for a period corresponding to three times the setting time, may have influenced the microhardness outcomes. In clinical practice, Biodentine is often given a longer maturation time before the application of composite resin, which could lead to higher bond strength and hardness. [12]

CONCLUSION

This study emphasizes the differences in mechanical properties among SDR, Biodentine, and Fuji II GIC liners. SDR showed the highest Vickers microhardness, followed by Fuji II, with Biodentine exhibiting the lowest. While SDR offers greater mechanical durability, particularly in high-stress areas, Biodentine's bioactive properties make it suitable for less mechanically demanding uses.

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