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Research Article

Effect of Wear Behaviour of a Polymer-Infiltrated Ceramic Network Material and Lithium Disilicate in Micro-Hardness

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Abstract

Introduction: Ceramic materials exhibiting desirable mechanical and chemical properties are widely utilized in permanent dental restorations. Multiple considerations in selecting these materials are being made, such as wear behaviour and micro-hardness. The aim of this study was to examine the two-body wear behaviour and micro-hardness of two different ceramics, a polymer-infiltrated ceramic network (PICN) material and Lithium disilicate.

Methods: The two-body wear behaviour was probed in a chewing simulator (75000 cycles, 49 N and 60 cycle/min.). The samples were segregated into two groups based on the kind of material: every group consisting of 14 ceramic discs. Vicker hardness test was conducted to assess micro-hardness of the material prior and after the wear test. Results were subjected to analysis of variance (ANOVA) and then verified by unpaired t-test.

Results: Lithium disilicate had a higher mean of micro-hardness values than PICN after chewing simulation.

Conclusion: Micro-hardness changes in Lithium disilicate were found to have higher values than PICN.

Keywords: *Chewing Simulator; Lithium Disilicate; Microhardness; Monolithic Ceramic; PICN; Two-Body Wear*

Abbreviations

CAD/CAM: Computer-Aided Design and Computer-Aided Manufacturing; PICN: Polymer-Infiltrated Ceramic Network

Introduction

The rise in several all-ceramic systems evolved due to progressive dental technology and research [1,2]. Glass-ceramics, as well as silicates, are continually being used as veneers for metal and/or all ceramic cores for improving structure and aesthetics. In monolithic restorations such as inlays, onlays, crowns, and laminate veneers, restorations are of relatively small size; as compared to fixed dental prostheses and crowns wherein the core materials are developed from high strength ceramics to extend their indications to the high load-bearing areas [3].

For the monolithic restoration, Lithium disilicate glass ceramic was used. There are two known forms of this material: an ingot with uniform appearance with varying degrees of opacity commonly utilized alongside hot-pressing technology, and a pre-crystallized block associated with CAD/CAM technology. Both types of this material can be utilized via a full anatomical contour approach. Stain and glaze can be applied or a cut-back and layering technique. Lithium disilicate is composed of 70% Lithium-disilicate crystals; usually, 0.5 µm to 5 µm long, scattered in a glassy matrix. Microscopically, its structure shows several small interlocking plate-like crystals in a random arrangement. This special microstructure benefits the material in properties such as increased fracture toughness and flexural strength as compared to Lucite-reinforced ceramics [4].

Hybrid ceramic is another monolithic material; it has a dual network structure, which joins the positive characteristics of composite and ceramic altogether in the same material. The superior ceramic network is further improved by the qualities of a polymer network, in which both networks penetrate completely [3]. Hybrid ceramics were introduced to reduce the current drawbacks of both composites and ceramics. PICN materials are expected to manifest characteristics such as high flexural strength with rigidity, low brittleness and easy milling in the CAD/CAM system [5]. Although there are many advantages to this ceramic material, it still has some drawbacks in its properties; among them is the wear that affects both material and opposing dentition. One important physical property is hardness, which may be referred to as "the resistance to permanent indentation or penetration of surface". It is measured as a force per unite area of indentation [6]. Abrasiveness level of a certain restoration against the opposing dentition can be determined by the material hardness [7], as well, ensures that the placed restorations are resistant to in-service scratching, from both mastication and abrasion [8].

This research thus was conducted to determine the influence of wear on micro-hardness of two monolithic materials: polymer-infiltrated ceramic network and Lithium disilicate.

It is essential to compare and study different properties of these introduced ceramic materials, as it has a huge role in the availability of clinical options for dentists and practitioners and treatment options for the patients [6] and to help in the proper selection of restorative material which will help in maintaining occlusal harmony and normal chewing function.

Aim of the Study

This study aims to assess the micro-hardness of PICN materials as well as the Lithium disilicate after being subjected to a wear test.

Materials and Methods

This research, with an experimental design that made use of judgment sampling as the materials, were specifically selected for their known mechanical and physical characteristics which are in a close approximate to the natural enamel, as well as their wide use in the dental practice. The study started from January 2019 till October 2019.

Materials

Six blocks of PICN hybrid ceramic (Vita enamic, Vita Zhanfabrick, Bad Sckingen, Germany) for CAD/CAM Technology, size (14), shade (A1) were used. This hybrid is composed of a structure-sintered ceramic matrix with polymer-containing pores. It consists of 86 wt% of inorganic ceramic and 14 wt% of organic polymer. Commonly, it is used as anterior/posterior crown, implant-supported crown and veneers. Six blocks of Lithium disilicate glass ceramic size (14), shade (A1) composed of 40% lithium metasilicate crystals (Li_2SiO_3) dispersed in a glassy matrix were also used. It is indicated for all-ceramic restorations, ranging from thin veneers to 3-unit bridges.

Methods

All blocks of both materials were ground to cylinders (10 x 10 mm) using a CAD/CAM machine (CAM 5-S1 Impression. Ammerbuch, Germany). Each cylinder was sectioned into discs using a microtome (IsoMet 4000 linear precision saw. Buehler, Illinios, USA). The top and bottom of each cylinder were excluded. Fourteen discs from each material were chosen with a total of 28 discs for all samples. Digital calibre was used to measure 2 ± 0.12 mm thickness of each disc.

According to manufacture instructions, Lithium disilicate discs were crystallized in a furnace (P500.Ivoclar Vivadent, AG, Schaan, Liechtenstein) 850°C (1562°F) for 35 minutes. While, for Vita enamic, polishing was done using Sof-Lex polishing disc followed by high-gloss polishing with grey diamond coated polisher (VITA ENAMIC polishing set, Vita Zhan Fabrick, Bad Sckingen, Germany) without water cooling [9].

Twenty-eight freshly extracted upper first premolars were acquired from different public hospitals from the treatment of diabetic patients. The extracted teeth were ensured to be caries-free and were cleaned using ultrasonic scaler equipped with PIEZO Scaler Tip (201) to eliminate any possible contamination of soft tissues and calculus. The teeth were also polished using a non-fluoridated polishing paste (Ivoclar Vivadent, Proxyt, Liechtenstein, Germany) and stored in saline solution (0.9% 500 ML R.C., Almottahedoon pharma, Egypt) [10]. The antagonist enamel cusp sample (n = 28) were made from the palatal cusp of an upper maxillary premolar. Each premolar was sectioned mesio-distally using slow-speed diamond disc (Diatech; Goltène AG, Switzerland) under copious water coolant [13] to obtain crack-free cusps. For the storage of the enamel antagonist cup, it was submerged in a saline solution, and the solution was changed every two days to eliminate the possibility of enamel specimen dehydration [10].

Samples of both groups; group (1) PICN and group (2) Lithium disilicate were placed in plastic holders with a circular hole (10 mm x 2 mm) in which the specimen can be embedded. The antagonist enamel cusp was individually and directly fixed in a metallic holder (Jackob's chuck) that can be tightened with a screw.

The two-body wear testing was executed through programmable equipment called ROBOTA; a chewing simulator capable of performing thermo-cyclic protocols operated on a servo-motor. This equipment possesses four chambers that can simulate simultaneous vertical and horizontal movements under a particular thermodynamic condition. Each chamber consists of an upper Jackob's chuck tooth antagonist holder that can be tightened with a screw and a sample holder for the specimen. The chewing simulator machine consists of two major parts; an upper part that is movable and lower part that is fixed. The antagonist enamel cusps were placed in the movable bars in the upper part while the ceramic samples were placed using a special plastic holder in the lower fixed part. Accompanying water cycling (5°C/55°C) was used as a lubricating medium (Table 1).

Cold/hot bath temperature: 5°C/55°C	Dwell time: 60s
Vertical movement: 1 mm	Horizontal movement: 3 mm
Rising speed: 90 mm/s	Forward speed: 90 mm/s
Descending speed: 40 mm/s	Backward speed: 40 mm/s
Cycle frequency 1.6 Hz	Weight per sample: from 5 kg
Torque; 2.4 N.m	

Table 1: *Chewing simulation parameters.*

Micro-hardness test

Surface micro-hardness of each group samples; group (1) PICN and group (2) Lithium disilicate was determined before and after chewing simulation using Digital Display Vickers Micro-Hardness Tester equipped with a Vickers diamond indenter and a 20x objective lens. The load was set to be 200g and was placed to the specimens' surface for 20 seconds. The three indentations, which were put over a circle equally and was made sure to be no closer than 0.5 mm to the adjacent indentations, were done on the specimen surface. Using the built-in scaled microscope, the diagonals' measurement between indentations were obtained, and the resulting Vickers values were transformed into its micro-hardness equivalence by utilizing the formula: $HV = 1.854(P/d^2)$

Where (HV) is Vickers hardness expressed in Kgf/mm^2 (kilograms-force per square millimetres), (P) is the set load expressed in Kgf (kilograms-force) and (d) is the diagonal length in millimetres.

Results

The collected data were analyzed using SPSS® Statistics Version 20. Results were checked for normality by evaluating the distribution of values using the Kolmogorov-Smirnov and Shapiro-Wilk tests. Test results point towards a parametric distribution. Parametric data were summarized into numerical values of mean and standard deviation at 95% Confidence Interval. Two-way ANOVA was utilized to understand the influence of wear and its relationship to mean micro-hardness. Unpaired t-test was performed for pair-wise comparison when ANOVA showed significance. A conventional P-value of .05 was the criteria to reject the null hypothesis.

Comparison between the mean micro-hardness (VHN) among PICN and Lithium disilicate groups; before and after chewing simulation

The highest mean VHN was recorded in group (2) Lithium disilicate before wear simulation, (486.3 ± 35.8VHN), whereas the least values were recorded in group (1) PICN after chewing simulation, (268.8 ± 38.9VHN). Statistical analysis using a two-way ANOVA test exhibited a significant difference ($p < 0.001$) when both groups were compared before chewing simulation, as well as significant difference ($p = 0.048$) between both groups after chewing simulation. Also, a significant difference ($p = 0.040$) between group (1) PICN (before and after chewing simulation values), as well as, a significant difference ($p < 0.001$) between group (2) Lithium disilicate (before and after chewing simulation values) has been observed. Data are represented numerically in the table 2 and graphically in figure 1.

Wear	PICN		Lithium disilicate		P-value (Between ceramics)
	Mean	SD	Mean	SD	
Before wear	305.5	14.4	486.3	35.8	< 0.001*
After wear	268.8	38.9	342.9	90.7	0.048*
P-value (Before and After wear)	0.040*		< 0.001*		

Table 2: *Comparison of micro-hardness values (VHN) among the two groups; group (1) PICN and group (2) Lithium disilicate before and after chewing simulation.*

**Significant at P ≤ 0.05.*

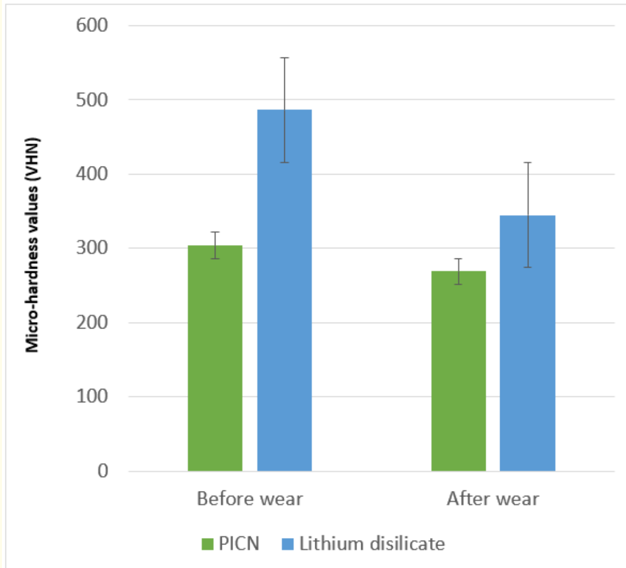

Figure 1: *Bar chart showing micro-hardness values (VHN) among the two group; group (1) PICN and group (2) Lithium disilicate before and after chewing simulation.*

Comparison between per cent of change in micro-hardness among the two groups; group (1) PICN and group (2) Lithium disilicate

The percentage change was recorded as the difference in microhardness divided by the microhardness before wear multiplied by **100.** Data are represented numerically in table 3 and graphically in figure 2.

	Per cent of change	SD
PICN	11.59	3.828
Lithium disilicate	38.05	5.1
t-value	15.526	
P-value	0.001*	

Table 3: *Comparison between percent of change in micro-hardness among the two groups; group (1) PICN and group (2) Lithium disilicate.*

**Significant at P ≤ 0.05.*

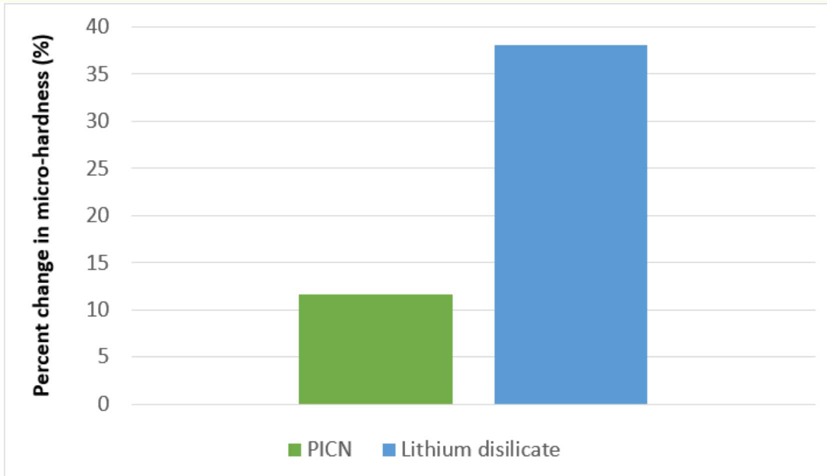

Figure 2: *Bar chart showing percent of change in micro-hardness among the two groups; group (1) PICN and group (2) Lithium disilicate.*

Regarding the per cent change in micro-hardness (%), a higher mean percent decrease was recorded in group (2) Lithium disilicate (38.05 ± 5.1) more than group (1) PICN (11.59 ± 3.828). An unpaired t-test revealed that the difference was highly significant ($p < 0.001$).

Discussion

In a world competing for perfection, many dental materials struggle to survive, while many others showed their proficiency in both function and aesthetic. Over the past twenty years, a huge evolution of ceramics technology for dental application has been remarkable, and new materials with processing techniques are regularly being introduced [11].

Lithium disilicate is a glass ceramic recognized for its outstanding properties as well as exceptional versatility and flexibility that all results with maximum aesthetics. This ceramic is widely used in dentistry as inlays, onlays, partial crowns, full crowns and veneers [12,13]. PICN (polymer infiltrated ceramic network) is the first dental hybrid ceramic with a dual-network fully integrated with one another resulting in specific properties as a high degree of elasticity, enormous load capacity and reduction of the wall thickness of restorations. It can be used as single crowns, inlay, onlay, implant supported crowns, partial crowns and veneers according to manufacturing indications [14].

In this study, samples were subjected to wear testing at a frequency of 60 cycle/min for (75,000 cycles), which represents six months in service [15]. The load of 5Kg (49N) used in this study is equal to the normal posterior teeth load during function [16]. Palatal cusps of upper maxillary premolars were used as natural antagonists. Many authors recommended flat planes of enamel prepared from labial, mesial or distal surface of tooth [17]; however, the cuspal enamel was found to be much stronger under compression than that found on tooth side [10], consequently using cusp specimens was more clinically relevant. The same parameters were performed in studies [10,18].

Hardness considered an important property when comparing restorative materials [19]. It is defined as the resistance to permanent surface indentation or penetration; in addition, it is a factor that affects the capability of getting finished and polished surface as well as, the resistance of a material to occlusal wear [7,19]. Hardness delineates the abrasiveness of a restoration to which the natural dentition may be submitted; an ideal restorative dental material should not wear the opposing dental tissues, and a ceramic with a higher hardness value might not be desired [20]. This study revealed a statistically significant difference in micro-hardness values of PICN (before and after chewing simulation) with a lower hardness value resulted after chewing simulation shown in table 2 (Figure 1). Similarly, a statistically significant difference in micro-hardness values was recorded among Lithium disilicate (before and after chewing simulation) with a lower hardness value resulted after chewing simulation, as shown in table 2 and figure 1. This decrease in micro-hardness might be due to the exposure of the new surface layer of the material after wear process, where this newly exposed layer might have different properties [21]. The current study revealed a statistically significant difference between both groups; group (1) PICN and group (2) Lithium disilicate (before chewing simulation). Micro-hardness value of group (2) Lithium disilicate (before chewing simulation) equals to (486.3VHN ± 35.8) found to be higher than the value of PICN group (1) (before chewing simulation) which equals (305.5VHN ± 14.4). These values apparently were following the manufacture manual of each material; where PICN hardness is (255 - 300VHN) [14], while Lithium disilicate is (480 - 500VHN) [12]. A statistically significant difference in micro-hardness values was found among both groups; group (1) PICN and group (2) Lithium disilicate (after chewing simulation) with higher values in group (2) Lithium disilicate. The lower micro-hardness of PICN is directly referred to the lower inorganic content of this material [14] as well as, the increase in its porosity, which increase its flexural strength and decrease its micro-hardness [22]. Hardness of PICN material is significantly below that of enamel and stays at lower end of the hardness of ceramics while being not significantly higher than that of composite [23]. In addition, a statistically significant difference in per cent change of micro-hardness between both groups; group (1) PICN and group (2) Lithium disilicate. The lower micro-hardness of PICN is directly referred to the lower inorganic content of this material [14] as well as the increase in its porosity, which increase its flexural strength and decrease its micro-hardness [22].

Conclusion

Considering the scope of this in-vitro study, Lithium disilicate showed a higher decrease in micro-hardness than PICN after chewing simulation, yet, Lithium disilicate remains with higher micro-hardness number than PICN after wear testing. Based on the results of this study, future studies may be conducted for the application of new high-performance materials to guarantee the lifetime of these materials and the long-term clinical success.

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Conflict of Interest

There are no relevant conflicts of interest regarding the study of this article. This article has not received at any time any financial support nor having any financial relationships. The study of this article has no patents, whether planned, pending or issued relevant to the work. There are no other relationship/conditions/circumstances that present a potential conflict of interest.

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