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Two-Body Wear And Surface Roughness of Three Different Ceramic Systems And Their Enamel Antagonist: An In Vitro Study

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ABSTRACT

Statement of the problem: Ceramics and glass-ceramics are materials of choice for dental crowns due to their attractive hardness, biocompatibility, etc. However, a major problem with their usage is the observed high wear of either the opposing dental enamel or both the enamel and ceramic itself. **Objective:** The present study aimed at ranking and comparing the wear performance of three different ceramic systems (monolithic zirconia, lithium disilicate glass ceramic and feldspathic porcelain) and their effect on the wear and surface roughness of their antagonist enamel. **Materials and methods:** Five cylindrical discs (n=5) were constructed from each of: BruxZir zirconia, IPS e.max CAD lithium disilicate based ceramic and feldspathic porcelain representing (N=15). Ceramic samples were polished till obtaining convergent surface roughness values of the three materials. Enamel antagonists were prepared as sectioned buccal cusps of maxillary first premolars (N=15). Baseline surface roughness and weight values were obtained using optical surface profiler and sensitive balance, respectively, for all samples (ceramic discs and their antagonist cusps) prior to subjecting the samples to chewing simulation procedure test including the application of 5kg (49N) load for 120,000 cycle with vertical movement 1mm, horizontal movement 3mm and frequency 1.6Hz. Weight loss was calculated for all samples (ceramic discs and their antagonists) as an indication of wear. In addition, change in surface roughness was calculated using optical surface profiler. **Results:** The statistically significant highest mean material's weight loss was recorded in porcelain group, whereas the statistically significant lowest mean weight loss was recorded in BruxZir group. The statistically significant greatest mean antagonist weight loss was recorded for e.max antagonist cusp, whereas the statistically significant lowest mean weight loss was recorded for BruxZir antagonist cusp. Surface roughness increased after wear procedure in all samples. **Conclusions:** Within the limitations of this in vitro study, monolithic zirconia and porcelain resulted in less wear depth to human enamel compared to lithium disilicate based ceramics (e.max CAD). However, porcelain is more affected by wear compared to zirconia.

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INTRODUCTION

A wide range of synthetic materials for dental prostheses is currently available, with varying performance with regard to factors such as corrosion behavior, mechanical/tribological properties (particularly, strength and wear resistance), cost, availability, biocompatibility and esthetics (1). Ceramics, in addition to their high hardness and esthetic potential, are rated more biocompatible than other restorative materials. Because of ceramics' superior wear properties and biocompatibility; they are the material of choice for dental crowns (2).

Computer aided design/computer assisted manufacturing (CAD/CAM) systems use a variety of ceramic blocks, such as lithium disilicate glass, leucite-reinforced glass, and yttria-stabilized zirconia. Also, there is a heat-press fabrication system that uses a custom block made of lithium disilicate glass (3, 4). These ceramic materials have better mechanical properties, especially flexural strength and fracture toughness, compared with feldspathic porcelains (5, 6). However, the abrasiveness of these ceramic materials against an enamel antagonist is still a clinical concern. Several investigators have demonstrated that in general, ceramic material causes greater enamel wear compared with any other restorative materials or enamel (2-6).

Enamel wear caused by antagonistic enamel and ceramic crowns has been investigated in vivo and in-vitro (7-10). In-vivo quantification of enamel and material wear is difficult and time consuming, In addition, such studies may result with relatively high standard deviations due to the biological spread between the studied Individuals. This explains the complexity of the wear process and its dependence on both intrinsic and extrinsic factors; like enamel thickness and hardness, masticatory function, tooth form and type, time of teeth eruption, teeth position in relation to the arch, and finally; the type and PH of the eaten food(11). Thus in vitro studies using chewing simulators are commonly used to conduct in-vitro tests attempting to simulate oral wear.

Dental ceramics wear by a different mechanism than any other restorative materials. They are composed of crystals embedded in a glassy matrix. The harder crystalline phase of the ceramic is more capable of causing wear to opposing enamel(12), however, ceramics with higher crystal content show greater wear resistance and produce less wear on opposing enamel[13]. The reason for this paradox is that crystals are thought to improve the fracture resistance of ceramics. Ceramics are brittle materials which wear by fracturing.

Fracturing of its surface roughens the ceramic and releases wear fragments, accelerating the wear of opposing enamel(14). Ceramic materials with high crystal content are less susceptible to fracture and produce less wear of opposing materials. Therefore, the wear of ceramics is dependent on the ability of the opposing structure to cause brittle fracture of the ceramic.

Zirconia has an elasticity modulus of 210 GPa and hardness of 1200 HV(15) On the other hand, since veneering glass ceramic has an elasticity modulus of 50–70 GPa and Vickers hardness of 470–600, more wear could be expected in enamel against non-veneered monolithic zirconia(16).

When monolithic translucent and shaded experimental zirconia samples were examined, they yielded superior wear behavior, and lower antagonistic wear

Compared to monolithic lithium disilicate and veneering porcelain samples (17) lithium disilicate glass was not only resistant to wear, but was also wear friendly to enamel antagonist surfaces in another study(18)

In another study, (19) monolithic zirconia showed low wear rate on enamel and in the material, itself. However, SEM examination of antagonist enamel showed that sliding of enamel on zirconia surface caused added cracks of the enamel. It should be noted that material behavior in previous studies are limited to the in-vitro experimental duration.

Those behaviors can be diversely changed if tested Materials were subjected to the wear procedure for a longer duration of time.

Regarding surface treatments, polished monolithic zirconia showed significantly lower wear rate on enamel antagonists than that produced by glazed monolithic samples [20].

This in-vitro study was thus conducted to compare and rank enamel wear caused by monolithic zirconia, lithium disilicate glass ceramic and porcelain in addition to wear of the materials' themselves. The null hypotheses tested were that no difference would be found in enamel wear and surface roughness against tested materials and that for each material, no difference would be found in material's wear and surface roughness against enamel.

MATERIAL AND METHODS

To conduct the present study, three types of ceramics representing monolithic restorations, namely zirconia (BruxZir, Glidewell Laboratories, USA), lithium disilicate (e.max CAD, Ivoclar, Vivadent) and Conventional feldspathic porcelain; (Super Porcelain AAA (E3), Kuraray Noritake Dental, Tokyo, Japan), were tested against natural teeth as antagonists.

Preparation of ceramic samples:

Fifteen standardized cylindrical disc samples (N=15) with 10mm diameter and 3mm thickness were constructed from the selected ceramic materials according to the following procedure:

Construction of the mold:

To standardize the shape and size of all ceramic samples; a copper mold was machined. The mold consists of two parts held together by two screws. When assembled the two parts complete the mold of a cylinder of 2 cm height and 1.5 cm diameter.

Construction of the porcelain sample:

Five cylindrical discs (n=5) were made using the specially constructed mold. The mold was placed over a glass slab and the inner surface of the mold and the slab were painted with separating medium. The powder and liquid were mixed according to the manufacturer recommendation and packed inside the mold using a vibrator. The mold was gently disassembled and the disks were carefully removed from the mold and fired up to 930°C (1706 °F) in the furnace (Programat P300/G2, Ivoclar Vivadent Inc., Schaan, Liechtenstein). Any deficiency was corrected through placing the samples inside the mold and porcelain slurry was added to compensate for the shrinkage with additional firing cycle until samples with homogenous surfaces were obtained. The sample was finally finished.

A porcelain sample also was used as a pattern to construct the machined samples (Bruxzir and e.max CAD)

Preparation of Bruxzir samples:

Five cylindrical disc samples (n=5) were constructed using Bruxzir zirconia blocks (Glidewell Laboratories, USA). Using the porcelain disc as a pattern; 20% larger discs were milled using S1 VHF (vhf camfacture, Ammerbuch/ Ger- many) milling machine. Samples were then sintered at 1500^{o}C in Sintramat High Temperature furnace (Ivoclar Vivadent; Bufflo, NY, USA) with a heating rate of 8oC/min and a holding time of 2 hours. After sintering they were polished with rubber disks (Shofu Dental; San Marcos, CA, USA).

Preparation of e.max CAD sample:

Five cylindrical disc samples (n=5) of e.max CAD (Ivoclar Vivadent, Schaan, Liechtenstein) were milled using CEREC inLab (Sirona, Bensheim, Germany) CAD/CAM machine where The porcelain disc was used as a pattern. The ceramic discs were milled and finished according to manufacturer instructions.

Preparation of the enamel antagonist

Fifteen (N=15) human intact maxillary first premolars, extracted for periodontal reasons were collected. Selection criteria included similar crown sizes with well-developed cusps. The samples were cleaned manually from any tissue debris. Each premolar was sectioned mesio-distally using slow speed diamond disc (Diatech; Goltène AG, Switzerland) under copious water coolant to obtain crack free cusps. Then, the cusps were ground down with a rotary cutting Instrument in the presence of water to form a flat circular area entirely of enamel with a diameter of at least 8 mm to enable it to undergo wear testing.

Wear simulation:

Quantification of wear process was done by calculating the amount of weight loss of samples (ceramic discs and natural cusps) after wear simulation procedure [(21-25)]. the weight of each sample was determined before and after wear to calculate the weight loss of each sample (mg). In addition, the surface roughness of the samples was characterized using 3D surface analyzer profiler before and after the two-body wear procedure.

Weighing of the samples before wear simulation procedure:

Each sample (cusps and ceramic discs) was individually weighed before initiation of the wear simulation procedure using electronic analytical balance (Sartorius, Biopharmaceutical and Laboratories, Germany) with an accuracy of 0.0001 gm. This electronic balance had a fully automated calibration technology and a micro weighing scale.

Determination of surface roughness:

Baseline surface roughness was determined before wear procedure for all samples (cusps and ceramic discs). Samples were photographed using USB Digital microscope with a built-in camera (Scope Capture Digital Microscope, Guangdong, China) connected with an IBM compatible personal computer using a fixed magnification of 120X.

The images were analyzed using WSxM software (Ver 5 develop 4.1, Nanotec, Electronica, SL) to calculate average of heights (Ra) expressed in µm, which can be assumed as a reliable index of surface roughness. [(9)]

Two-body wear procedure:

The 2-body wear testing was performed using ROBOTA chewing simulator integrated with thermocyclic protocol operated on servo-motor (model ach-09075dc-t, AdTech technology co., Germany). The chewing simulation test included the application of 5kg (49N) load for 120,000 cycle with vertical movement 1mm, horizontal movement 3mm and frequency 1.6Hz. The load application was associated with thermocycling procedure including the immersion in cold/hot water bath with temperature variation 5°C/55°C and dwell time 60 seconds.

After completion of the wear testing procedure all samples were thoroughly washed then dried with paper tissue. Each sample (cusp and ceramic disc) was weighed again using the electronic analytical balance to obtain the amount of weight loss due to wear.

Moreover, the surface roughness of the samples was evaluated after conducting the wear simulation procedure following the same procedure used for obtaining the baseline roughness and using the same devices at the wear scar.

Statistical analysis

Obtained data was statistically analyzed using (SPSS 16.0 (Statistical Package for Scientific Studies, SPSS, Inc., Chicago, IL, USA) for Windows. Data were explored for normality using Kolmogorov-Smirnov test of normality. The results of Kolmogorov-Smirnov test indicated that most of data were normally distributed (parametric data), so one way analysis of variance ANOVA test was used to compare between materials and antagonist cusps, followed by Tukey's post hoc test when the difference was found to be significant. Paired t-test was used to compare mean roughness values before and after chewing simulation. The significance level was set at $p \leq 0.05$.

RESULTS

I- Weight loss in mg

II- I.a. Weight loss of material:

The greatest mean was recorded in Porcelain, whereas the lowest weight loss was recorded in BruxZir. ANOVA test revealed that the difference was statistically significant (p=0.018). Tukey's post hoc test revealed a significant difference between BruxZir and porcelain (Table 1)

I.b. Weight loss of antagonist cusp

The greatest mean was recorded in e.max cad antagonist cusp, whereas the lowest weight loss was in recorded in Bruxzir antagonist cusp. ANOVA test revealed that the difference was statistically significant (p=0.043). Tukey's post hoc test revealed a significant difference between Bruxzir antagonist cusp and E.max cad antagonist cusp (Table 2)

Table (1) *Weight loss (mg) of material and significance of the difference using ANOVA test*

Material	Mean	Std Dev	Max	Min	F	P value
Bruxzir	0.53^{b}	0.17	0.70	0.30	4.698	0.018*
E.max CAD	$0.73^{a,b}$	0.25	1.20	0.30		
Porceiain	0.83^{a}	0.24	1.10	0.60		

*Significance level p<0.05, *significant*

Tukey's post hoc test: means with different superscript letters are significantly different

Table (2) *Weight loss (mg) of antagonist cusp and significance of the difference using ANOVA test*

Antagonist Cusp	Mean	Std Dev	Max	Min	F	P value
Bruxzir	**1.67^{b}**	**0.57**	**2.30**	**1.20**	**3.070**	**0.043***
E.max CAD	**2.13^{a}**	**0.25**	**2.40**	**1.90**		
Porceiain	**$1.90^{a,b}$**	**0.36**	**2.30**	**1.60**		

*Significance level p<0.05, *significant*

Tukey's post hoc test: means with different superscript letters are significantly different

II- Surface Roughness (Ra) in μm

II.a) Surface roughness (Ra) of material (µm)

The mean surface roughness increased after wear in all materials. T-test revealed that this difference was statistically significant (p<0.0001, p=0.0024, p=0.0083) for Bruxzir, E.max CAD and porcelain respectively).

Comparing all materials before wear revealed the highest mean in Porcelain, with a significant difference (p=0.032).

Comparing all materials after wear revealed the highest mean in porcelain, with no significant difference (p=0.469).

Comparing the percent change of all materials after wear revealed the highest mean percent increase in E. maxCAD, while the lowest percent increase was in Porcelain, with a significant difference (p=0.038), (Table3)

II.b) Surface roughness (Ra) of antagonist cusp (µm)

The mean surface roughness increased after wear in all cusps. T-test revealed that this difference was not statistically significant (p=0.222, p=0.1141 for Bruxzir antagonist cusp and E.max cad antagonist cusp respectively), while for Porcelain antagonist cusp the difference was statistically significant p<0.0001).

Comparing all cusps before wear revealed the highest mean in Bruxzir antagonist cusp, with a significant difference (p<0.0001).

Comparing all cusps after wear revealed the highest mean in Porcelain antagonist cusp, with a significant difference (p<0.0001).

Comparing the percent change of all cusps after wear revealed the highest mean percent increase in Porcelain antagonist cusp, while the lowest percent increase was in Bruxzir antagonist cusp, with a significant difference (p<0.0001), (Table 4)

Table (3) *Surface roughness (Ra) of material (µm) before and after wear and significance of the difference using ANOVA test*

Material	Before wear				After wear				Percent change after wear	Significance of increase	
	Mean	Std Dev	Max	Min	Mean	Std Dev	Max	Min		t value	P value
Bruxzir	0.250^{b}	0.003	0.253	0.247	0.258	0.001	0.259	0.257	$3.18^{b}\pm1.05$	8	<0.0001*
E.maxCAD	0.250^{b}	0.004	0.254	0.246	0.260	0.008	0.269	0.255	$3.92^{a}\pm0.95$	3.53	0.0024*
Porcelain	0.254^{a}	0.004	0.257	0.249	0.261	0.005	0.265	0.256	$2.93^{c}\pm1.11$	2.96	0.0083*
F value	3.902				0.778				3.706	-----	
P value	0.032*				0.469^{ns}				0.038*		

P1=Significance of the difference between materials before wear, after wear and significance of difference between increase in different materials

P2=Significance of Difference between after and before for each material

*Significance level p<0.05, *significant*

<u>*Tukey's post hoc test:*</u> *means with different superscript letters within the same column are significantly different*

Table (4) *Surface roughness (Ra) of antagonistic cusps (µm) before and after wear and significance of the difference using ANOVA test*

Antagonist cusp	Before wear				After wear				Percent change after wear	Significance of in-crease	
	Mean	Std Dev	Max	Min	Mean	Std Dev	Max	Min		t value	P value
Bruxzir	0.263^{a}	0.004	0.266	0.259	0.265^{a}	0.003	0.267	0.262	$0.73^{c}\pm0.22$	1.2649	0.222^{ns}
E.max CAD	0.252^{c}	0.007	0.260	0.247	0.256^{b}	0.003	0.259	0.254	$1.94^{b}\pm0.56$	1.6609	0.1141^{ns}
Porceiain	0.256^{b}	0.001	0.257	0.255	0.266^{a}	0.003	0.269	0.264	$4.10^{a}\pm0.7$	10	<0.0001*
F value	14.091				33.7				102.61	-----	
P value	<0.0001*				<0.0001*				<0.0001*		

P1=Significance of the difference between materials before wear, after wear and significance of difference between increase in different cusps

P2=Significance of Difference between after and before for each cusp

*Significance level p<0.05, *significant*

<u>*Tukey's post hoc test:*</u> *means with different superscript letters within the same column are significantly different*

DISCUSSION

"Dental Wear" is defined as tooth loss or surface damage caused by direct contact between teeth or between teeth and other materials [26].

Dental wear of natural teeth is considered normal. If restorative dental materials have different wear properties compared to the natural teeth, however, they can change the wear rate of antagonistic natural teeth [27]. In particular, excessive wear on the occlusal surface can cause an abnormal load and result in periodontal diseases, and can also cause temporomandibular disorders [28]. Therefore, wear that occurs between the enamel of teeth and restorations is a very important factor that should be considered in the selection of restorative materials in clinical practice. Seghi suggested that a restorative dental material should have a wear degree similar to that of the enamel [29].

Clinical in-vivo tests are essential for estimating the complex wear performance of dental materials. However, such in vivo evaluations are often restricted by high costs and high variability among patients because individual chewing forces or ambient conditions cannot be sufficiently controlled. [18]

In the present study, enamel antagonists were used in an attempt to simulate clinical situations. Enamel antagonists were used to conduct several similar in-vitro studies[20,27,30,31]. However, using enamel antagonist was sometimes criticized due to morphological and structural differences among enamel samples which make standardization difficult[26]. To decrease the amount of inhomogeneity; standardization of enamel samples through grinding and polishing was sometimes suggested [20,32]. The standardization procedure included grinding the cusp tip to achieve the desired shape. [33]

In the present study, the wear behavior of three types of ceramics was tested against enamel antagonists. The three materials selected were: a recently introduced monolithic zirconia, Bruxzir, claimed to be kinder on opposing dentition such that it can be used for bruxism patients, a lithium disilicate based glass ceramic; e.max CAD, and feldspathic porcelain. All Tested materials received a polishing procedure which aimed at reaching similar degree of baseline surface roughness.

To ensure standardization, baseline roughness measurements for all samples were obtained prior to conducting wear test to ensure that all samples have convergent baseline surface roughness values (tables 3&4). This procedure was suggested in a study conducted by Amer et al [20] who recommended standardization of the initial Ra values of all samples, regardless of the finishing method used, instead of standardization of polishing procedure, time and pressure.

Polished ceramic surfaces have been reported to be equal or surpass the smoothness accomplished with surface glazing [34]. It was reported that the Formed glaze layer is usually worn out within the first six months after the insertion of the restoration, [24] uncovering the restoration's deeper layer. The antagonist hitting the rough surface might lead to increased contact wear if a longer simulation program would have been conducted. [35]

Wear was quantified in the present study based on the amount of weight loss. It was calculated based on the difference between the initial weight (before chewing simulation procedure) and the final weight (after chewing simulation procedure), for each sample [36-39]. Different methods were employed for in-vitro quantification of wear among different studies making comparison difficult. Calculations of volume loss and height loss were among the widely used methods [34, 39]. However, Heintze et al [40] tested different methods used for the quantification of the in vitro wear of dental materials and found that all measuring principles were suitable for the quantification of the wear generated on flat samples.

The present study revealed that significant differences in the wear depth and surface roughness among test materials (Monolithic zirconia, Lithium disilicate Glass ceramic, feldspathic porcelain) and human enamel. Therefore, the null hypothesis was rejected.

Regarding the material loss after chewing simulation; porcelain samples showed the statistically significant highest material loss while BruxZir showed the statistically significant lowest material loss, table (1), suggesting that zirconia was the most resistant material to wear degradation. This result is in accordance with other studies, (27, 41-43) in which zirconia proved to be resistant to loss by wear when it was compared to different restorative materials. Moreover, polished zirconia-based ceramics showed no material loss after chewing simulation against enamel and steatite in other studies. (20, 26) Ceramics with higher crystal content as zirconia show greater wear resistance compared to ceramics with less crystalline content. (44-46)

On the other hand, regarding the antagonist cusp weight loss after chewing simulation, the least mean weight loss was recorded in antagonists cusps of porcelain and BruxZir with no statistically significant difference between the two materials, table (2). Antagonist cusps of e.max CAD recorded statistically significant higher weight loss values. Smoothly polished zirconia caused also less wear in antagonist enamel compared to lithium disilicate glass ceramics in other investigations. (20, 33, 47-49)

When ceramic slides against ceramic or enamel, wear does not occur by plastic deformation, as with metals, but by fracture. (40) The microfracture mechanism is the dominant mechanism responsible for the surface breakdown of ceramics after being subjected to wear simulation procedures. (41) Fracturing of ceramic's surface roughens the surface and releases wear fragments, accelerating the wear of opposing enamel. (40) In glass ceramics, as e.max CAD used in the present study, lower strength matrix is worn-out by fracture prior to the high strength crystals which will then act as asperities causing further wear of the antagonist enamel. (42) These asperities will themselves fracture after further conduction of the wear test as they are also brittle causing the process to be repeated thus resulting in material loss. (50) Meanwhile, glass particles that detach during the wear process behave as an abrasive medium and lead to a 3-body wear mechanism. (51) However, polycrystalline ceramics as zirconia are less susceptible to fracture due to their high mechanical properties thus produce less wear of opposing enamel, (30) in accordance of the results of the present study, table (2).

Hence, the possible explanation of superior wear of e.max CAD compared to BruxZir is that zirconia is less susceptible to the microfracture mechanism than glass ceramic because of the much higher fracture resistance of zirconia. The fracture toughness of the material is a key to the prevention of cracking. (52) Consequently, under the same condition of wear process, the microcrack is probably more difficult to propagate through the crystalline structure of zirconia compared to e.max CAD. (33)

On the other hand, the statistically significant highest material weight loss was recorded by porcelain samples indicating that it was the most affected material with the wear procedure conducted. Generally, feldspathic porcelains contain leucite crystals, cracks, and voids in the glass matrix, and their worn surfaces became rough and abrasive. (53)

Enamel wear caused by restorative materials is also a multifactorial condition.(49) Surface roughness, hardness, and fracture toughness of opposing restorative materials are some of the contributing factors that determine enamel wear caused by ceramics. (49)

Enamel wears by microfracture of the organic phase matrix followed by fracture of hydroxyapatite crystals. (39) However, the wear pattern consists of chips, not scratches as ceramics. The chipping occurs because enamel is stressed transversally to its prismatic orientation. (54)

Surface roughness is one of the factors that increase coefficient of friction and wear of the opposing surfaces. It can also be considered as a result of the wear process. In the present study, all samples (cusps and ceramic discs) were finished until roughness was adjusted to 0.250±0.02um so that a comparison of the surface roughness after chewing simulation could be processed. It was previously reported that patients can identify differences at surface roughness of 0.5 μm or more. [55]

Furthermore, weight loss of antagonist cusps occurring after wear procedure applied in the present study, (table 2), can be also attributed to the increased surface roughness which occurred in all tested materials after chewing simulation, (table 3). The coefficient of friction, which increases by surface roughness, has been reported to result in greater wear of the antagonist. [56] An in vitro study by Kadokawa et al [57] showed that the wear rate of enamel when opposed to a smooth porcelain surface was significantly lower than when opposed to a rough porcelain surface. However, some authors questioned the use of roughness parameter to evaluate surface degradation resulting from wear processes as degradation is a time dependent phenomenon, thus values may change according to the parameters of chewing simulation procedure and the stage of measuring, making comparison among studies difficult. [58, 59]

As e.max CAD recorded the statistically highest percent change in roughness after the wear procedure applied, its opposing cusp recorded the highest weight loss among tested cusps. While BruxZir recorded lower percent change in roughness; lower amount of weight loss was recorded for its antagonist cusps. These results coincide with those obtained by Sripetchdanond and Leevailoj, [33] indicating that when the roughness of the restorative material is increased due to the formation of asperities as a result of wear, opposing cusps are adversely affected. This relationship was previously verified in other studies. [42, 55, 60] The physical and microstructural characteristics, chemical degradation, and surface roughness of ceramics affect wear between ceramics and enamel. [53] Higher enamel wear caused by glass ceramic might also arise from the formation of wear debris. Glass particles that detach during the wear process might behave as an abrasive medium and lead to a 3-body wear mechanism. [50]

Although simulation of the clinical situation was followed during the course of the present study; in vitro studies need to be reinforced with clinical studies.

CONCLUSIONS

Within the limitations of the present study the following can be concluded: feldspathic porcelain and zirconia (BruxZir) produce less wear in opposing teeth compared to lithium disilicate based ceramics (e.max CAD). However, feldspathic porcelain shows material loss due to wear. Surface roughness of the restorative material can be correlated to its wear behavior, yet further investigation is required.

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