Wear Behavior of Monolithic Zirconia against Natural Teeth in Comparison to Two Glass Ceramics with two Surface Finishing Protocols: An In-Vitro Study

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**Abstract:**

 **Objective:** To study in-vitro wear behavior of monolithic zirconia against natural teeth in comparison to lithium di-silicate ceramic and nano-fluorapatite glass ceramic, with two finishing procedures; polishing and glazing. **Materials and Methods:** Forty two ceramic disc specimens (10mm x3mm) and forty two natural tooth antagonists were used. Samples were divided according to ceramic materials into 3 groups (n=14). Group I: nano-fluorapatite glass ceramic (IPS e.max Ceram), Group II: lithium di-silicate (IPS e.max CAD) and group III: monolithic zirconia (ZirkoZahn Prettau). Each group was further subdivided into two subgroups (n=7), according to the surface finish: polishing and glazing. Specimens were subjected to a custom designed two-body wear simulator. Quantitative wear assessment was carried out using weight loss measurements. Scanning electron microscope was used for characterization of wear patterns. Kruscal Wallis and Dunn’s tests were used to compare between weight loss of the three ceramic materials. Whitney U test was used to compare between the two surface finish protocols. Wilcoxon Signed rank test was used to compare between ceramic specimens and antagonist teeth (P ≤ 0.05). **Results:** After wear**,** lithium di-silicate and nano-fluorapatite showed significantly highest weight loss values while monolithic zirconia showed significantly the lowest one. For teeth antagonists, there was no significant difference between the weight loss values with the three materials. Polished and glazed specimens showed no significant difference in weight loss values. SEM images revealed that for polished and glazed specimens as well as their tooth antagonists, the wear pattern of Prettau Zirconia was not as deep as IPS e.max Ceram and IPS e.max CAD surfaces. **Conclusion:** Zirconia is more wear resistant than lithium di-silicate and nano-fluorapatite glass ceramics. The ceramic microstructure and the surface finishing protocols had no impact on the wear behavior of the antagonist teeth.

**Keywords:** Glass-ceramics, monolithic, two-body wear simulation, wear, Zirconia.

**Introduction**

The increased demand for esthetics in dentistry has led researchers to create ceramic restorations to exactly mimic the appearance of natural teeth and eliminate the need for metal substructures [1].Ever since the discovery of the unique transformation toughening capabilities and resistance to crack propagation of zirconia, it has become one of the main focuses for research. Its mechanical properties are basically the highest reported ever for dental ceramics, that is why its clinical use has increased [2, 3]. Zirconia is an opaque material and must be veneered with a more esthetic glass ceramic. Unfortunately, such restorations showed some problems such as crazing, cracking and de-bonding of the veneered layer while the zirconia core remained intact [4]. Such problems have hindered the application of zirconia in many clinical situations and the contraindications for their use remained the same as those of conventional and alumina based ceramics [4]. Also, we cannot neglect the concerns about the effect of ceramic materials as they cause accelerated wear of opposing enamel, and this is a major contraindication to their broader use [1].

To overcome many of these shortcomings of veneered zirconia based restorations, the introduction of full contoured zirconia restorations is advertised now in the dental market. They are stated to have an improved appearance which omits the need for a porcelain veneer with all its drawbacks [2]. Although zirconia has a fine microstructure, previous studies [5-11] reported diverse results regarding its abrasion properties, wear of opposing natural dentition, longevity of full contour restorations, and the low temperature degradation phenomenon.

Tooth wear is a general term describing the surface loss of dental hard tissues from causes other than developmental ones, dental caries and trauma. The wear of teeth is irreversible and cumulative with age. The problems associated with wear are likely to place greater demands upon dental professionals [12]. Tooth wear has definitive effects on patients’ satisfaction with different aspects of their dentition, such as appearance, pain, oral comfort, general performance and eating capacity; thus, affecting the quality of life for patients. Therefore, there is a need for highly qualified dental restorative materials to repair or replace teeth [13]. With the continuous development in dental industry, wear resistance of newer esthetic restorative materials has generally improved, and the damage to the opposing dentition has been reduced [13]. However, the different structures and physical properties of teeth and restorative materials will eventually lead to varying degrees of differential wear [14]. Therefore, the selection of restorative materials must be based on knowledge of their wear behavior and individual needs of each patient [15].

There are two different methods to analyze the wear of dental restorative materials: clinical-in vivo studies and laboratorial-in vitro studies [14]. Clinical and epidemiological studies, however are difficult to interpret and to compare due to differences in terminology and the large number of indices that have been developed for diagnosing, grading and monitoring dental hard tissue loss [15]. Also, there is lack of control over the oral environment [16]. The time necessary for acquiring results is quite extensive requiring minimum of 2 years [14-16]. Moreover, ethical enquiries about testing materials without full knowledge of their effect on human beings is illegitimate [15, 16]. Artificial mouths or masticatory simulators have been developed instead to simulate intraoral wear [15]. Although it is not possible to mimic exactly the oral environment, these accelerated laboratory evaluation methods can produce a reasonably accurate ranking of clinical wear occurring among various materials under specific test parameters [15].The literature survey [17] pointed out that, several two-body wear simulators were designed and used with varying degrees of success to imitate clinical wear. In addition, a number of three-body wear simulators have been developed to simulate masticatory abrasion, which include abrasive slurry that acts simultaneously with the surface in contact [17].

Tooth surface change is a complex process that can be measured in a variety of ways [18]. No single technique provides a comprehensive assessment of the remaining tooth surface, and each technique has its own limitations [18]. However, each technique used gives slight information related to how the surface may change in the immediate future [18]. Parameters for quantifying wear are depth or vertical loss, area and volume loss [19]. The preferred parameter for quantifying wear is volume as it is independent from occlusal factors and is a measure of work done [19]. If material and environmental factors remain constant, volume loss is linear with time [19]. Weight loss percent can also be used to quantify the amount of wear [14, 20].

Several types of materials are currently available in dentistry for teeth restoration and replacement. Hence, understanding their wear mechanisms is very essential. However, the different structures, physical properties of teeth and restorative materials, and finishing procedures will eventually lead to varying degrees of differential wear [13, 21]. Several previous studies [2, 22-24] provided us with useful data regarding the wear resistance properties and the effect of different ceramics and zirconia-based ceramics on opposing antagonists.Different scenarios of finishing procedure are available: grinding, polishing and glazing to create ceramic restorations with smooth surfaces. The effect of the surface finish on wear performance of the ceramic material and tooth antagonist has been widely published [6, 8, 25, 26] with controversy in their results. This debate is strongly dependent on the method chosen, procedure efficacy and material's microstructure [25-27].

Therefore, the aim of the present research was to study in-vitro the wear behavior of monolithic zirconia against natural teeth in comparison to the behavior of lithium di-silicate based ceramic and nano-fluorapatite veneering glass ceramic with two different finishing procedures: polishing and glazing. The first null hypothesis was that there would be no difference in the wear behavior of the three ceramic systems against natural teeth. The second null hypothesis was that different finishing procedures (polishing and glazing) would have no influence on the wear behavior of the three ceramic systems against natural teeth.

**Materials and Methods:**

Materials used in this study are described in table I. Forty-two ceramic disc specimens were constructed with dimensions of 10mm diameter x 3mm height. The disc specimens were divided according to the ceramic materials into three equal groups (n=14). Group I: Nano-Fluorapatite glass-ceramics IPS e.max Ceram (Ivoclar Vivadent, Schann, Lichtenstein, Germany), group II: Lithium di-silicate IPS e.max CAD (Ivoclar Vivadent, Schann, Lichtenstein, Germany), and group III: Zirconia ZirkonZahan Prettau (ZirkonZahn, Streger, Ahrntal, Italy). Each group was further subdivided into two equal subgroups according to the surface finish protocol; polishing and glazing (n=7).

**Table I: Ceramic materials used in this study.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Ceramic materials** | **Construction technique** | **Manufacturer** | **Lot #** |
| **Nano-flourapatite****e.max Ceram** | Conventional build-up technique | Ivoclar ,Vivadent , SchaanLiechtenstein | **R81614** |
| **Lithium di-silicate****e.max CAD** | CAD/CAM | Ivoclar, Vivadent, Schaan Liechtenstein | **R80027** |
| **Translucent zirconia****ZirkonZahn Prettau** | CAD/CAM | Zirkonzahn, Steger, Ahrntal, Italy. | **ZRAD8021** |

A total of 42 caries-free human maxillary central incisors which were extracted due to periodontal disease were used for this research. After disinfection, the samples were stored in a saline solution. For fixation during two-body wear simulation, each tooth was individually mounted in epoxy resin blocks (KemaPoxy 150, CMB International. ARE).

**Metal disc and Teflon mold construction**

In order to standardize the shape and the dimensions of IPS e.max Ceram using conventional build up technique, a specially designed mold was constructed. An outer metal ring was designed to support an inner Teflon mold with the desired dimension of 10mm diameter and 3mm height. The Teflon mold was split to allow easy removal of the discs after the build-up process [28]. While, for IPS e.max CAD and ZirkonZahn Prettau using CAD/CAM technology, a specially designed metal disc was constructed with the desired dimensions 10mm diameter x 3mm height [29].

**Construction of IPS e.max Ceram disc specimens**

The e.max Ceram nano-flourapatite powder (Ivoclar Vivadent, Shaan, Liechtenstein, Germany) was mixed with the build-up liquid (Ivoclar Vivadent, Shaan, Liechtenstein, Germany) according to the manufacturer’s instructions. The slurry mix was packed and condensed into the mold and blotted with a dry tissue to remove excess liquid. Ceramic disc specimens were fired in the ceramic furnace, Ivoclar Vivadent Programat EP 3010 (Ivoclar Vivadent, Shaan, Liechtenstein, Germany) following the manufacturer’s instructions. For glazed subgroup specimens,IPS e.max Ceram glaze powder (Ivoclar Vivadent, Shaan, Liechtenstein, Germany) was mixed with e.max Ceram glaze and stain liquid (Ivoclar Vivadent, Shaan, Liechtenstein, Germany), applied on the disc surfaces and fired according to the manufacturer’s instructions. For polished subgroup specimens,polishing was done using the SHOFU porcelain adjustment kit (SHOFU INC. 11 Kamitakamatsu, Fukuine, Higashiyama-ku, Kyoto 605-0983 Japan) following the manufacturer’s instructions. The kit has three Dura-White Stones for adjusting, three Ceramiste Standard Polishers for pre-polishing, and three Ultra (yellow-band) Polishers for polishing and three Ultra II (white-band) Polishers for super- polishing. Polishing of the samples was done in a sequential order followed by a diamond polishing paste (ADS, American Dental Supply, INC, USA) for a smooth finish.

**Construction of e. max CAD disc specimens:**

Metal disc was scanned by CEREC AC system camera (Blue Cam) (Sirona Dental GMBH, Bensheim, Germany) and a three dimensional virtual disc was designed using CEREC 3D software. E. max disc specimens were milled using the InLabR MC XL milling unit (Sirona Dental Systems GMBH, Bensheim, Germany). For glazed subgroup specimens**;** IPS e.max CAD Crystal/ Glaze paste (Ivoclar Vivadent, Shaan, Liechtenstein, Germany) was applied over the disc surfaces and fired according to manufacturer’s instructions using Ivoclar Vivadent Programat 3000 ceramic furnace (Ivoclar Vivadent, Shaan, Liechtenstein, Germany). For polished subgroup specimens(n=7)**,** discs were cleaned and sintered in ceramic furnace following the manufacturer instructions. Polishing was carried out following the manufacturer’s instructions by using the same porcelain adjustment kit and diamond polishing paste as previously described for polishing IPS e.max Ceram.

**Construction of zirconia disc specimens:**

The Metal disc was scanned by fully automated optical scanner S60 (ZirkonZahn, Steger, Ahrntal, Italy) (fig. 25). Virtual disc was designed by using a special software (ZirkonZahn Modellier) (ZirkonZahn, Steger, Ahrntal, Italy). Zirconia discs were milled by using 5-axesmilling unit M5 (ZirkonZahn, Steger, Ahrntal, Italy). Coloring and sintering of zirconia discs were carried out in the sintering furnace, Zirkonofen 600 (ZirkonZahn, Steger, Ahrntal, Italy) following the manufacture’s recommendations. For glazed subgroup specimens**,** Glaze Plus (ZirkonZahn, Steger, Ahrntal, Italy) was applied over the disc surfaces and fired at 780-800o C following the manufacturer’s recommendations. While for polished subgroup**,** polishing was done manually with lab hand-piece using silicon polishers according to the manufacturers’ instructions.

**Thermo-cycling:**

 All ceramic disc specimens were subjected to thermo-cycling (Julabo, Germany) in distilled water for 3500 cycles at changing temperatures between 5oC and 55oC, with the duration of 2 minutes for each cycle [30]. Thermo-cycling was done to simulate intra-oral conditions.

**Wear testing**
**Wear testing machine:**

A specially constructed two-body wear simulator was particularly designed to perform this research (figs. 1, 2). The custom designed two-body wear simulator simulates horizontal movements that occur naturally in oral cavity. The machine was deployed inside a 250mm x 400mm x 600mm steel metal frame casing (fig. 1b) which carries the whole mechanism. The machine was composed of upper (fig. 2f) and lower (fig. 2g) sample holders. Both sample holders were designed to be emerged inside a plastic beaker (fig. 2b) that is filled with distilled water in which the process will occur. The upper sample holder is attached by two M4 socket head screws on the power screw nut; which is a main component of the driver head, it was connected rigidly to guarantee no vibration between the ceramic sample and antagonist tooth during the operation. The power screw and, in turn, the nut are actuated by a pneumatic piston in a rocker mechanism, connected to it by a low vibration coupling wheel; which transmits the motion from the mechanism to the antagonist causing friction over the sample. The lower sample holder was designed to hold ceramic samples, while the upper sample holder was designed to be home for an antagonist natural tooth in a positive mold. The pneumatic circuit is actuated via a 2HP air compressor with a 25L tank that gives the required power supply. The simulator was programmed to perform 240,000 loading cycle backwards and forwards (fig. 3) by holding an antagonist (fig. 3a) against a sample (fig. 3b) which are comparable to one year chewing condition [2].

Wear parameters,stroke length/ horizontal movement, frequency of loading cycles, operational liquid temperature, water jet frequency and weight per sample could be adjusted according to different experimental conditions. The applied load can be changed by simply changing the weights (fig. 2a) that are inserted over the machine driver. The loading cycles can be increased or decreased by reprogramming the system’s controller and so is the stroke length. The temperature is adjustable from the temperature unit on the control panel (fig.1a) and is always monitored by a thermo-sensor mounted on the operation beaker. Water jet (fig. 2e) cleaning frequency can also be adjusted from knobs inside the control unit.

**Two-body wear test:**

For fixation during two-body wear simulation, the specimens were embedded in the middle of their holders using a light cured dental composite resin (Hybrid light cure composite. Alpha-dent, 6901 N Hamlin Avenue, Lincolnwood, Illinois 60712, USA) to ensure proper positioning during the test. A weight of 5 kg, which is equivalent to 49N of chewing force [26, 27] was applied over the machine driver. A number of 240,000 cycles were repeated on each sample at a frequency of 1.7 Hz (which equals to 102 cycles/minute). The stroke length of the horizontal movement equals to 1mm2 (fig. 3). A continuous flow of distilled water was directed on the wear area maintaining the environmental temperature at 37oC.

**Weight loss measurement:**

The substance loss of the teeth specimens and ceramic samples before and after two-body wear simulation was measured by weighing in an electronic balance (Sartorius, Biopharmaceutical and Laboratories, Germany) with an accuracy of 0.0001 gr [20].

**Scanning electron microscope (SEM):**

For characterizing wear patterns, ceramic samples and natural teeth antagonists (before and after two-body wear test) were subjected to scanning electron microscopy using the FEI Quanta 250 FEG-SEM (FEI COMPANY, Nederland) attached with EDAX Unit (Energy Dispersive X-ray Analyses), with accelerating voltage 30 kV. Natural teeth were examined at a magnification of 160x, while ceramic samples were examined at a magnification of 1000x.

**Statistical Analysis**

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). Kruskal-Wallis test was used to compare between weight loss of the three ceramic materials. Dunn's test was used for pair-wise comparisons when Kruskal- Wallis test is significant. Mann-Whitney U test was used to compare between the two surface finishes (glazing and polishing). Wilcoxon signed-rank test was used to compare between specimens and antagonist teeth. The significance level was set at P ≤ 0.05.

**Results:**

**Weight loss:**

For polished as well as glazed ceramic specimens, Kruskal-Wallis test indicated no significant difference between IPS e.max CAD and IPS e.max Ceram. Both showed significantly the highest mean weight loss values; while Prettau Zirconia showed significantly the lowest mean weight loss values P ≤ 0.05. As for their tooth antagonist, no significant difference was found in the mean weight loss values among the three ceramic materials (fig. 4). For all groups**,** whether for the ceramic specimens or teeth antagonists, Mann-Whitney U testshowed no statistically significant difference in the mean weight loss values between polished and glazed specimens (fig.5). Also, Wilcoxon signed-rank test showed that ceramic specimens had statistically significantly lower mean weight loss values than tooth antagonists P ≤ 0.05 (fig.6). Paired t-test indicatedsignificant decrease in weight after wear procedure for all the ceramic specimens except for glazed IPS e.max Ceram specimens and polished IPS e.max Ceram tooth antagonists as there was a decrease in weight but not statistically significant (table II).

Table (II). The mean, standard deviation (SD) values and results of paired t-test for comparison between weights before and after wear within each group.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Substrate |  | Surface finish | Before wear | After wear | *P*-value |
| Material | Mean | SD | Mean | SD |  |
| Specimen | IPS e.max CAD | Polished | 0.6429 | 0.0057 | 0.6280 | 0.0072 | <0.001\* |
| Glazed | 0.6471 | 0.0104 | 0.6330 | 0.0103 | 0.004\* |
| IPS e.max-Ceram | Polished | 0.9315 | 0.0254 | 0.9128 | 0.0242 | 0.003\* |
| Glazed | 0.8907 | 0.0313 | 0.8784 | 0.0231 | 0.192 |
| Prettau Zirconia | Polished | 1.8499 | 0.0370 | 1.8482 | 0.0371 | 0.003\* |
| Glazed | 1.962 | 0.1135 | 1.9595 | 0.1140 | 0.001\* |
| Tooth | IPS e.max CAD  | Polished | 2.339 | 0.1276 | 2.2279 | 0.1674 | 0.024\* |
| Glazed | 2.2824 | 0.1833 | 2.1917 | 0.1448 | 0.031\* |
| IPS e.max Ceram | Polished | 2.3110 | 0.1625 | 2.2310 | 0.1413 | 0.095 |
| Glazed | 2.2923 | 0.1125 | 2.2383 | 0.1219 | 0.006\* |
| Prettau Zirconia | Polished | 2.3550 | 0.1371 | 2.2931 | 0.1461 | 0.004\* |
| Glazed | 2.3314 | 0.0894 | 2.2686 | 0.0980 | 0.001\* |

*\*: Significant at P ≤ 0.05*

**Scanning Electron microscope analysis**

SEM analysis of polished and glazed IPS e.max Ceram surfaces and tooth antagonists are presented in (figs. 7&8). The SEM image of polished surface shows surface scratches which indicate the direction of polishing. The polishing process has resulted in some pulling out of some grains/crystals (fig. 7.a). The wear polished surface shows that the microstructure of the material started to prevail. The wear pattern is evident as furrows which are neither faint nor deep (in between). It can be stated that the crystalline nature of the material dictated the wear pattern due to the pathway of existing crystals (fig.7.c). The wear antagonist enamel surface (fig 7.d) shows that the parallel striations of the wear pattern are hardly detected (they are only just felt) when compared to enamel surface before two-body wear test which revealed a smooth incisal edge (fig. 7.b). There is also an evidence of crack propagation directed sideways (fig. 7.d); while for glazed IPS e.max Ceram surface, SEM image shows a transparent glaze layer, underneath it a uniform crystalline structure in a partially preferred parallel orientation (fig. 8.a). The wear surface shows pulling out of some crystals across the parallel striations of the wear pattern. The glazed surface remained intact but is clearly affected (fig. 8.c). The wear antagonist enamel surface shows an evident wear pattern on the inscisal edge compared to a smooth incisal edge before wear test (fig 8.b). It reveals long, parallel, deep striations forming a uniform broad surface. Sites of crack propagation are seen moving upwards (fig. 8.d).

SEM analysis of polished and glazed IPS e.max CAD surfaces and tooth antagonists are presented in (figs. 9&10). The SEM image of polished surface before two-body wear test, shows striations which indicate the direction of polishing. Also, some pulling out of the grains/crystals can be observed (fig. 9.a). The wear surface shows a clearly evident wear pattern, seen as very deep furrows and subsidiary grooves which are parallel to one another and to the main furrow (fig. 9.c). The antagonist enamel surface before two-body wear test shows a smooth inscisal edge (fig. 9.b); while after wear test, the SEM image reveals a clearly evident wear pattern detected as very deep furrows and islands of crystals. The tooth is deeply affected by the opposing ceramic (fig. 9.d). For glazed IPS e.max CAD surface, SEM image shows a uniform glaze and dendritic shaped crystals appearing under the transparent glaze (fig 10.a). The wear glazed surface shows a uniform crystalline microstructure of the respective composition. The wear pattern shows deep furrows. Relics of the glazed surface remain scattered and are seen lighter in color (fig.10.c). After wear test, the SEM image of antagonist enamel surface represents a clearly evident wear pattern. Pulling out of the enamel crystals from the inscisal edge has followed; however, the crystals have somehow preserved their shape (fig 10.d).

For Prettau zirconia, SEM analysis of polished and glazed surfaces and tooth antagonists are presented in (figs. 11&12). SEM image of polished Prettau zirconia sample shows striations along the surface which indicate the direction of polishing (fig. 11.a).The wear polished surface shows that the surface is mildly affected. The wear pattern is seen as parallel striations that are not deep as previous samples (fig. 11.c). It can be stated that the material is not seriously affected as other investigated specimens. The wear antagonist demonstrated an evident wear pattern with very faint striations parallel to one another (fig 11.d), while the contact point is only affected as opposed to the smooth incisal edge prior to wear (fig. 11b). For glazed Prettau zirconia surface, SEM image reveals a uniform layer of glaze and small dendritic crystals (fig 12.a). After two-body wear test the wear pattern is characterized by short spindle-shaped lines, parallel to one another (they have a starting and ending point). The glazed surface appears to remain intact (fig. 12.c). The wear patterns of antagonist enamel surfaces opposed to whether polished or glazed surfaces are evident as very faint striations parallel to one another. The striations are not as deep as the other previously described ceramic surfaces. The contact point is the only affected (fig. 12.d) compared to smooth inscisal edge before wear test (fig.12.b).

**Discussion**:

In this study, the results showed that the wear behavior is strongly material-dependent and different finishing procedures (polishing and glazing) have no influence on the wear behavior of the three ceramic systems against natural teeth. So, the first null hypothesis was rejected and the second one was accepted.

 In this study a specially designed **two-body wear simulator** was designed. The advantages of in-vitro testing are stated as follows: it offers a controlled exposure time, a high level of standardization can be obtained, larger number of samples can be tested over a short time, and it provides control over the testing environment and temperature and the possibility of controlling numerous variables [14,31]. Simulation of two-body wear was chosen as it happens most frequently in oral conditions. Physiological causes of two-body wear occur inevitably due to the function of mastication during direct contact and sliding contact. They occur progressively and very slowly over time. Pathological causes of two-body wear such as bruxism, xerostomia and unusual oral habits can cause accelerated and excessive wear of teeth and restorations [32]. The two-body wear simulator is programmed to perform 240,000 loading cycles backwards and forwards by holding the natural tooth antagonist against the ceramic disc sample. According to studies [2, 26], 240,000-250,000 loading cycles in a chewing simulator are comparable to a one-year chewing condition. The stroke length/ horizontal movement of the antagonist natural tooth over the ceramic sample equals to 1mm2 per direction [22]. The frequency of the loading cycles was set to be 1.7 Hz which equals 102 cycles/minute [26, 33]. The samples were immersed in distilled water and a continuous flow was directed on the wear area maintaining the environmental temperature at 37oC [33]. A weight of 5 kg, which is equivalent to 49 N of chewing force, was applied [26, 27, 35].

The homogeneity and particle size of the microstructure of the material had an effect on the wear process and wear varied according to the structure of the ceramic tested [36, 37]. In the present study, difference in the composition of the ceramic materials tested was behind the significant higher wear loss of IPS e.max CAD and IPS e.max Ceram than Prettau Zirconia. Both IPS e.max CAD and IPS e.max Ceram are glass ceramics. IPS e.max CAD consists of approximately 70% fine grain elongated lithium di-silicate crystals embedded in a glassy matrix [38]. IPS e.max Ceram consists of 19-23% nano-fluorapatite crystals embedded in a glassy matrix [39], while Prettau Zirconia is a polycrystalline ceramic, which consists of a fine uniform microstructure of 95% zirconium oxide as a main component along with 4.95-5.26 % Yttrium oxide [40]. These findings came in agreement with those reported by several authors [35, 41-43] who found that wear performance of lithium di-silicate was greater than that of zirconia. Furthermore, Albasharieh et al [37] found that zirconia specimens demonstrated significantly lower vertical and volumetric loss than nano-fluorapaptite and lithium di-silicate glass ceramics. They clamied that the inclusion of Yttria additives in zirconia ceramic may have enabled the crystal structure to retard crack propagation as a result lower wear values occurred due to the loss of slight amount of material from the surface [37]. The highest mean weight loss values of glass ceramics could be due to the disappearance of glassafter wear exposing their constituting crystals which act as abrasive materials [44]. SEM analysis verified out results as the wear patterns of both IPS e.max Ceram and IPS e.max CAD whether polished (figs 7.c & 9.c.) or glazed (figs. 8.c & 10.c) were more evident than Prettau zirconia whether polished (fig. 11.c.) or glazed (fig. 12.c). Consequently, the surface of Prettau zirconia is mildly affected after two-body wear test compared to IPS e.max Ceram and IPS e.max CAD surfaces.

In the current study, the non-significant difference in the weight loss between polished and glazed ceramic specimens and teeth antagonists could be attributed to the fact that polishing and glazing are common methods used to create a smooth surface on ceramic restorations [27]. Glazing produces a final smooth hygienic surface, and increases the overall mechanical strength of ceramic restorations by reducing porosity, reducing the depth and sharpness of surface flaws and blunting flaw tips [27]. Polishing, on the other hand, causes a reduction in initial surface flaws and defects inhibiting further crack propagation and, thus, increasing the restoration’s resistance to fracture [45]. Also, polishing might produce residual compressive strength, consequently increasing ceramic surface hardness [45]. These results came in agreement with a previous study [34], which found that wear characteristics of polished specimens were similar to that of glazed specimens when comparing wear of enamel against low fusing ceramics. The study suggested that polishing can improve the surface roughness of the ceramic, similar to that of glazing. Also, Preis et al. [35] reported that polishing and glazing tended to enforce ceramic and antagonist wear but without a statistically significant difference. The results of Lawson et al. [42] partially agreed with those of the present investigation. It has been found that polished zirconia caused less wear of opposing enamel than glazing, while glazed and polished lithium di-silicate caused similar enamel wear. They stated that the lower enamel wear against polished and glazed ceramics in laboratory studies may reflect a delay in the wear of opposing enamel. They further explained that, once the smooth surface layer of glazed or polished porcelain is roughened and worn through, the polished or glazed porcelain will likely wear at the same rate [41]. Other studies [2, 26, 46, 47]came in disagreement with the findings of the present study as they found that more material wear was shown in glazed zirconia than polished zirconia specimens. Jung et al. [2] attributed their results to the addition of porcelain composite in the glazing process. On the contrary, Passos et al. [33], claimed that the glaze layer presented as a protection to the ceramic surface and exhibited fewer cracks and less loss of material than polished surfaces. Their study also showed that the wear of bovine enamel opposing glazed surfaces showed a volume loss significantly higher than that opposing polished ceramics [33].

Surface hardness and the resistance to fracture influence the loss of substance from the surface of materials tested [37]. Higher hardness and fracture toughness values suggest a greater resistance to surface scratch or damage caused by other materials [48]. Previous in vitro studies reported that ceramics are harder than the dental enamel or steatite antagonists [2, 25-27, 33-35, 37, 42, 49-51]. Accordingly, the lower weight loss of all ceramic materials, whether polished or glazed, could be attributed to the higher physical properties of the ceramic materials when compared to those of tooth enamel. IPS e.max Ceram has a fracture toughness of 0.9 MPa m1/2 and hardness of 5400±200 MPa [42], IPS e.max CAD has a fracture toughness of 2.0-2.5 MPa m1/2 and hardness of 5800±100 MPa [38], whereas Prettau Zirconia has a fracture toughness of 5-10 MPa m1/2 and Hv10 is > 1250 [40]. The fracture toughness of tooth enamel is 0.8 MPa m1/2 and the hardness of 3230 MPa [52]. In the present study, difference in the wear patterns also became obvious in SEM evaluation which are clearly more evident in the natural tooth antagonists (figs. 7.d, 8.d, 9.d, 10.d, 11.d & 12.d) than those of the ceramic samples (figs. 7c, 8.c, 9.c, 10.c, 11.c & 12.c).

It is to be considered that the physiological wear of teeth is a normal occurrence in the human dentition which occurs gradually but slow; while material loss results from micro-fracture, with an annual wear rate of about 30-40 μm [27]. Albashaireh et al. [37], explained that glass ceramics are more sensitive to fatigue resulting from flaws in the material. Glass ceramics wear is of fatigue type, which is initiated by the formation of cracks in the subsurface. Cracks propagate as a result of repeated cycles and eventually spreads to the surface; the ceramic that is surrounded by the cracks is lost. The displaced ceramic itself may form debris and act as a slurry, causing abrasion in a 3-body wear mode; whereas Y-TZP demonstrates a mode of wear consistent with adhesive or attritional wear. Adhesive wear occurs when two surfaces slide against one another causing friction between the surfaces. The effects of friction causes the asperities of one surface to become cold welded on the other surface. These asperities usually plough into the softer surface of the two occluding materials, resulting in further removal of substance by abrasive wear [37]. In this study, significant decrease in the weight after two-body wear test in all ceramic materials, except for glazed IPS e.max Ceram specimens and polished IPS e.max Ceram tooth antagonists, is likely to be attributable to the fact that wear process occurs whenever two surfaces interact with one another, causing loss of substance from the surfaces of materials. SEM analysis revealed that several sites of crack propagation were seen on the natural teeth antagonists (figs. 8.d & 7.d) placed against IPS e.max Ceram glazed and polished samples. Also, IPS e.max CAD polished sample demonstrated some dark lines which might indicate beginning of a fracture sight (fig 9.c).

The limitations of the study, just like those of any in-vitro study, are that it remains unclear to what extent the wear observed clinically may differ. Only two-body wear test of ceramic specimens against natural teeth was evaluated. Further investigation should be required with a three-body wear test as different results may be obtained. Also, the number of specimens could have been increased to reduce influence of data variations on the statistical outcome.

**Conclusions:**

Despite the limitations of the present study, the following conclusions were drawn:

1. Wear process is strongly material-dependent.
2. Zirconia is more wear-resistant than lithium di-silicate and nano-fluorapatite glass ceramics.
3. The microstructure of the tested ceramics had no impact on the wear behavior of the antagonist teeth.
4. Surface finishing methods (glazing or polishing) of the tested ceramics did not influence the wear behavior of antagonistic enamel.

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**Figure 1:** Two-body wear simulator: a, side view showing the driver head of the machine, power supply unit, temperature control unit and monitor. b, shows the machine which is deployed inside a steel metal frame.

**Figure 2:** Schematic Diagram representing the two-body wear process orientation; a, weight. b, plastic beaker. c, ceramic sample. d, natural teeth antagonist. e, water jet (2 seconds on/30 seconds off). f, upper sample holder. g, lower sample holder.

**Figure 3:** Diagram representing the stroke direction& length during two-body wear simulation process; the natural tooth antagonist (a) moved horizontally backwards and forwards (red arrows) and 1 mm/ direction over the ceramic sample (b).

 **Figure 4:** Bar chart representing mean and standard deviation values of weight loss of the three ceramic materials with different interactions of the variables.

**Figure 5:** Bar chart representing mean and standard deviation values of weight loss of polished and glazed ceramic specimens with different interactions.

**Figure (6):** Bar chart representing mean and standard deviation values of weight loss of ceramic specimens and tooth antagonists.

**Figure 7:** SEM images of polished IPS e.max Ceram (Magnification 1000x) and tooth antagonist (Magnification 160x); a and b; before two-body wear test. c and d; After two-body wear test.

**Figure 8:** SEM images of glased IPS e.max Ceram (Magnification 1000x) and tooth antagonist (Magnification 160x); a and b; before two-body wear test. c and d; After two-body wear test.

**Figure 9:** SEM images of polished IPS e.max CAD (Magnification 1000x) and tooth antagonist (Magnification 160x); a and b; before two-body wear test. c and d; After two-body wear test.

**Figure 10:** SEM images of glazed IPS e.max CAD (Magnification 1000x) and tooth antagonist (Magnification 160x); a and b; before two-body wear test. c and d; After two-body wear test.

**Figure 11:** SEM images of polished Prettau zirconia (Magnification 1000x) and tooth antagonist (Magnification 160x); a and b; before two-body wear test. c and d; After two-body wear test.

**Figure 12:** SEM images of glazed Prettau zirconia (Magnification 1000x) and tooth antagonist (Magnification 160x); a and b; before two-body wear test. c and d; After two-body wear test.