Randomized controlled clinical trial of wear characteristics of Cad/Cam lithium silicate versus monolithic zirconia crowns

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ABSTRACT

Objectives This clinical study aims to compare the wear characteristics of lithium silicate to monolithic zirconia crowns after a year of cementation.

Methodology Twenty-eight patients were randomized to receive either monolithic zirconia crowns (STML zirconia) or CAD/CAM lithium silicate crowns (Obsidian) for first molars that were opposed by natural antagonistic teeth. Impressions of Vinyl polysiloxane were made after cementation and poured into type IV dental stone. Patients were recalled for re-impressions after one year, replica stone casts were made. The replicas were scanned and digitally superimposed (at baseline and after one year) to assess the wear of the crowns and their antagonist's enamel. All of the data was assembled, checked twice, revised, and entered into a computer. The data was statistically analyzed using an independent t-test.

Results Following a year of clinical use, the amount of enamel wear against monolithic zirconia crowns was mean ±SD (0.0655 ± 0.0116 mm), which was significantly higher than the amount of enamel wear against lithium silicate crowns mean ±SD (0.0457± 0.0099 mm), $p < 0.05$. Wear testing of STML zirconia crowns produced a result of mean ±SD (0.0203 ± 0.0049 mm), which was significantly less than the amount of wear of lithium silicate crowns mean ±SD (0.0310 ± 0.0031 mm) $p < 0.05$.

Conclusions Within the limitations of the current research, monolithic zirconia crowns exhibit more enamel wear than Lithium silicate crowns. Monolithic zirconia ceramic material, on the other hand, showed less wear than lithium silicate glass-ceramics.

Clinical significance The usage of lithium silicate crowns in the posterior region shows less opposing enamel attrition than monolithic zirconia crowns, making this study clinically significant.

INTRODUCTION

Recent advancements in dental ceramics have significantly improved their mechanical and physical properties, overcoming the weaknesses of all ceramic restorations, such as veneer ceramics chipping, fracture, cracking, delamination, and wear. A wide range of dental ceramics are available on the market, including monolithic zirconia, which attracts many dentists around the world due to its superior mechanical properties,(1-4) biocompatibility, and appropriate esthetics(5-8).Because of its high cubic composition, multi-layered zirconia offers good flexure strength and great translucency. It is intended to replicate the shade gradient present in natural teeth, making it an ideal choice for monolithic posterior restorations(9,10). Furthermore, the monolithic zirconia crown requires less tooth reduction in comparison to glass ceramics and ceramo-metallic crowns. It also has good physical properties, which help to maintain its surface smoothness and lustre during function in the oral cavity(11).

Glass ceramics are recognised for their excellent biocompatibility, strength, and esthetics, since they may mimic human tooth structure(12-14). Lithium silicate glass ceramic has recently entered the market. It has high translucency and strength after crystallisation, making it ideal for anterior and posterior crown fabrication(15-18).

Tooth wear is a complex phenomenon that is influenced by a variety of biological, chemical, and mechanical factors. The appearance of flat rounded facets on enamel and/or restorative material are clinical signs of tooth wear. Cusp height tends to decrease as wear progresses, occlusal inclined planes flatten, vertical dimension loss, increased tooth sensitivity, and unsatisfactory aesthetics occur(5, 19-21).

Because the ceramic restoration's wear properties can influence the antagonist enamel's rate of wear, the ceramic restoration's wear resistance must be comparable to or equal to enamel's (11, 21, 22). In addition to environmental factors, surface roughness, hardness, abrasiveness, and surface finishing (polished, glazed, or polished and glazed) of the ceramic material have been shown to influence the wear degree of an antagonistic tooth(5, 22-25).

The wear characteristics of a variety of restorative materials, including glass ceramic, porcelain, zirconia, hybrid ceramics, and composite, have been the subject of several research studies. Baldi et al (26) discovered that compared to polymer-infiltrated network ceramics used as occlusal veneers, cubic zirconia and lithium disilicate glass ceramics have higher wear rates of opposing enamel.

According to research by Jang et al,(27) when compared to zirconia and composite resin, enamel loss with porcelain was the most pronounced, with microhybrid composite coming in second, although the direct microhybrid composite and the zirconia surfaces did not show obvious wear, the surface of the nanocomposite was severely damaged , and zirconia's surface polishing can reduce this wear even more.While, Esquivel-Upshaw et al (28) reported that monolithic zirconia demonstrated equal antagonist enamel wear to metal-ceramic crowns and control enamel after one year of clinical use, Deval et al, (29) found that monolithic zirconia significantly reduces enamel wear on the opposing tooth as compared to feldspathic porcelain in an in-vivo study. Lawson et al (22) found that, to make zirconia and lithium disilicate wear compatible with enamel, they advise polishing them after adjustment.

Despite the popularity of all-ceramic restorations and growing patient concern about aesthetics, only a few in-vivo studies on the rate of enamel wear antagonist to monolithic zirconia ceramic and lithium silicate ceramic crowns have been published. The goal of this study was to see how much natural enamel wear antagonists monolithic zirconia, and lithium-silicate crowns were present after a year of clinical use. Crowns made of lithium-silicate and monolithic zirconia were also evaluated for wear. In this study, the hypothesis was proposed that there would be no differences in lithium-silicate crown wear when compared to monolithic zirconia crowns and their antagonist enamel after one year of follow-up.

MATERIALS AND METHODS

The proposed study was a randomised clinical trial that was approved by Cairo University's Faculty of Dentistry's Scientific Research Ethics Committee (approval no: 18933). This trial was carried out in compliance with the Helsinki Declaration's principles and the CONSORT (Consolidated Standards of Reporting Trials) guidelines. The registration number for this study is NCT03530020 on https://clinicaltrials.gov/. The sample size was 22 patients, obtained according to data from a previously published study(20), but this number was expanded to 28 to account for potential losses during follow-up (25% more than calculated). Using a power analysis with 80% power and a significance level of 5%, G*Power Version 3.1.9.2 (Vanderbilt University, Nashville, Tennessee, USA) to calculate the sample size. Twenty-eight female patients were recruited at the out-patient clinic of Cairo University's Faculty of Dentistry's Department of Fixed Prosthodontics. A complete medical and dental history was provided by each participant. Following a clinical examination, each patient's treatment plan was explained, and all participants signed an informed consent form.

All participants met the following criteria for inclusion

1. Female patients must be 21 to 45 years old and able to read and sign the informed consent agreement. (Because gender can affect the wear of ceramic crowns and their antagonist enamel, all of the participants in this study were females.)(30) ;
2. Have good oral hygiene, no active periodontal or pulpal diseases, and teeth that have been well restored; (
3. A full-coverage restoration is indicated for the endodontically treated mandibular or maxillary first molar tooth/teeth (Molars are thought to wear more than premolars due to higher occlusal forces, related to the occlusion area, mastication forces, and the number of contacts in the molar region being greater than those in the premolar region.(2, 20);
4. Patients who have had unrestored or partially restored natural tooth on the opposing side. Patients who bruxed or showed evidence of severe attrition were eliminated from the trial, as were pregnant or lactating female patients, patients with parafunctional habits, patients with temporomandibular joint dysfunction, and patients with low oral hygiene compliance.

Randomization was carried out at Cairo University's centre for evidence-based dentistry using computer software (www.randomizer.org). A 1:1 allocation ratio was used to divide the participants into two groups. The allocation sequence was concealed from the researchers as they enrolled and evaluated individuals in sequentially numbered, sealed, opaque, and stapled envelopes. This was a double-blinded RCT in which the outcome assessors, participants, and statistician were all blind to the crown material, but the operator (the researcher) was not due to differences in restorative materials demonstration and application protocol.

Each patient was examined thoroughly clinically and radiographically, and a full-coverage single restoration was planned for them. A total of 28 patients were rondamized into two main groups (N=14/each) based on the material used for crown fabrication, Table 1.

Group I (STML zirconia): Comparator group; included patients receiving full coverage supertranslucent multilayered monolithic zirconia (KATANA STML, Noritake Kurary,-Germany) crowns.

Group II (Obsidian): Intervention group: included patients receiving full coverage CAD/CAM lithium silicate glass ceramics (Obsidian, Glidewell Dental Laboratories, Newport

Material	Composition and Description	Properties	Manufacturer
STML zirconia Super-translucent multilayer Monolithic zirconia KATANA	• ZrO2 + HfO2 88–93% • Yttrium oxide (Y2O3) 7-10% • Other oxides 0–2%	• Flexure strength 748 MPa • Coefficient of thermal expansion (25–500 °C) 9.8 ± 0.2 10-6K-1 • Translucency 38%	Noritake Kurary (Germany)
Obsidian Lithium silicate glass ceramic	• Crystalline lithium silicate and lithium phosphate • silicon dioxide • aluminum dioxide • potassium oxide • lithium oxide • 7.6% germanium dioxide • (4–6 wt.% ZrO2)	• Flexural Strength (Biaxial) 385 +/- 45 Mpa • Coefficient of Thermal Expansion (CTE) (298-773K) 12.2 x 10ˆ-6/K • fracture toughness: 2.56MPa m½ • Modulus of Elasticity: 76.46 GPa • Weibull Characteristic Strength 404 Mpa.	Glidewell Dental Laboratories, Newport Beach, USA)

TABLE 1 Composition, Properties and Manufacturer of the ceramic materials used in the present study

Beach, USA) crowns.

A single operator used a standardised diamond stone to prepare all of the teeth (Intensiv; Intensiv SA, Montagonola, Switzerland). The abutment teeth were prepared for STML zirconia or Obsidian crowns based on the randomization list. The tooth preparation for a zirconia crown included an occlusal and axial 1.0 mm tooth reduction with a deep chamfer margin(7). For the obsidian crown, an axial tooth reduction of >= 1.5mm, an occlusal reduction of 1.5-2mm, and a deep chamfer margin design of 1mm broad were used. After completing the preparation, the final impression was taken using a two-step impression method using vinylpolysiloxane addition silicon (Elite HD + Zhermack, Italy). Provisional crowns were placed on all prepared teeth after preparation and impression. The master casts were poured with a type IV dental stone after the dental laboratory received the final impression, as per the manufacturer's instructions. CAD/CAM technology was used to fabricate the full-coverage restorations. The master casts were skilfully scanned (DOF FREEDOM UH, DOF, Seoul, Republic of Korea). Exocad software was used to design the desired crowns. (DOF FREEDOM UH, DOF, Seoul, Republic of Korea) All crowns were milled using a 5-axis milling machine (CORiTEC 350i Loader pro, imes-icore® GmbH, Germany). Zirconia crowns were milled from super-translucent multilayered zirconia katana blanks (Kuraray Noritake, Germany) and sintered in a sintering furnace (Infire HTC, Dentsply sirona, Germany) following manufacturer specifications. While lithium silicate crowns were milled from Obsidian blocks (Glidewell Dental Laboratories, Newport Beach, USA) and fired in a ceramic furnace (Programat EP 3010, Ivoclar Vivadent, Liechtenstein) according to the manufacturer's instructions. Finishing and polishing of monolithic crowns in the two groups were performed using a Panther polisher kit (Valcalon, Germany) according to the manufacturer's instructions, first by medium grain, then by the extra-fine grain one. Final stain was applied to the monolithic crowns when desired, the crowns were all glazed according to the manufacturer recommendations. Before cementation, marginal fit, occlusal anatomy, contact with adjacent teeth, and the shade matching of the fabricated monolithic crowns were checked intra-orally. For confirmation, a periapical radiograph was taken. The monolithic zirconia crowns' fitting surfaces were abraded with airborne particle abrasion with 110 m aluminium oxide for 15 seconds at 2 bar pressure, then cleaned in an ultrasonic bath with isopropyl alcohol for 3 minutes(31). While the internal surface of the obsidian crown was etched for 10 seconds with 9.5% buffered hydrofluoric acid (UltradentTM Porcelain Etch, USA) according to the manufacturer's instructions. Using a three-way syringe, the crown was rinsed for 20 seconds and then air dried. The crown surfaces appeared to be clean and frosty, resembling etched enamel. The silane coupling agent (UltradentTM Silane, USA) was applied with a micro brush and allowed to react for 60 sec., then the excess was dispersed with air to ensure the solvent's evaporation. Prior to bonding, the tooth surfaces were cleaned with pumice paste and a polishing brush mounted at a low-speed contra angle to eliminate traces of temporary cement that could negatively affect the luting agent's bond strength to ceramic. Isolation was then granted, for each prepared tooth surface, a single application of single bond universal adhesive (3M ESPE, Germany) was applied and rubbed on for 20 seconds before air drying the adhesive for roughly 5 seconds and light curing it for 10 seconds. The crowns were cemented with a self-etch adhesive system (rely X ultimate resin cement) (3M ESPE, Germany). If occlusal adjustment was needed after cementation, each crown was adjusted with a fine diamond bur on a high-speed handpiece (8368SU. FG.016 Fine Football Diamond, Komet, USA) with water coolant.

Zirconia crowns were polished with the EVE Diacera kit (EVE Diacera, EVA Ernst Vetter GmbH, Pforzheim, Ger-

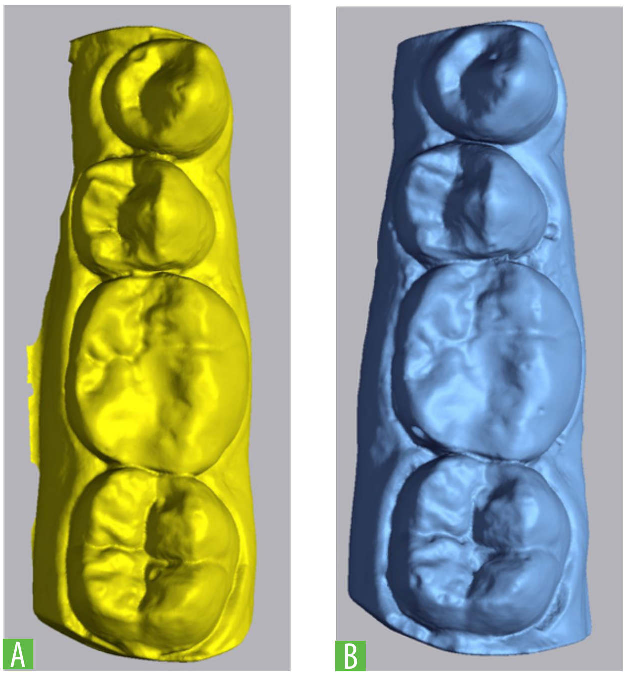


FIG. 1 A 3D model A: Reference: at baseline B: Measured: After one year

many), while Obsidian crowns were polished using the EVE Diapro kit (EVE Diapro, EVA Ernst Vetter GmbH, Pforzheim, Germany). Polishing was done, as recommended by the manufacturer and as described in a previous study conducted by Caglar et al.(32) (2018).

Assessment of wear of the tested ceramic crowns and antagonist enamel

Replica technique: A baseline check was performed one week following cementation to ensure that the patient was satisfied with the crown and that no further adjustments were necessary.(28, 30) Plaque and saliva were removed from the teeth and crowns when no additional occlusal adjustments were required. A vinylpolysiloxane impression (Elite HD+, Zhermack, Italy) of the mandibular and maxillary quadrants, where the crown and opposing tooth are placed, was obtained to record the occlusal surfaces of each crown and its opposing tooth(20, 28, 30). Participants were asked to return after one year to have their quadrant impressions retaken. Replica casts were poured with a type IV dental stone (GC FUJIROCK EP, GC, America) according to the manufacturer's instructions,(33) The casts were then labelled "reference cast" (baseline at 0 months) and "follow up cast" (12 months). To locate occlusal contact areas and serve as occlusal matching references, photographs of the quadrants were taken with articulating paper to mark the occlusal contacts, (Double check blue- red articulating paper, Sweden) (19, 28). A 3D white light scanner(DOF-EDGE, DOF, Seoul, Republic of Korea) with an accuracy up to 7 μm was used to scan the replica casts at baseline and 1 year follow-up.

Exocad software was used to provide a 3D image of the scanned cast and transforme it into (.stl) format. The reference and measured models (.stl) files were imported to the Geomagic Control x 2017.0.2 software. The initial fit alignment feature was chosen to align the two models with a feature recognised choice to improve fit result quality. After the alignment process, the result quality can be enhanced by the best fit feature with 100% sampling ration and 50 iterations to ensure that the result is very accurate with 0.0043 mm maximum deviation. Planes pass through the measuring points were created according to intra-oral photographs which represent the occlusal contacts (Fig. 1). Each plane was individually selected to take the results reading (vertical loss) at specific points by

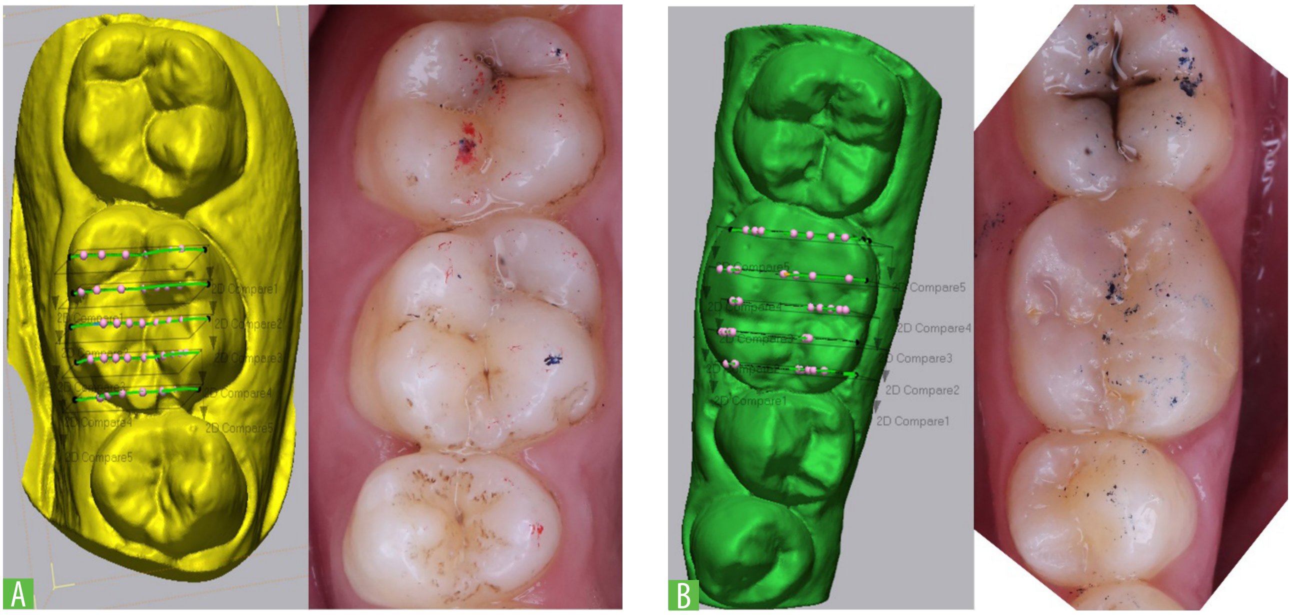
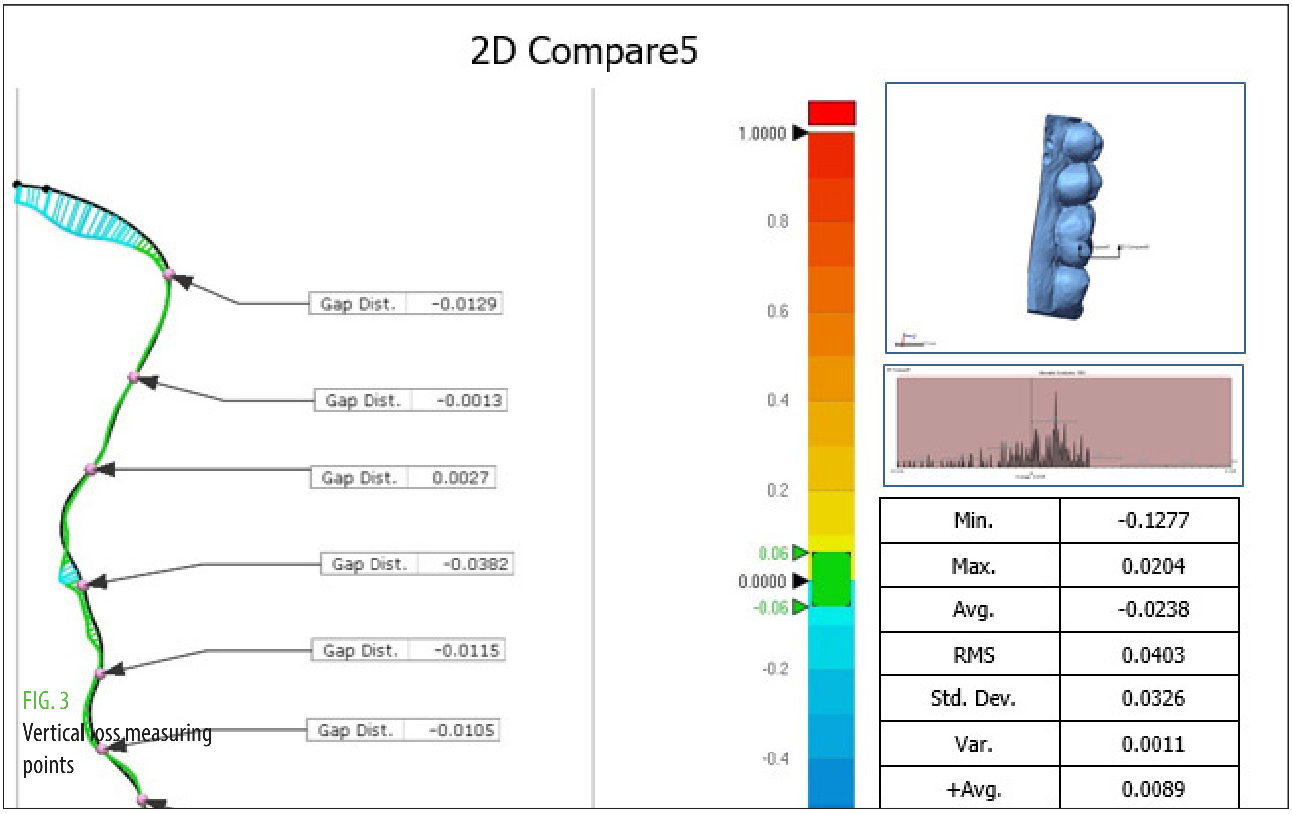


FIG. 2 Correlation between occlusal contact intraorally and wear measuring points. A: opposing tooth. B: crown



Min.	-0.1277
Max.	0.0204
Avg.	-0.0238
RMS	0.0403
Std. Dev.	0.0326
Var.	0.0011
+Avg.	0.0089

FIG. 3
Vertical loss measuring points

2D compare feature (Fig. 2). The max. value on the color bar is 1mm (Red color), and the minimum value is -1mm (Blue color) with ± 0.6mm tolerance(34). The mean average of vertical loss for the crown and its antagonist enamel was recorded for every patient. The degree of wear of enamel and ceramic crowns was described in terms of average vertical loss of the occlusal contact regions of teeth and crowns to determine the amount of wear.

Statistical analysis

The results were obtained from only 22 participants due to six dropouts. Four patients did not attend the follow-up visit, and two patients had unmatchable casts. The mean and standard deviation were used to express the wear (height loss) data. Statistical analysis was carried out using Graph Pad Prism® 1 and Microsoft Excel 2016. The Shapiro-Wilk Normality test was used to examine all data for normality, and the results were presented as means and standard deviations (SD). The independent t-test was used to compare the two groups (quantitative data).

RESULTS

The wear testing of antagonist enamel to STML zirconia crowns and Obsidian crowns after 1 year

Results showed that the enamel wear antagonist STML zirconia in group I was mean ± SD (0.065mm ± 0.011 mm), while the enamel wear antagonist Obsidian crowns in group II was mean ± SD (0.045mm ± 0.0099 mm).
Comparison between them was accomplished by using an independent t-test, which revealed that the amount of enamel wear antagonist to STML zirconia ceramics in group I was significantly higher than the amount of enamel wear antagonist to Obsidian ceramics in group II at $P< 0.05$, as presented in (Table 2) and (Fig. 3).

Results of the wear testing of STML zirconia crowns and Obsidian crowns after 1 year

The amount of wear of STML zirconia crowns in group I was mean ± SD (0.02 mm ± 0.004), while the amount of wear of Obsidian crowns in group II was mean ± SD (0.03mm ± 0.003). Comparison between them was accomplished by using an independent t-test which revealed that group II was significantly higher than group I at $P< 0.05$ as described in (Table 3) and (Fig. 4).

DISCUSSION

Wear is a complex, progressive phenomena. As a result, understanding the wear potential of materials based on composition and microstructure features that govern their physical and mechanical properties is crucial (35, 36). The wear characteristics of the two tested crowns and their

Antagonist enamel			
Groups	Mean (mm)	SD	P value
Group I: STML crowns	0.0655	0.0116	0.0001*
Group II: Obsidian crowns	0.0457	0.0099	

Significant differences between groups(p<0.05)

TABLE 2 Results of the wear testing of antagonist enamel to STML zirconia crowns and Obsidian crowns after 1 year

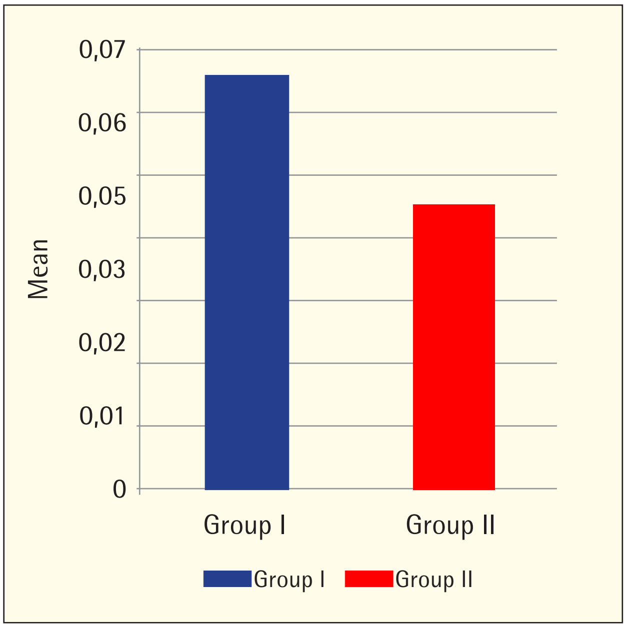


FIG. 4 Histogram display results of the wear testing of antagonist enamel to STML zirconia crowns (group I) and Obsidian crowns (group II) after 1 year

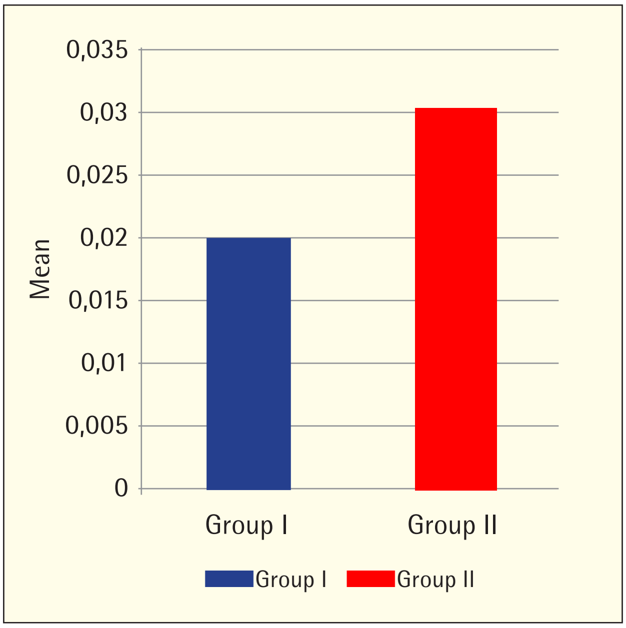


FIG. 5 Histogram display the results of the wear testing of STML zirconia (group I) and Obsidian crowns (group II) after 1 year

antagonist enamel were quantified by superimposing the 3D scanning images of the replica casts at different time periods, and the average vertical loss was calculated.

This method is regarded as a highly precise, quantitative way for measuring wear. It may give storable 3D datasets that can be compared to any other 3D database and is useful to both the clinic and the laboratory (19, 20, 28).

	Crowns		
	Mean (mm)	SD	P value
Group I: STML zirconia crowns	0.0203	0.0049	0.0001*
Group II: Obsidian crowns	0.0310	0.0031	

**Significant differences between groups(p<0.05)*

TABLE 3 Results of the wear testing of STML zirconia crowns (group I) and Obsidian crowns (group II) after 1 year

Regarding the results of the wear testing of STML zirconia crowns, Obsidian crowns and their antagonist enamel, the hypothesis was rejected. The significant differences in enamel wear between the two groups could be attributed to monolithic zirconia's higher hardness (1200–1300 VH), which may cause more enamel wear than Obsidian(632–760 VH), both of which are harder than enamel (268–375 VH) (12, 35, 37, 38). Another explanation for the results could be related to the modulus of elasticity and strength of the ceramic materials, as the modulus of elasticity and strength of the zirconia ceramic are (210 GPa) and (748 Mpa) respectively, whereas the modulus of elasticity and strength of the lithium- Obsidian crowns are (67–95 GPa) and (385 +/- 45 Mpa) respectively(35, 39).

The considerable differences between the two ceramic materials may explain why enamel opposing STML zirconia wears so much more than enamel opposing Obsidian. In this case, the considerable mismatch between the hardness, elastic modulus, and strength of the ceramic materials and enamel placed the enamel under high stress concentration during function, causing stress abrasion and wear.

Furthermore, when compared to STML zirconia crowns, Obsidian crowns have a high amount of ultrafine nanometer-sized crystalline structures and a modulus of elasticity (67-95 GPa) that is close to that of enamel, which are thought to be the causes of less enamel wear.The high hardness of STML zirconia, combined with its high flexure strength and elastic modulus, may explain why STML zirconia crown surfaces wear less than Obsidian crown surfaces after one year of wear. Zirconia can resist surface damage and wear under stress while also maintaining surface smoothness and lustre(11, 35) .

Also, the wear potential of ceramic materials may also be influenced by the composition of the ceramic materials(34, 40). Because zirconia has a polycrystalline structure (88-93 percent ZrO2 + HfO2) and no glass matrix, it is extremely resistant to wear during use. Obsidian crowns, on the other hand, are composed of a soft glass matrix that rapidly wears away during mastication, exposing the crystals. Material debris between both the rubbing surfaces may enhance the wear rate of both the glass ceramics and the enamel, this could explain why Obsidian wears out faster than STML zirconia ceramic (35).

This result is consistent with previous researchs conducted by Mörmann et al.(41) (2013); Ludovichetti et al. (35)

(2018), who discovered a substantial association between the physical qualities of ceramic materials such as hardness, modulus of elasticity, and flexure strength of the ceramic materials and the wear of opposing enamel.

According to them, the lower the hardness, the less enamel wear. In contrast, Çakmak et al.(42) (2021) found no correlation between the hardness of the ceramic materials and enamel wear, and linked the enamel wear to the composition of the materials.

Regarding the results of the wear testing of STML zirconia and Obsidian crowns and their antagonist enamel, our findings agree with those of a study conducted by Esquivel- Upshaw et al.(28) (2018), who found insignificant differences between the wear of the two tested groups (monolithic zirconia crowns and metal ceramic crowns) P>0.05.

After one year, the amount of wear reported for the zirconia crown was (46.1 μm) while for antagonist enamel was (70.3 μm). Tang et al. (43) (2021), who also tested the wear of polished monolithic zirconia crowns on antagonist enamel, they found that the mean vertical loss of antagonist enamel was (81.7± 25.49 μm), whereas it was (27.2 ± 7.63 μm) for the crown itself. In contrast, the results of our study, Pathan et al.(19) (2019), recorded much lower values than the present study for enamel wear opposing to monolithic zirconia crowns, which were (15.50 μm and 16 μm) after 6 months and one year of function, respectively, despite the same measuring method.

In addition to Nazirkar et al.(44) (2020), they discovered statistically negligible variations in the quantity of enamel wear opposing polished zirconia crowns (42± 6.66 μm) and the amount of enamel wear against LDS ones (40 ±7.03 μm) (p>0.05). Aladağ et al. (34) (2019), stated that zirconia reinforced lithium silicate crowns (VITA SUPRINITY) are to a lesser extent self-worn than the antagonist enamel. The wear values of monolithic zirconia crowns against enamel vary greatly between studies.

There were several limitations to the study, including a small number of participants and a short follow-up time, both of which could have influenced the final results.

CONCLUSION

The following conclusions were withdrawn within the current study's limitations:

- STML zirconia crowns showed more wear to the antagonist enamel than Obsidian crowns after a one-year follow-up period.
- STML zirconia crowns themselves produced less wear than Obsidian crowns after a one-year follow-up period.

Clinical significance

Due to its superior strength, aesthetic features, and lower enamel wear when compared to monolithic zirconia, lithium silicate glass ceramic material has the potential to be a versatile restorative material in normal clinical situations.

Recommendations

1. For analysing the wear properties of STML zirconia and Obsidian, larger sample sizes and longer follow-up periods are advised.
2. More clinical studies on the wear behaviour of the tested materials with various surface finishing protocols are recommended.
3. More clinical studies with direct wear quantitative measures using 3D intraoral scanners and digital software are recommended to assess the wear behaviour of the tested materials.

Author contribution

R. Salem contributed to the study's conception and design, as well as conducting a baseline examination on the participants, methodology, investigations, data collection, and manuscript writing.

GA El Naggar contributed to the study's conception and design, supervision, visualisation and evaluation of the results, study administration, and writing (review and editing).

MA Taymour contributed to assessing the results, data collection, supervision, study administration, and writing (review and editing).

Informed consent

Before the trial began, the participants were asked to read and sign a written consent form in their native language.

Conflict of interests

There were no potential conflicts of interest among the authors.

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