EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 68, 3565:3578, October, 2022

Print ISSN 0070-9484 • Online ISSN 2090-2360

Fixed Prosthodontics and Dental Materials

Submit Date : 09-04-2022 • Accept Date : 11-10-2022 • Available online: 01-10-2022 • DOI : 10.21608/edj.2022.149290.2177

WEAR AND SURFACE ROUGHNESS OF MONOLITHIC CAD/CAM MATERIALS USING TWO-BODY CHEWING SIMULATION AGAINST ENAMEL ANTAGONISTS

Hadil Ahmed Sabry* and Nehal Lotfy Abouraya**

ABSTRACT

Background: Wear and surface roughness are major interacting properties that affect the function and appearance of esthetic CAD/CAM monolithic restorative materials and opposing natural dentition.

Aim: Our research aimed to evaluate the wear and surface roughness of different esthetic monolithic CAD/CAM blocks and natural teeth antagonists before and after the chewing simulation procedure. Three types of esthetic CAD /CAM block materials were included in this study, nano-ceramic resin (*Lava Ultimate*), polymer infiltrated ceramic *(VITA Enamic)*, and lithium silicate glass ceramic enriched with zirconia *(VITA Suprinity)*.

Methodology: Twelve test samples were cut off as 2 mm thickness from size '14' blocks of each material, with a saw microtome. The polishing procedure was done according to the steps determined by the manufacturers. Enamel cusps from extracted human premolar teeth were used as antagonists. A chewing simulator was used to perform the 2-body wear test. Wear was quantified by weight loss and roughness measurement.

Results: *Lava Ultimate* exhibited the highest wear and surface roughness while its antagonist showed the least wear and roughness. There was no difference between wear weight loss in *Enamic* and *Suprinity*. *Enamic* had higher roughness than *Suprinity*. Natural tooth antagonists of *Suprinity* had the highest wear and surface roughness compared to that of *Lava Ultimate* and *Enamic*.

Conclusion: *Lava Ultimate* is the least material that produced wear and roughness in the natural antagonist thus considered the friendliest material to natural teeth. However, *Enamic* can be recommended as CAD/CAM restorative material regarding the wear of the restoration and its enamel antagonist.

KEYWORDS CAD/CAM monolithic esthetic blocks, Chewing Simulation, Surface Roughness, Two-Body Wear

* Associate Professor, Associate Professor of Dental Materials, Biomaterials Department, Faculty of Dentistry, October 6th University, Egypt.
** Lecturer of Dental Materials, Biomaterials Department, Faculty of Dentistry, Cairo University.

INTRODUCTION

Computer-aided design and Computer-aided machining (CAD/CAM) provided a time-saving solution for precise, esthetic restorations.[1,2] Development of monolithic restorative materials such as glass ceramics, hybrid ceramics, and composites has evoked to cope with patients' demands. Such materials are required to restore esthetics and function and withstand the harsh environmental conditions in the oral cavity without adversely affecting the existing opposing natural teeth.[3,4] Among the most commonly used materials for this purpose are lithium silicate glass-ceramics such as *Suprinity (VITA Zahnfabrik, Bad Sachingen, Germany*), Polymer Infiltrated Ceramic Network *(PICN*) as *Enamic* (*VITA, Bad Sachingen, Germany*) as well as nanoceramic composite *Lava Ultimate*.

Suprinity is introduced in a state of partially crystallized, which requires an additional thermal cycle. These ceramics have good mechanical properties based on their zirconia reinforced microstructure associated with excellent esthetic quality. However, they tend to abrade opposing teeth. Pre-polymerized resin blocks were developed to be used with CAD/CAM systems offering fast-milling and wear-friendly alternative ceramics. However, they suffered from several drawbacks as poor mechanical properties and wear resistance. Resin nano-ceramic *LAVA Ultimate* was introduced in 2012, with better mechanical properties. It contains nanoceramic powder 80wt% enhancing tribological, mechanical properties embedded in a polymer matrix[2]. *Enamic* has been introduced to the market since 2013 as a porous ceramic network that is infiltrated with an interpenetrating polymer network where ceramic dominates *(Polymer-Infiltrated Ceramic Network, PICN)*.[5 6,7,8]

Wear of the restorative material and opposing natural tooth structure is a determinant property affecting the function and the restoration lifetime.[4] Clinically, the resistance of restorative material to wear is mandatory to avoid loss of occlusal vertical dimension as consequence of material loss, hence interrupting function: esthetics/mastication and harming the temporomandibular joint [9]. In addition, natural teeth can suffer from wear when opposed by harder and rough surfaced restorative materials which may have impact on esthetics, and pulp health.[9,10,11]

Several factors affect amount and rate of wear namely: surface roughness, material properties such as microstructure and fracture toughness, patient's saliva, occlusion and dietary habits.[9,10,12] Contact stress and high fracture toughness of a restoration cause more gouging and impact damage to the antagonist enamel surface.[13]

Microfracture mechanism can be considered as the main cause of enamel and ceramics wear. Enamel wear primarily occurs due to micro-fracturing and through delamination and micro-ploughing. Under loading, crack nucleates at the enamel inter-rod discontinuities and propagates in the organic matrix, with increased loading, more crack propagation occurs through the apatite crystals and trans-granular breakage occurs. Lamellar wear particles are formed by parallel crack propagation towards the surface resulting eventually in fatigue wear. On contrary, dentine wear is characterized by ductile chip formation.[11] Moreover, chipped hydroxyapatite particles may further act as an abrasive resulting in three-body wear.[14,15] Enamel can be subjected to this type of microfracture due to severe localized stresses resulting from ceramic asperities extending from its surface. Other fact such as large hardness differences between contacting surfaces or particles, rough glass ceramic surface and impact or erosion of abrasive particles in saliva lead stress microfracture and increased localized tensile stress. Consequently, periodic finishing and polishing of the ceramic are necessary to decrease wear rates.[4,16,17]. *VITA Suprinity* showed high fracture resistance thus is less susceptible to microfracture. As an advantage, its polished surface maintains smoothness for longer time, but the rugosity of rough surface will persist.[18] This raised a concern that high strength, elastic modulus and surface hardness of ceramic materials can cause excessive abrasion of the antagonist teeth.[19] Whereas *VITA Enamic* representing PICNs have an elastic modulus approximately 50% lower than feldspathic ceramics and approaches that of dentin. Consequently, it is of higher damage tolerance, easier to be milled and adjusted allowing effortless repair by composite resins.[20] On the other hand, CAD/CAM resin-based blocks represented in our research as *Lava Ultimate* can endure and absorb direct impact forces that result in increased wear resistance of opposing materials due the low modulus and the high resilience.[21]

Since clinical wear analysis is too much problematic to be standardized, in-vitro wear tests are used for their rapid evaluation of wear properties of restorative materials such as the two-body wear, three-body wear, rotating sliding wear and toothbrush simulation as well as pin-on-plate test. Materials that reveal acceptable results can be further submitted to chewing simulation that can reproduce the physiological conditions such as the biting force, chewing movement and lubrication. These tests satisfactory replace clinical tests which are expensive and may take years to generate results,[12,22,23,24]

Therefore, this in-vitro study aimed to assess the wear and surface roughness of different CAD/CAM monolithic ceramic materials and enamel cusp antagonist before and after the chewing simulation wear procedure. The null hypotheses were that different evaluated CAD/CAM materials: *VITA Suprinity*, *VITA Enamic* and *Lava Ultimate* would not differ in their wear and their resultant surface roughness. In addition, their influence on the wear and roughness of the natural enamel cusp antagonist would not vary.

METHODS

Sample preparation

Three esthetic CAD/CAM blocks were included in this study, nano-ceramic resin *(Lava Ultimate)*, polymer-infiltrated ceramic *(VITA Enamic)*, and lithium silicate glass ceramic enriched with zirconia *(VITA Suprinity)* shown in table (1).

A total of 36 samples were prepared by slicing 12 test samples from size '14' blocks of each material with a microtome saw *(IsoMet 4000 - linear precision saw, Buehler, USA)*. Each sample was measured for the thickness of 2±0.12mm using the digital caliper *(Mitutoyo 500- 197-20/30 Absolute Digital Digimatic Vernier Caliper 200 mm/8", Aurora, Illinois, USA)*.[25]

The polishing procedure was done respective to the manufacturers using an electric contra-angle handpiece *(NSK EX-6B, Japan)*. The handpiece was mounted to a special device to ensure standardization of grinding pressure, rate, and direction to which the samples were subjected.

Polishing procedure

***Lava Ultimate*:** Each sample was cleaned in an ultrasonic bath and dried with air. A *"Robinson"* brush loaded with polishing paste was applied at low speed on the surface of the sample followed by a muslin rag wheel.

***VITA Enamic*:** The sample was cleaned in an ultrasonic bath and dried with air. A diamond grinding tool with ablating grinding pin was used. Polishing was performed with the *VITA Enamic* polishing instruments set in wet conditions.

***VITA Suprinity*:** Samples were crystallized by firing in a ceramic oven *(Programat P310; Ivoclar Viva-dent AG)* for 8 minutes at 840°C. Polishing was done using a pink diamond instrument at a speed from 7000 to 12,000 rotation/min.

TABLE (1): Composition of the used materials according to the manufacturers

Material	Shade	Block dimensions (mm)	Chemical Composition (% by weight)	Manufacturer
Lava Ultimate Resin nano-ceramic	A2/HT	18x14.5x14.5	*80 wt.% (65 vol%) nanoceramic fillers, 31% ZrO_2 (4-11 nm)- 69% SiO_2 fillers (20 nm)- aggregated ZrO_2/SiO_2 (in 0.6-10 mm) nanoclusters filler in 20 wt.% (35 vol%) highly cross-linked acrylate polymer matrix (UDMA, Bis-GMA, Bis-EMA, TEGDMA).*	*3M Espe, Seefeld, GERMANY*
VITA Enamic Polymer-infiltrated ceramic network	2M2/HT	18x14x12	*Hybrid ceramic with a dual network structure (Glass ceramic in a resin interpenetrating matrix). The main feldspathic ceramic network: As 86% (58 to 63% of SiO_2, 20 to 23% of Al_2O_3, 6 to 11% of Na_2O, 4 to 6% of K_2O, 0.5 to 2% of B_2O_3, <1% of CaO and <1% of TiO_2) is reinforced with a polymer 14% (UDMA, TEGDMA).*	*VITA Zahnfabrik, Bad Säckingen, GERMANY*
VITA Suprinity Lithium silicate	A2/HT	18x14x12	*Lithium silicate reinforced ceramic enriched with ZrO_2 (8% - 12%), SiO_2 (56% - 64%), Li_2O (15% - 21%), K_2O (1% to 4%), P_2O_5 (3% - 8%), Al_2O_3 (1% - 4%) and CeO_2 (0% - 4%).*	*VITA Zahnfabrik, Bad Säckingen, GERMANY*

The high-gloss polishing was done with the gray diamond tool at a reduced speed from 4000 to 8000 rotation/min with gentle and uniform contact pressure.

The cut samples were adjusted to fit the sample carrier cavity in a specially designed lower Teflon housing of the chewing simulator.

Antagonist preparation:

Natural enamel cusp was used as the antagonist. Extracted human teeth were collected from the Department of Oral and Maxillofacial surgery, Faculty of Dentistry, October 6 University, Giza, Egypt as approved by the Research Ethics Committee (No. RECO6U/3-2020) following the principles of the Declaration of Helsinki. The extracted teeth were thoroughly cleaned to remove any calculus and soft-tissue remnants using an ultrasonic scaler with PIEZO Scaler Tip 201 (*PIEZO soft Ultrasonic Scaler, KaVo Dental, Biberach an der Riss, Germany)*. Afterwards, teeth were polished with SofLex polishing discs (3M ESPE, St. Paul, USA) of descending roughness and then stored in distilled water at the room temperature until the tests were conducted. All teeth were examined under 4x magnification loops *(HEINE Optotechnik GmbH & Co.KG)*. Teeth with caries, enamel defects or hypo-mineralization were discarded. Buccal cusp specimens were prepared to obtain the antagonist enamel cusp specimens (n=36) by longitudinal sectioning of the upper first premolar using a high-speed handpiece mounted with a long carbide fissure bur with copious water coolant to obtain crack-free cusps (Fig.1).[26] Finally, specimens were stored in saline solution *(0.9% 500 mL R.C., Almottahedoon Pharma, Elsharkeya, Egypt*), which was renewed every 2 days to avoid desiccation of the enamel specimens. The cusp antagonist was fixed in upper Jackob's chuck in a tooth antagonist screw-tightened holder.[27,28]

Wear test by weight loss:

An electronic analytical balance (*Sartorius, Biopharmaceutical and Laboratories, Ger*) was employed to weigh all ceramic samples and antagonists with an accuracy of 0.0001g. before wear chewing simulation cycle. As this electronic balance had a fully automated calibration technology and a micro weighing scale, values were accurately measured. The balance was always kept on a free-standing table, away from vibrations to ensure accuracy. During weighing the samples, the glass doors of the balance were kept closed to avoid the effect of air drafts.

Two-body wear test was performed using programmable logic-controlled equipment. The newly developed four stations multimodal *ROBOTA* chewing simulator integrated with thermo-cyclic protocol operated on a sea servomotor *(Model ACH-09075DC-T, AD-TECH TECHNOLOGY CO., LTD., GERMANY)*.

The chewing simulator *(ROBOTA)* has four chambers simulating the vertical and horizontal movements simultaneously in the thermodynamic condition. Each chamber consists of an upper Jackob's chuck where the tooth antagonist holder can be tightened with a screw. The ceramic samples were placed in a Teflon mold housing that is fixed in the lower chamber that contains distilled water as a lubricant (Fig. 2). Thermocycling and wear testing parameters are mentioned in table (2). For clinical simulation of the six months chewing cycle repetition of the test for 75000 times was done.[9,26,29,30,31]

After chewing simulation cycles that represented wear of 6 months, each sample was examined, cleaned and dried with a paper tissue and re-weighed using the same electronic balance for quantitative loss. [9,27,31,32]

Fig.(1): Antagonist fixed in Jackob's chuck in a tooth holder

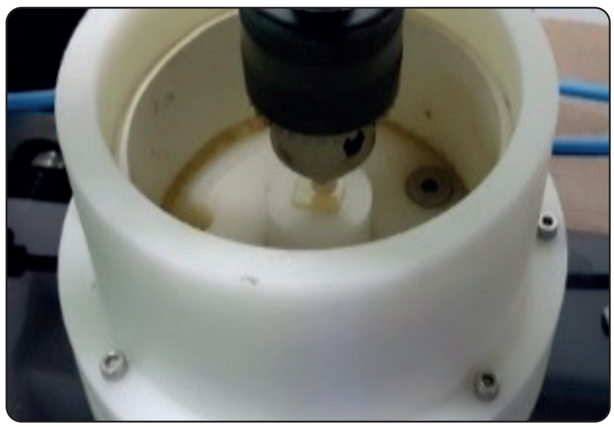

Fig. (2): Ceramic sample embedded in Teflon housing

TABLE (2): Parameters of Chewing simulator cycle

Cold-hot bath temperature:	5”-55”	Dwell time:	60 seconds
Vertical movement:	1 mm	Horizontal movement:	3 mm
Rising speed:	90 mm per second	Forward speed:	90 mm per second
Descending speed:	40 mm per second	Backward speed:	40 mm per second
Cycle frequency	1.6 Hz	Weight per sample:	5 kg
Torque:	2.4 N.m		

Surface roughness testing

Wear was also quantified by the roughness measurement of both materials and the antagonists. The Optical Profilometry allowed for quantitative characterization of surface topography without contact.[29] A 3D-surface analyzer system was used to quantitatively analyze two-body wear of samples and their antagonists pre- and post-loading. Samples were photographed using a built-in camera (Scope Capture Digital Microscope, Guangdong, China) attached to a USB Digital microscope that connected with IBM compatible personal computer. A fixed magnification of 120X was used. The images were recorded with a resolution of 1280x1024 pixels per image. Microsoft office picture manager was used to crop the digital microscope images to 350x400 pixels to specify/standardize the area of roughness measurement.[33] The cropped images were analyzed using WSxM software (Ver 5 develop 4.1, Nanotec, Electronica, SL). Within the WSxM software, all limits, sizes, frames, and measured parameters were expressed in pixels. Therefore, system calibration was performed to convert the pixels into absolute real-world units (μm). Calibration was made by comparing an object of known size with a scale generated by the software.

WSxM software was used to calculate the average of heights (Ra) expressed in μm, which can be assumed as reliable indices of surface roughness.[34] Subsequently, 3-D images of the surface profile of the samples were created using a digital image analysis system *(Image J 1.43U, USA)*. The non-worn surface served as a reference. This method generated a 3-D geometry of the wear surface.[31]

Statistical analysis:

Descriptive statistics for each group results were performed. Significant differences between groups were detected by one-way ANOVA followed by pair-wise Tukey's post-hoc tests. The difference between weight pre- and post-wear was found by paired t-test. Statistical analysis was conducted using SPSS 16® (*Statistical Package for Scientific Studies*), Graph pad prism and Microsoft office excel 365. *P*-values ≤ 0.05 were statistically significant in all tests.

Exploration of the given data was performed using the Shapiro-Wilk test and Kolmogorov-Smirnov test for normality and revealed that P-value was significant as P-value ≤ 0.05 which indicated that alternative hypothesis was rejected, and the concluded data originated from parametric data (normal distribution).

RESULTS:

Wear by *weight loss*:

Recorded weight loss (gram) of all materials and the antagonistic cusp before and after 6 months chewing simulator cycles expressing wear are shown in table (3). Comparison of the weight loss before and after wear simulation of all materials revealed significant wear expressed as weight loss in *Lava Ultimate* samples (-0.0512±0.0004 gm) (P <0.05). *Lava Ultimate* samples showed significantly higher weight loss compared to *VITA Enamic* (-0.0011±0.0005 gm) and *VITA Suprinity* (-0.0029±0.0048 gm) samples with no difference between the latter two showing insignificant weight loss after wear simulation cycle (P>0.05). Antagonist samples opposing *VITA Suprinity* exhibited significant higher weight loss (-0.0466 ± -0.0040 gm) (P <0.05) compared to those opposing *VITA Enamic* (-0.0009 ±0.0001 gm) and *Lava Ultimate* (0.00615 ±0.0132 gm) where no difference was detected between them (P>0.05).

Surface roughness:

Recorded surface roughness (Ra = μm) of all materials before and after 6 months chewing simulator cycles are shown as mean values and standard deviations (SD) in table (4). The 3-D geometry of the worn surfaces was produced as images of the surface profile of the samples in

TABLE (3): Wear as weight values (Mean values ±SD) for the tested materials' groups and antagonists before and after chewing simulator cycles

	Wear	Before		After		Mean difference		*P*-value
		M (gm)	SD	M (gm)	SD	M (gm)	SD	
Materials	*Lava Ultimate*	0.6687 a	0.0265	0.6175 a	0.0263	-0.0512 a	0.0004	0.04*
	VITA Enamic	0.7284 b	0.0121	0.7272 b	0.0118	-0.0011 b	0.0005	0.82
	VITA Suprinity	0.9287 c	0.0066	0.9258 c	0.0085	-0.0029 b	0.0048	0.36
	P value	0.001*		0.001*		0.001*		
Enamel Antagonist	*Lava Ultimate*	0.4576 a	0.0565	0.4638 a	0.0605	0.00615 a	0.0132	0.79
	VITA Enamic	0.4740 a	0.091	0.4731 a	0.0916	-0.0009 a	0.0001	0.98
	VITA Suprinity	0.4498 a	0.0493	0.4032 b	0.0361	-0.0466 b	-0.0040	0.01*
	P value	0.69		0.03*		0.0001*		

M: mean SD: standard deviation * significant difference as P<0.05

Means with the same small letters in the same column are insignificantly different.

Means with different small letters in the same column are significantly different.

TABLE (4): Roughness (Ra) values in μm (Mean values ±SD) for the tested materials groups and antagonists before and after chewing simulator cycles

	Wear	Before		After		Mean difference		*P*-value
		M	SD	M	SD	M	SD	
Materials	*Lava Ultimate*	0.252 a	0.001	0.255 a	0.002	0.002 a	0.003	0.001*
	VITA Enamic	0.254 a	0.005	0.253 b	0.001	- 0.001 a	0.005	0.54
	VITA Suprinity	0.251 a	0.002	0.251 c	0.001	0.000 a	0.002	1.00
	P-value	0.07		0.001*		0.12		
Enamel Antagonist	*Lava Ultimate*	0.2551 a	0.0022	0.2567 a	0.0019	0.0016 a	0.0038	0.13
	VITA Enamic	0.2581 a	0.0015	0.2594 a	0.0051	0.0013 a	0.0051	0.84
	VITA Suprinity	0.2562 a	0.0420	0.2891 b	0.0030	0.0335 b	0.0434	0.01*
	P-value	0.95		0.001*		0.004*		

M: mean SD: standard deviation * significant difference as P<0.05

Means with the same small letters in the same column are insignificantly different.

Means with different small letters in the same column are significantly different.

figures (3-8). Mean values of surface roughness (Ra) after wear simulation were highest for *Lava Ultimate* (Ra=0.255±0.002 μm) followed by *VITA Enamic* (Ra=0.253±0.001 μm) and the least value was recorded for *VITA Suprinity* (Ra=0.251±0.001 μm) (P <0.05). The antagonist facing *VITA Suprinity* exhibited a higher mean value for Ra (0.2891±0.0030 μm) (P <0.05) than those facing *VITA Enamic* (0.2594 ±0.0051 μm) and *Lava Ultimate* (0.2567 ± 0.0019 μm) with no difference between them (P >0.05) after wear simulation cycle. *VITA Suprinity* exhibited a significantly higher increase in roughness of antagonist as shown by mean difference values (P <0.05) than the other two materials with the difference between them non-significant (P >0.05).

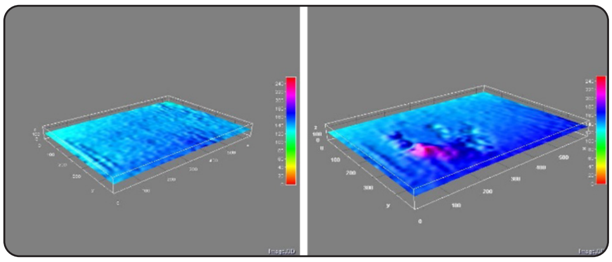

Fig. (3): Three-dimensional surface topography of Lava Ultimate sample before and after chewing simulation

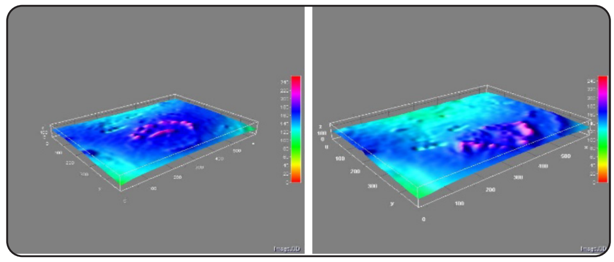

Fig. (4): Three-dimensional surface topography of Lava Ultimate cusp antagonist before and after chewing simulation

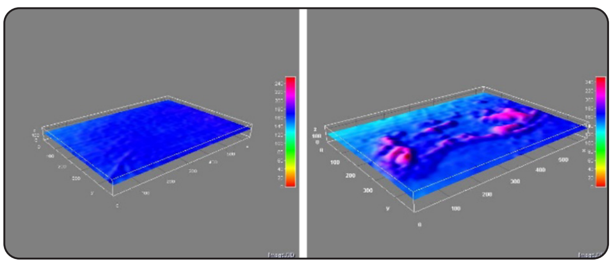

Fig. (5): Three-dimensional surface topography of VITA Enamic sample before and after chewing simulation

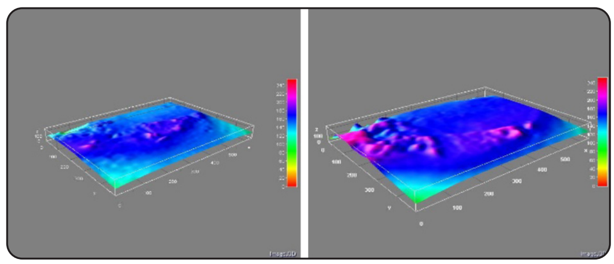

Fig. (6): Three-dimensional surface topography of VITA Enamic cusp antagonist before and after chewing simulation

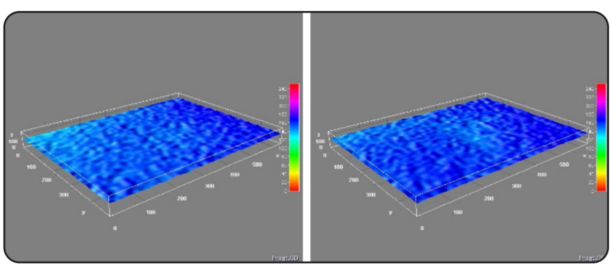

Fig. (7): Three-dimensional surface topography of VITA Suprinity sample before and after chewing simulation

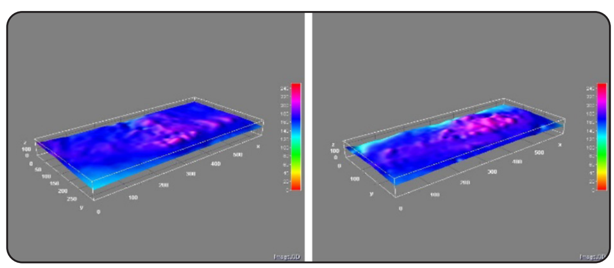

Fig. (8): Three-dimensional surface topography of VITA Suprinity cusp antagonist before and after chewing simulation

DISCUSSION

Wear of restorative materials is an important phenomenon as it can reduce the occlusal thickness of restorations which may cause functional problems, change surface topography and alter their esthetic appearance.[25,35] The importance and clinical implication of this study are depicted by a proper understanding of wear mechanism, associated surface roughness and their cross effect on natural teeth and CAD/CAM restorative materials. This will eventually help in the selection of the material for ideal performance in the oral environment.

Surface roughness is an important property of material that interacts with wear. The correlation between wear and surface roughness is emphasized by increasing enamel wear rate as the released wear particles cause enamel delamination and lead to three-body abrasion and eventually surface roughening.[15] For that purpose, dental materials with less surface roughness are desired.[36] It should be pointed out that, the surface roughness effect is diminished with the progression of wear, thus, the inherent ceramic bulk mechanical properties become more important regarding the rate of wear.[32]

Chewing simulators are preferred to conduct in-vitro wear studies to simulate oral conditions. Despite standardizing the experiment, regarding contact time, frequency, force profile, and sliding movement, yet clinically, teeth collision could occur, leading to a faster rate of restoration wear.[2,3,26] Five kg load (49 N) employed in this study is representative of normal physiological masticatory load during function as the amount, duration and velocity of loading are influencing factors on enamel wear.[9,37] In addition, freshly extracted non-attrited, non-carious premolars of young adult patients extracted for orthodontic reasons were used to avoid variation in enamel properties due to tooth position and histological structure.[11,16,38] Smoothening of the surface was done to standardize the surface roughness of the samples before conducting the test despite long-term minimal influence.[39,40] Since this research was conducted to observe the enamel wear behavior in clinical circumstances, only the cuspal tips were held in contact with the ceramic samples. A pointed stylus represented by an enamel cusp was held in contact with the ceramic samples as cuspal enamel samples were highly clinically relevant and sliding of the stylus is a mandatory process to expose the sample to micro-fatigue.[11,25,32,38] According to Heintze et al., the pointed stylus produced higher wear than a rounded stylus as the fatigue stress might be reduced due to the large area of contact. The water acted as a lubricant that could reduce the friction coefficient and hence wear. [26] Water used for lubrication in this study was continuously changed to remove the wear particulates from the intervening area in-between the cusp and the restoration to minimize their effect, which may act as an abrasive medium which may in turn convert the test into a three-body wear test adding a source of variation.[11]

The moisture of dentinal tubules which is persistent and difficult to remove despite drying samples and cannot be determined, may adversely affect the measurements.[9,10,41] Thus, wear was evaluated by measuring sample weight losses. For every specimen, weight change was calculated individually and statistically analyzed to exclude the effect of tooth moisture.

In our study, *Lava Ultimate* showed the highest statistically significant increased wear after chewing simulation compared to *VITA Enamic* in agreement with Ghahramanzadeh et al.[43] as well as a previous study which stated that resin matrix ceramic revealed higher wear amounts than *Suprinity* glass matrix ceramics[35]. This can be related to the low hardness of *Lava Ultimate* compared to glass and hybrid ceramics and its composition that relies on 80% nanoceramic particles bound to 20% resin matrix as shown in table (1) making it more prone to fatigue wear. The reciprocating movement of the stylus during the wear test could create compression and tension stress zones that may result in subsurface cracks, fragmentation in addition to debonding of fillers and their loss. Over time, these fragmented wear debris and worn particles caused 3-body abrasive wear that increases material loss under chewing simulation wear process.[9,25,42,43,44]

The obtained results contradicted reports of another study stating that resin-based ceramics had high flexural strengths, relatively low Young's modulus, characterized by being less brittle than glass ceramic and resisted chipping and cracking on milling. [2] Other researchers assumed that high wear resistance of the material could be attributed to the high content of filler particles with a fine size of 1 μm or less with less interparticle spacing, that may strengthen and protect matrix and reduce plucking of filler.[15,21,40,42,45,46]

VITA Enamic and *VITA Suprinity* showed high wear resistance with no significant difference between them after chewing simulation agreeing with previous studies that showed less degradation of *VITA Enamic* compared to materials with a greater content of resin matrix.[47]

VITA Enamic ceramics include 86% ceramic inorganic phase and 14% polymer organic phase and possessed features of both composites and ceramics, leading to sufficient flexibility, optimal distribution of chewing forces and high resistance to loads. *Enamic* structure depends on an interconnected ceramic network which is infiltrated with polymer. This structure could dampen the stresses inside the material and consequently minimize fatigue wear.[2,3,43,48] Meanwhile, *VITA Suprinity* lithium silicate ceramics are strong with a high flexural strength of around 407 MPa and high hardness resulting in high wear resistance.[2,43]

However, our findings disagreed with Elhomaimy et al. 2015,[32] who found that *VITA Enamic* revealed less wear compared to lithium disilicate-based ceramic (IPS e.max press). This was explained by the slight reduction of hardness in a wet environment based on glass matrix corrosion as positive water ions diffuse into the glassy matrix and plowing of the molecules from the surface. Also, it was found that loss of mechanical properties occurred in *Enamic* following aging which can be attributed to its low polymer content (14%) and difficulty of water penetration into the resin part and salinized polymer feldspar interfacial zone.[32]

VITA Suprinity showed the highest significant wear value of opposing enamel cusps compared to *Enamic* and *Lava Ultimate*. It could be referred to the high fracture toughness values of *Sprinity* 2 MPa•m$^{1/2}$ as reported by Srichumpong et al. 2019 causing more gouging, contact stress, and impact damage to antagonist enamel. In contrast *VITA Enamic* and *Lava Ultimate*, showed less fracture toughness of 1.23 MPa•m$^{1/2}$ and 1.29 MPa•m$^{1/2}$ respectively.[13,16,42]

This was in agreement with Mendonca et al. who explained that the lower hardness (200-255 VHN) of this hybrid material, *Enamic,* prevented the wear of the opposing natural teeth [50]. The combination of less rigidity and hardness with satisfactory flexural and fracture strength values makes it a suitable choice as a restorative material and a potential candidate for enamel substitution as stated by several authors.[2,23,49,50]

Comparing surface roughness Ra values after chewing simulation of the three materials revealed a statistically significant difference with high values in *Lava Ultimate* followed by *VITA Enamic* and the least for *Suprinity*. Being nano-filled resin composite, the Ra of *Lava Ultimate* is significantly increased after the wear simulation test. This could be related clinically where polished restorations could become rough or undergo wear by time in daily function without any occlusal adjustment. Likewise, the manufacturers recommended intraoral clinical repolishing every 6 months to decrease antagonist enamel and restoration wear.[17,35]

For *VITA Enamic*, the surface roughness might be due to fatigue and the release of the hard ceramic particles. The pull-out of ceramic particles from the polymeric matrix and abrasion signs in the sample surface led to the surface roughness. Microcracks formed at the interface between the ceramic particles and polymeric networks caused detachment and fracture of these particles. Three-body abrasion could be induced consequently.[23]

Another explanation for the obtained results was that polymer infiltration within the porous ceramic network resulted in less modulus of elasticity and hardness in comparison to *Suprinity* which had the highest hardness and rigidity among all tested materials.[50]

A study stated that human enamel exhibited a lower wear rate when the enamel is opposed to ceramic of surface roughness (Ra) of 0.24 μm to less than 0.75 μm and increased dramatically when the antagonistic Ra value increased to 2.75 μm. which was related to resistance to friction. The friction coefficient increased with an increase in surface roughness, thus increased wear.[51] This contradicts our findings as *Suprinity* had Ra mean value of 0.25 μm but its antagonist showed high wear compared to the antagonists of the other tested materials which may be attributed to the higher hardness of *Suprinity*.[52] In addition, the existence of zirconia as a reinforcing agent in the glassy phase (8-12%), supposedly strengthened the material through a crack interruption mechanism under cyclic loading using a chewing simulator. Zirconia transformed from the metastable tetragonal phase to a stable monoclinic phase with an increase in grain volume, which hindered crack development and propagation thus impeding fragmentation and consequent roughness.[50]

The rougher the material, the more wear of the material itself, as well as the opposing structure.[36] The results of the present study coincide with this fact as *Lava Ultimate* with the highest Ra value showed significantly the highest wear.

On the other hand, there was no difference between the Ra of *VITA Enamic* and *VITA Suprinity* pre-and post-testing. This might be due to the high hardness and fracture toughness of both materials. This was in agreement with the results of Tachibana et al. 2021 [18] who declared high damage tolerance of *Enamic* that exhibited some elastic deformation in reaction to repeated wear impacts and less degree of surface roughness under load.[25]

No difference was noted in surface roughness values of *VITA Enamic* before and after chewing simulator cycles, compared with higher surface roughness of *Lava Ultimate* after chewing simulator cycles. These results agreed with those obtained by a study conducted in 2017.[3]

CONCLUSIONS

Within the limits of this research, it could be proposed that PICN material; *VITA Enamic*, can be considered as recommended material of choice as CAD/CAM dental restorative material as regards material loss due to wear and its effect on the antagonist.

For nanoceramic resin CAD/CAM posterior restorations, (*Lava Ultimate*) with the lowest impact on antagonist enamel loss, is the most wear-friendly material against natural antagonists; nevertheless, it may suffer from material loss by wear.

Limitations of the study

Material wear in-vivo is a variable and complicated mechanism that differs among patients. Thus, the laboratory wear tests, even the most sophisticated ones only imply estimates of the clinical performance of restorative materials.

Moreover, dissimilar testing methods of wear could result in discrepancies in outcomes, consequently, comparison of the obtained results with other studies represented difficulty.

Recommendation:

Future research is recommended to evaluate the long-term serviceability of these investigated materials, the effects of different occlusal loads and pH changes and under loads similar to those occurring intraorally. As well, submission of the samples to toothbrushing devices with toothpaste.

REFERENCES

1. Datla SR, Alla RK, Alluri VR, P JB, Konakanchi A. Dental Ceramics: Part II – Recent Advances in Dental Ceramics. Am J Mater Eng Technol. 2015;3(2):19-26. doi:10.12691/materials-3-2-1
2. Skorulska A, Piszko P, Rybak Z, Szymonowicz M, Dobrzyński M. Review on Polymer, Ceramic and Composite Materials for CAD/CAM Indirect Restorations in Dentistry—Application, Mechanical Characteristics and Comparison. Materials (Basel). 2021;14(7):1-21. doi:10.3390/ma14071592
3. Naumova EA, Schneider S, Arnold WH, Piwowarczyk A. Wear behavior of ceramic CAD/CAM crowns and natural antagonists. Materials (Basel). 2017;10(3):1-13. doi:10.3390/ma10030244
4. Souza JCM, Silva CS, Caramês J, et al. Biotribology Wear behavior of dental glass-ceramics : a scoping review on the damage of opposing tooth enamel surfaces. 2020;(May 2019).
5. da Silva LH, de Lima E, Miranda RB de P, Favero SS, Lohbauer U, Cesar PF. Dental ceramics: A review of new materials and processing methods. Braz Oral Res. 2017;31:133-146. doi:10.1590/1807-3107BOR-2017.vol31.0058
6. Kim SH, Choi YS, Kang KH, Att W. Effects of thermal and mechanical cycling on the mechanical strength and surface properties of dental CAD-CAM restorative materials. J Prosthet Dent. Published online February 2021:1-10. doi:10.1016/j.prosdent.2020.11.014
7. de Andrade GS, Augusto MG, Simões BV, Pagani C, Saavedra G de SFA, Bresciani E. Impact of simulated toothbrushing on surface properties of chairside CAD-CAM materials: An in vitro study. J Prosthet Dent. 2021;125(3):469.e1-469.e6. doi:10.1016/j.prosdent.2020.08.028
8. Öztürk E. Repair of aged polymer-based CAD/CAM ceramics treated with different bonding protocols. Int J Prosthodont. Published online 2021:1-26. doi:10.11607/ijp.6660
9. Gwon B, Bae E Bin, Lee JJ, et al. Wear characteristics of dental ceramic CAD/CAM materials opposing various dental composite resins. Materials (Basel). 2019;12(11). doi:10.3390/ma12111839
10. Choi JW, Bae IH, Noh TH, et al. Wear of primary teeth caused by opposed allceramic or stainless steel crowns. J Adv Prosthodont. 2016;8(1):43-52. doi:10.4047/jap.2016.8.1.43
11. Heintze SD, Reichl FX, Hickel R. Wear of dental materials: Clinical significance and laboratory wear simulation methods —A review. Dent Mater J. 2019;38(3):343-353. doi:10.4012/dmj.2018-140
12. F. Esquivel-Upshaw J, Hsu SM, Bohórquez AC, et al. Novel methodology for measuring intraoral wear in enamel and dental restorative materials. Clin Exp Dent Res. 2020;6(6):677-685. doi:10.1002/cre2.322
13. Srichumpong T, Phokhinchatchanan P, Thongpun N, Chaysuwan D, Suputtamongkol K. Fracture toughness of experimental mica-based glass-ceramics and four commercial glass-ceramics restorative dental materials. Dent Mater J. 2019;38(3):378-387. doi:10.4012/dmj.2018-077
14. Ratledge DK, Smith BGN, Wilson RF. The effect of restorative materials on the wear of human enamel. J Prosthet Dent. 1994;72(2):194-203. doi:10.1016/0022-3913(94)90080-9
15. Branco AC, Colaço R, Figueiredo-Pina CG, Serro AP. A State-of-the-Art Review on the Wear of the Occlusal Surfaces of Natural Teeth and Prosthetic Crowns. Materials (Basel). 2020;13(16):1-27. doi:10.3390/ma13163525
16. Anusavice KJ, Shen C, Rawls HR. Phillip's Science of Dental Materials. 12th ed. ELSEVIER SAUNDERS 3251 Riverport Lane St. Louis, Missouri 63043; 2013.
17. Sripetchdanond J, Leevailoj C. Wear of human enamel opposing monolithic zirconia, glass ceramic, and composite resin: An in vitro study. J Prosthet Dent. 2014;112(5):1141-1150. doi:10.1016/j.prosdent.2014.05.006
18. Tachibana K, Atsuta I, Tsukiyama Y, et al. The need for polishing and occlusal adjustment of zirconia prostheses for wear on antagonist teeth. Dent Mater J. Published online 2021. doi:10.4012/dmj.2020-190
19. Stober T, Bermejo JL, Schwindling FS, Schmitter M. Clinical assessment of enamel wear caused by monolithic zirconia crowns. J Oral Rehabil. 2016;43(8):621-629. doi:10.1111/joor.12409

20. Silva, Lucas Hian; Lima, Erick de; Miranda, Ranulfo, Benedito de Paula; Favero, Stéphanie Soares; Lohbauer, Ulrich; Cesar PF. Critical review Dental Materials/ Dentistry Dental ceramics: a review of new materials and processing methods. Braz oral Rest. 2017;31:133-146. https://doi.org/10.1590/1807-3107BOR-2017.vol31.0058

21. Oouchi H, Takamizawa T, Tamura T, et al. Flexural properties and wear behavior of computer-aided design/ computeraided manufacturing resin blocks. Dent Mater J. Published online April 20, 2021. doi:10.4012/dmj.2020-381

22. Altaie A, Bubb NL, Franklin P, Dowling AH, Fleming GJP, Wood DJ. An approach to understanding tribological behaviour of dental composites through volumetric wear loss and wear mechanism determination; beyond material ranking. J Dent. 2017;59:41-47. doi:10.1016/j.jdent.2017.02.004

23. Santos F, Branco A, Polido M, Serro AP, Figueiredo-Pina CG. Comparative study of the wear of the pair human teeth/Vita Enamic® vs commonly used dental ceramics through chewing simulation. J Mech Behav Biomed Mater. 2018;88(August):251-260. doi:10.1016/j.jmbbm.2018.08.029

24. Tsujimoto A, Barkmeier WW, Fischer NG, et al. Wear of resin composites: Current insights into underlying mechanisms, evaluation methods and influential factors. Jpn Dent Sci Rev. 2018;54(2):76-87. doi:10.1016/j.jdsr.2017.11.002

25. Hamed W, Anwar E, Adel R, et al. Surface roughness of two different monolithic materials after chewing simulation. J Int Oral Heal. 2020;12(7):S47-S52. doi:10.4103/jioh.jioh_272_19

26. Heintze SD, Cavalleri A, Forjanic M, Zellweger G, Rousson V. Wear of ceramic and antagonist-A systematic evaluation of influencing factors in vitro. Dent Mater. 2008;24(4):433-449. doi:10.1016/j.dental.2007.06.016

27. Habib S, Alotaibi A, AlHazza N, Allam Y, AlGhazi M. Two-body wear behavior of human enamel versus monolithic zirconia, lithium disilicate, ceramometal and composite resin. J Adv Prosthodont. 2019;11(1). doi:10.4047/jap.2019.11.1.23

28. Tokunaga J, Ikeda H, Nagamatsu Y, Awano S. Wear of Polymer-Infiltrated Ceramic Network Materials against Enamel. Published online 2022.

29. Abouelatta OB. 3D surface roughness measurement using a light sectioning vision system. WCE 2010 - World Congr Eng 2010. 2010;1(May):698-703.

30. Nawafleh N, Hatamleh M, Elshiyab S, Mack F. Lithium Disilicate Restorations Fatigue Testing Parameters: A Systematic Review. J Prosthodont. 2016;25(2):116-126. doi:10.1111/jopr.12376

31. Hamza GE, Salem HN and, Samman MA. Evaluation of two-body wear rate and roughness of polyetheretherketone and zirconia opposing enamel structure: an in-vitro study. J Arab Soc Med Res. 2019;14(2):73. doi:10.4103/jasmr.jasmr_14_19

32. Elhomiamy E, Aboushady Y, El Malakh B. Wear Behaviour and Surface Roughness of Polymer Infiltrated Ceramic Material Compared To Pressable Glass Ceramic. Alexandria Dent J. 2015;40(1):65-70. doi:10.21608/adjalexu.2015.58738

33. Giacomelli L, Derchi G, Frustaci A, et al. Surface Roughness of Commercial Composites after Different Polishing Protocols: An Analysis with Atomic Force Microscopy. Open Dent J. 2010;4(1):191-194. doi:10.2174/1874210601004010191

34. Kakaboura A, Fragouli M, Rahiotis C, Silikas N. Evaluation of surface characteristics of dental composites using profilometry, scanning electron, atomic force microscopy and gloss-meter. J Mater Sci Mater Med. 2007;18(1):155-163. doi:10.1007/s10856-006-0675-8

35. Aladağ A, Oğuz D, Çömlekoğlu ME, Akan E. In vivo wear determination of novel CAD/ CAM ceramic crowns by using 3D alignment. J Adv Prosthodont. 2019;11(2):120-127. doi:10.4047/jap.2019.11.2.120

36. Mörmann WH, Stawarczyk B, Ender A, Sener B, Attin T, Mehl A. Wear characteristics of current aesthetic dental restorative CAD/CAM materials: Two-body wear, gloss retention, roughness and Martens hardness. J Mech Behav Biomed Mater. 2013;20:113-125. doi:10.1016/j.jmbbm.2013.01.003

37. Magne P, Oh WS, Pintado MR, DeLong R. Wear of enamel and veneering ceramics after laboratory and chairside finishing procedures. J Prosthet Dent. 1999;82(6):669-679. doi:10.1016/S0022-3913(99)70008-9

38. Preis V, Weiser F, Handel G, Rosentritt M. Wear performance of monolithic dental ceramics with different surface treatments. Quintessence Int. 2013;44(5):393-405. doi:10.3290/j.qi.a29151

39. Cazzaniga G, Ottobelli M, Ionescu AC, et al. In vitro biofilm formation on resin-based composites after different finishing and polishing procedures. J Dent. 2017;67(May):43-52. doi:10.1016/j.jdent.2017.07.012

40. Çakmak G, Subaşı MG, Yilmaz B. Effect of thermocycling on the surface properties of resin-matrix CAD-CAM ceramics after different surface treatments. J Mech Behav Biomed Mater. 2021;117(November 2020):104401. doi:10.1016/j.jmbbm.2021.104401

41. Ulucan MÇ, Bolayır G, Saygın A, Soygun K. Wear of Ceramics Systems with Different Surface Applications in a Chewing Simulator. Med Sci Discov. 2020;7(10):670-679. doi:10.36472/msd.v7i10.427

42. Sonmez N, Gultekin P, Turp V, Akgungor G, Sen D, Mijiritsky E. Evaluation of five CAD/CAM materials by microstructural characterization and mechanical tests: A comparative in vitro study. BMC Oral Health. 2018;18(1):1-13. doi:10.1186/s12903-017-0458-2

43. Ghahramanzadeh Asl H, Sağsöz Ö, Kara L. Investigation of mechanical and wear properties of five (5) different CAD/CAM restorative materials. El-Cezeri J Sci Eng. 2020;7(1):57-66. doi:10.31202/ecjse.593747

44. de Angelis F, D'Arcangelo C, Malíšková N, Vanini L, Vadini M. Wear properties of different additive restorative materials used for onlay/overlay posterior restorations. Oper Dent. 2020;45(3):E156-E166. doi:10.2341/19-115-L

45. Tsujimoto A, Barkmeier WW, Takamizawa T, Latta MA, Miyazaki M. Influence of thermal stress on simulated localized and generalized wear of nanofilled resin composites. Oper Dent. 2018;43(4):380-390. doi:10.2341/16-206-L

46. Imai A, Takamizawa T, Sugimura R, et al. Interrelation among the handling, mechanical, and wear properties of the newly developed flowable resin composites. J Mech Behav Biomed Mater. 2019;89(July 2018):72-80. doi:10.1016/j.jmbbm.2018.09.019

47. Tribst JPM, Maria de Oliveira Dal Piva A, Werner A, et al. Effect of surface treatment and glaze application on shade characterized resin-modified ceramic after toothbrushing. J Prosthet Dent. 2021;125(4):691.e1-691.e7. doi:10.1016/j.prosdent.2020.12.040

48. Dal Piva AMO, Tribst JPM, Werner A, Anami LC, Bottino MA, Kleverlaan CJ. Three-body wear effect on different CAD/CAM ceramics staining durability. J Mech Behav Biomed Mater. 2020;103(December 2019):103579. doi:10.1016/j.jmbbm.2019.103579

49. Ludovichetti FS, Trindade FZ, Werner A, Kleverlaan CJ, Fonseca RG. Wear resistance and abrasiveness of CAD-CAM monolithic materials. J Prosthet Dent. 2018;120(2):318.e1-318.e8. doi:10.1016/j.prosdent.2018.05.011

50. Furtado de Mendonca A, Shahmoradi M, de Gouvêa CVD, De Souza GM, Ellakwa A. Microstructural and Mechanical Characterization of CAD/CAM Materials for Monolithic Dental Restorations. J Prosthodont. 2019;28(2):e587-e594. doi:10.1111/jopr.12964

51. Ghazal M, Kern M. The influence of antagonistic surface roughness on the wear of human enamel and nanofilled composite resin artificial teeth. J Prosthet Dent. 2009;101(5):342-349. doi:10.1016/S0022-3913(09)60068-8

52. Hassan S, Gad N. Two-Body Wear And Surface Roughness of Three Different Ceramic Systems And Their Enamel Antagonist: An In Vitro Study. Al-Azhar Dent J Girls. 2017;4(4):347-357. doi:10.21608/adjg.2017.5282