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Wear behavior of bonded occlusal veneers constructed from machine milled glass and polymer infiltrated ceramics in contact with enamel: An *in vitro* study

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Abstract
Statement of problem: Occlusal veneer is considered an extra-coronal restoration with less invasive preparation. Yet there is a shortage of information as regards the wear behavior of materials from which occlusal veneers are manufactured and their opposing enamel**.**
Purpose: Evaluate the wear of bonded occlusal veneers constructed from two dissimilar materials along with their opposing enamel following chewing simulation.
Material and Methods: 16 table tops of two dissimilar materials "lithium disilicate and polymer infiltrated ceramics" were manufactured with a complete digital workflow. The occlusal veneers were bonded in accordance with the manufacturer's directions to their corresponding epoxy resin dies. 2-body wear test with 49 N of mastication force and 37,500 cycles was done and wear behavior was determined by substance loss and roughness changes.
Results: The weight loss of Rosetta SM occlusal veneers was higher than Vita Enamic occlusal veneers p value <0.0001 however, the roughness of enamel opposing Vita Enamic was statistically higher than Rosetta SM after wear simulation test p-value $=0.02$.
Conclusions: Rosetta SM occlusal veneers have better wear resistance than Vita Enamic occlusal veneers. However, the Rosetta SM occlusal veneers showed better influence on the enamel antagonists in comparison to Vita Enamic occlusal veneers after wear simulation.

Keywords: Occlusal veneers, glass ceramics, hybrid ceramics, enamel antagonists, wear, thermocycling

Introduction

Teeth wear is concomitant with extreme damage of the crown that could be interrelated to single or multiple causes, for instance, food intake and dietary lifestyle initiating damage to tooth structure [17].

For this purpose, the management of worn teeth through a more conservative preparation by using indirect restorations as an implementation of the non-invasive approach has been proposed [20].

Occlusal veneers are a conservative substitute for prosthetic rehabilitation of posterior dentitions without the need for a significant amount of tooth reduction [3].

Glass-ceramic was the leading manufactured all-ceramic material for CAD/CAM systems. They have high quantity of glass in their structure, which makes them among the most natural-looking materials [22].

The proven competence of lithium disilicate material has been acknowledged which encourages its use in restoring worn teeth through a more conservative approach [4].

These days, the CAD/CAM hybrid ceramics have been presented with rapid restoration manufacturing with no need for firing after milling and uncomplicated intraoral mending of the restoration using direct composite material [22].

Polymer-infiltrated ceramic network material is a "hybrid ceramic" with two-folded network "glass-ceramic in a resin interpenetrating matrix". The key feldspathic ceramic network (86% by weight) is strengthened with a polymer "UDMA, TEGDMA" (14% by weight) [24].

"Polymer-infiltrated ceramics" are more resilient than glass ceramics, along with having outstanding fatigue strength.

Conversely, wear, discoloration, and decreased fracture strength should be put into consideration [4].

The wear resistance of dental materials is a crucial property that qualifies the material to be used in the daily dental workflow [15].

The initial null hypothesis was the wear behavior of lithium disilicate occlusal veneers and polymer-infiltrated ceramic would be the same after chewing simulation.

The other null hypothesis was the wear behavior of natural opponents facing either lithium disilicate glass, or polymer-infiltrated ceramic would be similar after chewing simulation.

Materials and Methods

Ethical Approval

The "research ethics committee" at the Faculty of Dentistry Cairo University has accepted this study with a consent number of 16-7-20.

Sample size

The sample size of 8 in every group has a 95% power to spot the variation between means of 4.47 with a significance level of 0.05 (two-tailed). In 95% (the power) of those experiments, the P value would be smaller than 0.05 (two-tailed) so the findings will be considered "statistically significant". In the remaining 5% of the experiments, the variations among means will be estimated as "not statistically significant".

Preparation of typodont tooth

A mandibular right first molar of a Typodont model "NISSIN Dental Model, Kyoto Japan" was selected to execute the main preparation, which is the conventional planar occlusal veneer design. (Figure 1)

Tapered round-end diamond stones with a 2-degree angle (komet dental) were utilized to prepare the occlusal surface following tooth anatomy through a 1.5 mm reduction at the cusp tip and a 1 mm reduction at the fossa.

Finishing and polishing of the typodont tooth were completed using "3M Sof –Lex polishing spiral wheels" and EVE Diacomp plus occluflex.

Putty guides were utilized to verify the homogeneity and the sum of the reduction.16 epoxy resin replicas of the prepared typodont model were created using a silicon mold of the prepared typodont tooth.

A CAD/CAM CEREC system (CEREC PrimeScan intra-oral scanner, CEREC software version 5.2, and 4-axis milling machine MC XL) was used for scanning, designing and milling Vita Enamic and Rosetta SM occlusal veneers in this study.

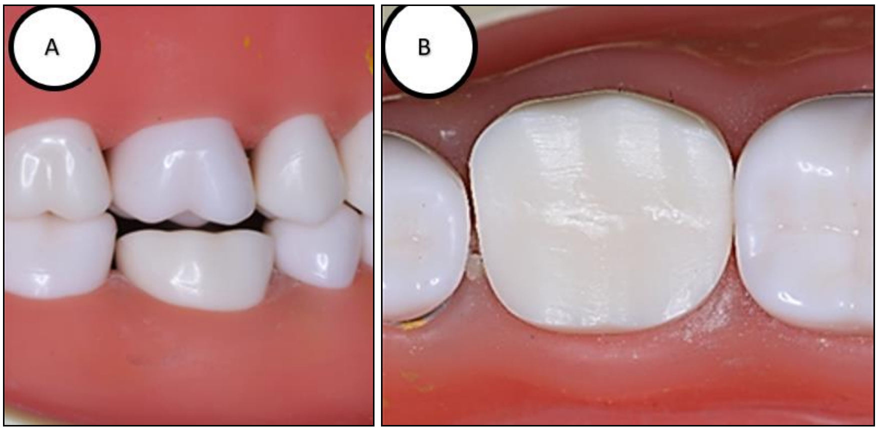

Fig 1: The convintional planar occlusal veneer design (A) buccal view (B)occlusal view

Surface treatment and cementation of the occlusal veneers

Surface treatment of the duplicated epoxy resin dies was done using aquacare air abrasion unit for 5 seconds at 2.5 bars at a 10 cm distance with 50 µm aluminum oxide particles then washed with water and dried with air.

For Rosetta SM: the internal surface of the Rosetta SM occlusal veneers was etched using (Bisco Porcelain Etch) 9.5% hydrofluoric acid ceramic etching gel for 20 seconds, then water washed and air-dried.

For Vita Enamic: The inner surface of the Vita Enamic occlusal veneers was etched using (Bisco Porcelain Etch) 9.5% hydrofluoric acid ceramic etching gel for 60 seconds, then water rinsed and air-dried.

The intaglio surface of both types of occlusal veneers were then silanized with Bisco Silane for 60 seconds and then air-dried for 5 seconds.

The cementation of the 16 occlusal veneers to the 16 epoxy resin dies was done using DUO-LINK UNIVERSAL™ Resin Luting Cement, 5 minutes of load application using a custom-built loading device to direct a 3 kg of constant load parallel to the long axis of each die during cementation which was allowed to confirm self-curing of the cement as recommended by the manufacturer. (Figure 2) Light curing of every surface for 20 seconds.

Fig 2: A customized loading device with a constant load of 3 Kg applied during occlusal veneers cementation to thier corresponding epoxy resin dies.

Collection of natural teeth

16 Recently extracted human maxillary molars for orthodontic or periodontal reasons were carefully chosen to be used in this study. The molars were picked with meticulous inspection using 3.5X magnifying loupes (UNIVET LOUPES Spa) to guarantee they were caries, defects, and cracks free.

Using a digital caliper, it was confirmed that the mean measurement variation between teeth was not more than 2.5% concerning the buccolingual width of the teeth, besides having equivalent crown and root measurements to ensure a similar modulus of elasticity.

Calculus, debris, and soft tissue deposits were eliminated using an ultrasonic scalar. The teeth were maintained in saline solution in a well-secured container at room temperature until use.

Each tooth was segmented mesiodistally using a low-speed cutting appliance into equivalent buccal and lingual halves.

The bonded occlusal veneers to the epoxy resin models were indiscriminately distributed into two equal groups, (groups A and B) with eight samples in the group, in compliance with the material to be investigated; group A machinable lithium disilicate glass-ceramic (Rosetta®SM) and group B machinable polymer infiltrated ceramic (VITA ENAMIC®).

The natural antagonists opposing the occlusal veneers were indiscriminately distributed into two groups (groups A and B) eight per each according to the occlusal veneer materials opposing the enamel antagonist; group A enamel antagonist opposing machinable lithium disilicate glass-ceramic (Rosetta®SM) and group B enamel antagonist opposing machinable polymer infiltrated ceramic (VITA ENAMIC®)

The 2-body wear test was carried out via the ROBOTA chewing simulator, which is running with a servomotor (Model ACH-09075DC-T, AD-TECH TECHNOLOGY CO., LTD., GERMANY). (Figure3)

Every single chamber contains a superior Jacob's chuck that could grasp the buccal half of the upper molar and the epoxy resin die with the bonded occlusal veneer was embedded in the inferior sample holder.

A 5 kg dead weight, that simulates 49 N of mastication force, was used with 37,500 times of test repetition, which clinically simulates 3 months of chewing. (Table 1)

Distilled water dropper was used every 5000 cycles to dissipate the heat and remove any debris that could affect the test. The wear was measured by weight loss and roughness changes.

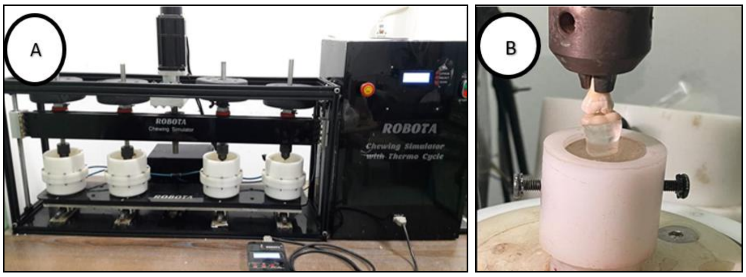

Fig 3: (A) The chewing simulator (ROBOTA) (B) the chewing simulator chamber with the enamel antagonist is in the upper compartment while the epoxy resin die in the lower compartment.

Table 1: Wear test parameters

Wear test parameters	
Vertical movement: 1 mm	Horizontal movement: 3 mm
Rising speed: 90 minis	Forward speed: 90 mm/s
Descending speed: 40 mm/s	Backward speed: 40 mm/s
Cycle frequency 1.6 Hz	Weight per sample: 5 kg
Torque: 2.4 Nm	

The substance deficit of the samples following chewing simulation was quantified by weighing the epoxy resin dies with bonded occlusal veneers and the enamel antagonists prior and subsequent to wear simulation in the electronic analytical balance "Sartorius, Biopharmaceutical and Laboratories, Ger"

Numerical estimation of two-body wear on occlusal veneers and their natural tooth opponents was done before and after the wear simulation test using a 3D surface analyzer system. Photographs of the tested samples were captured before and after the wear simulation test with a USB Digital microscope, the images were investigated by means of WSxM software "Ver 5 develop 4.1, Nanotec, Electronica, SL"

Results

Statistical analysis was accomplished with "SPSS 20, Graph Pad Prism, and Microsoft Excel 2016". All quantitative data were presented for normality by applying the Shapiro-Wilk Normality test and conducted as means and standard deviation (SD) values.

P value was used to indicate the significance level where P >0.05 is "non-significant" and P < 0.05 is "significant".

1. Wear evaluation by weight loss

Comparison between the weight loss of glass ceramic (Rosetta SM) group A and Polymer Infiltrated Ceramic (Vita Enamic) group B was done by applying independent t-test, which showed that the weight reduction before and after wear simulation test was significantly higher in Rosetta SM bonded occlusal veneers when compared with Vita Enamic bonded occlusal veneers with no difference regarding the opposing enamel antagonist. (Table 2)

Table 2: Mean and standard deviation of weight of bonded occlusal veneers and natural antagonists before and after wear simulation test in Rosetta SM group A and Vita Enamic group B and comparison between them:

	Material	**Rosetta SM (group A)**		**Vita Enamic (group B)**		**P value**
		M	**SD**	**M**	**SD**	
Before	Occlusal veneer	7.6454	1.1962	7.3322	0.9004	0.56
	Opposing	0.4679	0.1363	0.7211	0.2861	0.04*
After	Occlusal veneer	7.6119	1.1963	7.3288	0.9001	0.61
	Opposing	0.4649	0.1369	0.7166	0.2835	0.04*
Difference	Occlusal veneer	-0.0336	0.0001	-0.0034	-0.0003	<0.0001*
	Opposing	-0.0030	0.0006	-0.0045	-0.0026	0.13

M: mean SD: standard deviation

P: probability level, which is significant at $P \leq 0.05$

2. Wear evaluation by surface roughness changes

Comparison between Rosetta SM (group A) and Vita Enamic (group B) was carried out by applying independent t-test which revealed that the roughness of the natural antagonist opposing Vita Enamic occlusal veneer was significantly higher than the roughness of the natural antagonist opposing Rosetta SM occlusal veneer after wear simulation test($p<0.05$). (Table 3)

Table 3: Mean and standard deviation of surface roughness in occlusal veneers and natural antagonist before and after wear simulation test in Rosetta SM (group A) and Vita Enamic (group B) material groups and comparison between them

Material		Rosetta SM (group A)		Vita Enamic (group B)		P value
		M	SD	M	SD	
Before	Occlusal veneer	0.2911	0.0028	0.2922	0.0030	0.46
	Natural antagonist	0.2892	0.0025	0.2914	0.0033	0.15
After	Occlusal veneer	0.2898	0.0030	0.2915	0.0025	0.23
	Natural antagonist	0.2894	0.0031	0.2926	0.0018	0.02*
Difference	Occlusal veneer	-0.00132	0.000147	-0.00074	0.001	0.12
	Natural antagonist	0.000256	0.000556	0.001172	0.002	0.23

M: mean SD: standard deviation

P: probability level, which is significant at $P \leq 0.05$

Discussion

Ideally, the wear of dental restorative materials should be like enamel wear. However, the rate of dental wear might be affected by the use of restorations, which have wear features that are very different from the teeth enamel [6].

In our study, we used tabletops with 1.5 mm thickness which was supported by Andrade *et al.* [5] study which evaluated the impact of several ceramic materials "IPS e.max CAD, Vita Enamic, and Lava Ultimate" with different thicknesses (0.6 mm and 1.5mm) on the fracture resistance of occlusal veneers and concluded that the occlusal veneers of IPS e.max CAD, VitaEnamic, and Lava Ultimate, with thicknesses of 0.6 mm and 1.5 mm, obtained fracture resistance similar to those of intact teeth.

The conventional planar preparation was done to follow the occlusal anatomy with 1.5mm occlusal reduction at the cusp tip and 1mm reduction at the fossa to confirm the sufficient thickness of the occlusal veneers which comes in accordance with Halim *et al.* [8] who conducted a study to detect the fracture resistance and failure mode of "zirconia reinforced lithium silicate and hybrid ceramic" occlusal veneers with two preparation designs conventional planar preparation and modified design, and it was concluded that both designs offered fracture resistance mean values that exceeded the clinically accepted range with the two tested materials

To standardize the preparation in all the tested samples we executed the main preparation on a typodont lower right first molar tooth and duplicated the prepared typodont tooth using epoxy resin to get 16 epoxy resin dies as replicas of the prepared typodont tooth, which was confirmed by Nawafleh *et al*. [24] who confirmed that the use of (die) materials such as epoxy resin or acrylic resin are not difficult to standardize and fabricate, on the other hand, natural teeth are inconstant in size, shape, and condition, creating difficulty in standardizing tooth preparation.

In our study, we used occlusal veneers in different materials to test wear rather than a flat sample in accordance with Heintze *et al*. [10] who assessed the difference in wear resistance between flat samples and anatomical samples (crowns) in four different ceramic materials (Empress, e. max press, IPS Eris and Pro Cad) opposed with Empress stylus using Ivoclar wear method which disclosed significant differences among flat samples and crowns. The wear of all materials was significantly higher in the flat samples when compared with the crowns.

In our study we used sandblasting as the surface treatment of choice for the epoxy resin dies in accordance with Naguib *et al*. [22] who tested the fracture resistance of resin-bonded bridges that were cemented on epoxy resin dies and used sandblasting with aluminum oxide of 50 µm particle size for 5 seconds at 10 centimeters distance with the pressure of 2.5 bar as surface treatment for the epoxy resin dies.

The vital difficulty with the clinical wear tests is the variable key factors that may impact the wear sequence. Alternatively, the laboratory wear study permits accurate control of the setting and variables, which affect the wear activity of teeth and biomaterials [18].

A device that is utilized to examine the wear of dental materials must possess the following qualities: force and force impulses should be reproducible and adjustable in the range of 20–150 N, adjustments should not be essential for the testing of each material, lateral movement of the stylus should be included in the system to allow micro fatigue testing, constant water replacement would similarly be incorporated to eradicate chafed particles from the interface between stylus and material and finally all movements should be automatic and modifiable Heintze *et al.* [11] which have matched the characteristics of wear simulation machine that was used in our study (ROBOTA) (Model ACH-09075DC-T, AD-TECH Technology CO., LTD. Germany).

In our study we used a loading force of 49N for wear measurement in accordance with Turker and Kursoglu [27] who stated that loading force is crucial in laboratory wear studies, as in oral cavity, physiologic forces of mastication are ranging from 10N to 120 N with a loading force of 49 - 50 N is commonly used as the mean value of physiological forces of mastication.

Thermocycling was not conducted in our study settings to avoid the absorption of water by the epoxy resin dies, which may affect the weight.

In our study, natural enamel was the material of choice when used as a natural antagonist opposing the bonded occlusal veneers in accordance with Lambrechts *et al.* [17] who stated that natural enamel opponents are superior in the simulation of wear in the occlusal area.

We used sectioned upper first molar as the natural antagonist where the buccal cusps of the tested upper first molar come in contact with the tested occlusal veneers during wear simulation which was supported by Elhomiamy *et al.* [7] who stated that the enamel of tooth cusp thought to be considerably stronger than the proximal surface enamel, so using cusp samples created comparable oral environment.

The buccal half of the maxillary molar was used as the natural antagonist because the buccal cusps have preserved enamel compared to the palatal cusps of the upper molars with the latter being the functional cusps and thus having lesser enamel.

We used 37500 cycles and 49 N force to simulate 3 months of wear effect in accordance with Nawafleh *et al*. [24] who confirmed that the magnitude of loading force may strongly affect the mechanical behavior of the loaded object for example when applying 50 N load, a total of 750,000 cycles are required to mimic 5 clinical years, while 590,000 cycles were suitable when using a greater load of 100 N.

Many numerical analysis techniques of quantifying the laboratory wear performance of dental materials have been applied. Wear behavior assessment based on weight losses and surface roughness of material before and after loading was proposed, in agreement with Abo El Fadl *et al*. [1] who estimated the wear resistance of three ceramics "IPS e.max, Lava Ultimate, and Vita Enamic" using weight loss and surface roughness.

Both our study hypotheses were rejected as there was a difference in the wear behavior of both types of occlusal veneers after wear simulation and there was a difference in the wear behavior of enamel antagonists opposing both types of occlusal veneers after wear simulation.

Regarding the comparison between the glass ceramic (Rosetta SM) and polymer-infiltrated ceramic (Vita Enamic) occlusal veneers, it showed a statistically significant increase in weight loss in glass ceramic occlusal veneers (Rosetta SM) when compared with polymer-infiltrated ceramic occlusal veneers (Vita Enamic) after wear simulation.

These same findings have been stated by Abo El Fadl *et al*. **[1]** who opposed their samples of CAD/CAM ceramic materials "Lithium disilicate glass ceramic, resin nanoceramic, Polymer infiltrated ceramic" with freshly extracted upper premolar and exposed it to an upright load of 50N for 1. 2×105 cycles at a frequency of 1.6 hertz (lateral motion of 2 mm). Moreover, it was found that there were higher weight loss differences prior and subsequent to wear simulation between glass ceramics and hybrid ceramics, meanwhile, the glass-ceramics showed a higher amount of weight loss than polymer-infiltrated ceramics.

This may be due to the high friction coefficient of lithium disilicate additionally; the microstructure of lithium disilicate is not entirely free of porosities particularly if crystallization was not perfectly executed and Vita Enamic is a hybrid ceramic with elastic modulus and wear behavior similar to the opposing enamel **[1].**

However, our outcomes contradicted the results by Hamed *et al*. [9] who compared the percentage of weight changes in polymer-infiltrated ceramics and glass ceramics and established that there was a statistically significant higher weight loss in polymer-infiltrated ceramics when compared to glass ceramics after wear simulation. This may be due to the use of thermo-cycling in wear testing of Hamed *et al*. (2020) however, in our study, we used only water every 5000 cycles to dissipate the heat and remove debris. This conclusion was supported by Mandour *et al*. [20] who stated that during wear test associated with thermocycling, the silane hydrolyzes in water which caused low bonding at the crystal boundary favoring the release of polymer matrix

When comparing the difference in weight loss in the enamel antagonists opposing the glass ceramics (Rosetta SM) and polymer-infiltrated ceramic occlusal veneers (Vita Enamic) before and after wear simulation, no statistically significant difference has been noted.

This was supported by Ahmed *et al*. [2] who found no statistically significant difference in the percentage of weight change in the enamel surfaces opposing the polymer-infiltrated ceramic and glass ceramic samples, Hmaidouch *et al*. [12] conducted a systematic review and justified this by the fact that the wear process of the antagonistic enamel is more related to the roughness rather than the hardness of ceramic material, this conclusion supported the results of our study which showed no statistically significant difference regarding the roughness of both tested materials before and after wear simulation.

Regarding the difference in the roughness before and after wear simulation when comparing polymer-infiltrated ceramic occlusal veneers (Vita Enamic) and glass-ceramic occlusal veneers (Rosetta SM), there was a non-significant difference in the roughness before and after wear simulation, which goes hand in hand with Ahmed *et al*. [2] who concluded that there was no significant difference in the percentage of roughness change before and after wear simulation between glass ceramic and polymer infiltrated ceramic.

However, it contradicted the results of Hamed *et al*. [9] who found that difference in Roughness before and after chewing simulation was significant between glass ceramics and polymer-infiltrated ceramics with Vita Enamic being rougher which was justified by the fact that the wear test in this study was subjected to thermo-cycling and lithium disilicate glass-ceramic was rarely affected by thermo-cycling (Abdel-Aziz and Fouad, 2021) [4].

However, Vita Enamic is affected by thermo-cycling, as it is polymer-based material, which could affect its mechanical properties [7].

Regarding the difference in the surface roughness before and after wear simulation test in the enamel antagonists opposing glass ceramic (Rosetta SM) and polymer-infiltrated ceramic occlusal veneers (Vita Enamic), it was found that the difference is not statistically significant, which goes hand in hand with Ahmed *et al*. [2] who found a statistically insignificant difference in roughness difference before and after wear simulation in enamel antagonists opposing glass ceramics and hybrid ceramics.

Conclusion

Within the restrictions of this experiment, the subsequent conclusions could be illustrated:

1. Wear behavior of Vita Enamic occlusal veneers is better than Rosetta SM occlusal veneers.
2. Rosetta SM occlusal veneers have a better influence on the natural enamel antagonist when compared with Vita Enamic occlusal veneers.
3. Both materials could be used to restore occlusal surface tooth loss.
4. Both materials are enamel friendly.

Conflict of interest: Authors confirm the absence of contradiction of interest

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