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Impact of Simulated Gastric Acid Exposure on the Surface Roughness of Various Dental Restorative Materials

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Research Article

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ABSTRACT

Objectives: This study aimed to evaluate the effects of simulated gastric acid exposure on the surface roughness of anterior composite resin, lithium disilicate-reinforced glass ceramic, and feldspathic ceramic materials after polishing.
Materials and Methods: Forty-eight specimens were prepared and divided into three groups: anterior composite (G-aenial anterior), lithium disilicate-reinforced glass ceramic (GC Initial LiSi), and feldspathic ceramic (Cerec Block). The specimens were immersed in a simulated gastric acid solution (0.06 mol HCl, pH 1.2) at 37°C for 96 hours. Surface roughness (Ra) was measured using a profilometer before and after acid exposure. Statistical analysis was performed using ANOVA and paired t-tests ($p < 0.05$).
Results: Before acid exposure, there was no significant difference in surface roughness among the materials ($p > 0.05$). After acid exposure, feldspathic ceramics exhibited the highest increase in surface roughness ($p < 0.05$), followed by composite resin. Lithium disilicate-reinforced ceramics showed no statistically significant change ($p > 0.05$).
Conclusions: Feldspathic ceramics were the most affected by gastric acid exposure, while lithium disilicate-reinforced ceramics demonstrated the highest resistance. These findings emphasize the importance of material selection for patients at risk of gastric acid exposure. Future studies should consider intraoral factors such as salivary buffering and mechanical wear.

Keywords: Gastric acid, composite resins, dental ceramics, surface roughness.

Simüle Edilmiş Mide Asidi Maruziyetinin Çeşitli Dental Restoratif Materyallerin Yüzey Pürüzlülüğü Üzerindeki Etkisi

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ÖZ

Amaç: Bu çalışmanın amacı, polisajlama sonrası anterior kompozit rezin, lityum disilikat ile güçlendirilmiş cam seramiği ve feldspatik seramik materyallerin yüzey pürüzlülüğü üzerine simüle edilmiş mide asidi maruziyetinin etkilerini değerlendirmektir.
Gereç ve Yöntemler: Kırk sekiz örnek hazırlanarak üç gruba ayrıldı: anterior kompozit (G-aenial anterior), lityum disilikat ile güçlendirilmiş cam seramik (GC Initial LiSi) ve feldspatik seramik (Cerec Block). Örnekler 0.06 mol HCl (pH 1.2) içeren simüle edilmiş mide asidi solüsyonuna 37°C'de 96 saat süreyle daldırıldı. Yüzey pürüzlülüğü (Ra), asit maruziyeti öncesi ve sonrası bir profilometre ile ölçüldü. İstatistiksel analizler ANOVA ve eşleştirilmiş t-testleri ile gerçekleştirildi ($p < 0.05$).
Bulgular: Asit maruziyeti öncesinde materyaller arasında yüzey pürüzlülüğü açısından anlamlı bir fark bulunmadı ($p > 0.05$). Asit maruziyeti sonrasında feldspatik seramikler en fazla yüzey pürüzlülüğü artışı gösterdi ($p < 0.05$), ardından kompozit rezin geldi. Lityum disilikat ile güçlendirilmiş seramiklerde ise istatistiksel olarak anlamlı bir değişiklik gözlenmedi ($p > 0.05$).
Sonuçlar: Feldspatik seramikler mide asidi maruziyetinden en fazla etkilenen materyal olurken, lityum disilikat ile güçlendirilmiş seramikler en yüksek direnci göstermiştir. Bu bulgular, mide asidi maruziyeti riski bulunan hastalar için restoratif materyal seçiminde dikkatli olunması gerektiğini vurgulamaktadır. Gelecek çalışmalar, tükürüğün tamponlama kapasitesi ve mekanik aşınma gibi intraoral faktörleri de dikkate almalıdır.

Anahtar Kelimeler: Mide asidi, kompozit rezinler, dental seramikler, yüzey pürüzlülüğü.

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Introduction

In the past two decades, the causes, diagnosis, and management of dental erosion have garnered significant attention in general dentistry.[1] Recent years have seen a heightened understanding of the potential consequences of erosive acids. Dental erosion is characterized as the "loss of tooth structure resulting from nonbacterial chemical factors".[2,3] The acid attack degrades the tooth surface, making it susceptible to more abrasive wear, so the phrase "erosive tooth wear" was established.[4] Erosive acids may originate intrinsically, as in stomach acid, or extrinsically, as found in acidic beverages and foods.[5] The pH and erosive capacity of gastric acid are considerably higher than those of dietary acids, resulting in a typically more severe level of damage.[6] Gastric acid enters the oral cavity via vomiting or regurgitation.[4] Eating disorders, including anorexia and bulimia nervosa, are recognized etiological factors in the onset of tooth erosion.[7] Regurgitation, characterized as the involuntary expulsion of gastric contents from the stomach into the mouth, is recognized as a prevalent cause of significant dental erosion.[8,9] A prevalent characteristic of medical problems that result in gastric acid entering the mouth cavity is gastroesophageal reflux disease (GERD). The term gastroesophageal reflux disease (GERD) refers to the symptoms and alterations of the esophageal mucosa caused by the reflux of gastric contents into the esophagus.[10] Reports indicate that 10–20% of the population is afflicted by GERD.[9] The relationship between GERD and dental erosion is illustrated by individuals with GERD subsequently diagnosed with dental erosion and patients with dental erosion later identified as having GERD.[11] Gastric acid possesses a markedly low pH (<2.0), significantly beneath the critical pH of enamel, hence presenting a considerable risk for erosive tooth damage.[12] GERD is an automatic reaction not regulated by the autonomic nervous system. There may be inadequate time for saliva to exert its effects prior to the onset of erosion.[9] Consequently, in conjunction with the composition of gastric acid, primarily consisting of 0.1 M Hydrochloric acid (HCl), with a pH of approximately 0.5, gastric acid may be regarded as the most perilous erosive acid for the degradation of dental hard tissues, potentially resulting in a decrease in an individual's vertical dimension of occlusion.[9] The rehabilitation of such situations can be rather complex, with the objective of preserving as much dental structure as possible.[9]

The resulting loss of tooth structure necessitates comprehensive restorative treatments. The selection of appropriate restorative materials is crucial for the long-term success of these treatments.[13] Contemporary dental practice utilizes a range of materials, including computer-aided design and computer-aided manufacturing (CAD/CAM) blocks made from ceramics, composites, or hybrid structures.[1,2,5,14] These materials offer several advantages, including efficient chair-side workflows and standardized industrial production.[13,15] Among these materials, lithium disilicate-reinforced glass ceramics and feldspathic ceramics are extensively used due to their advantageous mechanical and esthetic characteristics.[5] Additionally, resin composites, including microhybrid and nanofilled varieties, are frequently employed.[2] However, the oral environment presents several challenges to these materials. Factors such as pH fluctuations, humidity, temperature, and mechanical stress can influence their long-term performance.[16] In particular, acidic environments can cause significant surface changes, including increased roughness.[17,18] Studies have shown that exposure to gastric acid can lead to surface degradation, ion leaching, and reduced mechanical strength in various restorative materials.[2,11,19] These changes not only affect the material's structural integrity but also its esthetic qualities, leading to discoloration and increased plaque accumulation.[20,21]

Therefore, it is essential to understand how different restorative materials respond to acidic challenges, particularly from gastric acid. This understanding is crucial for selecting materials that offer both esthetic appeal and long-term stability in the oral environment. The objective of this study was to evaluate the effect of simulated gastric acid exposure on the surface properties of anterior composite, lithium disilicate-reinforced glass ceramics, and feldspathic ceramic after polishing. The null hypothesis proposed that there would be no difference in surface roughness and characteristics either among the groups or within each group prior to and following acid immersion.

Materials and Methods

Specimen Preparation of Sample Size

Determination of sample size was done by G*Power package. For n = 16, the analysis was based on a 95% confidence interval, 80% power, and effect size value of 0.40, with one-way ANOVA power analysis. A minimum sample size of sixteen specimens per category was established.

In conditions such as anorexia, bulimia, and gastroesophageal reflux disease, gastric acid frequently comes into contact with the enamel surface. In these situations, laminate veneer restorations on labial or palatal/lingual surfaces are often indicated, both as an esthetic and protective treatment. For this reason, composite resin, lithium disilicate-reinforced glass ceramic (LDS), and feldspathic ceramic (FC) block materials—commonly preferred for direct and indirect laminate veneer restorations in clinical practice—were included in this study.

Accordingly, fourty-eight square speciemens (10x10x2 mm) were manufactured and divided into the the following groups (n = 16):

- Anterior composite: G-aenial anterior composite (GC Corp, Tokyo, Japan) polished
- LDS: milled lithium disilicate-reinforced glass ceramic (Initial Lisi, GC, Corp, Tokyo, Japan) polished and no glazing
- FC: milled feldspathic ceramic (Cerec Block, Dentsply Sirona, USA) polished and no glazing

Detailed information on the materials is presented in Table 1. The specimens were sliced from the LDS and FC blocks under water cooling using a waterjet precision sectioning device (Metkon Micracut, Metkon Instruments) equipped with a low-speed diamond bur. The specimen surfaces were smoothed under water cooling using silicon carbide papers in a sequential manner with grit sizes of #600, #1200, #1500, and #2000, respectively (3M ESPE, St. Paul, MN, USA). The surface polishing process was performed using the ceramic polishing system (OptraFine, Ivoclar Vivadent AG, Schaan, Liechtenstein), following the manufacturer's recommendations.

G-aenial composite resin (GC Corp, Tokyo, Japan) samples were prepared using the incremental technique with the aid of pre-made transparent silicone matrices. Each surface was light-cured for 20 seconds using a light-emitting diode (LED) device (Guilin Woodpecker Medical Instrument Co., Ltd., Guilin, China). Subsequently, the surface polishing process was performed according to the manufacturer's recommendations using polishing discs (Sof-Lex, 3M ESPE, St Paul, MN, USA), which were replaced after every five samples. The entire polishing procedure was conducted by the same researcher. Following the polishing process, all sample surfaces were cleaned in an ultrasonic cleaning device (BioSonic UC50, Coltene/Whaledent) with distilled water.

Table 1. Detailed information about the used materials

Materials commercial name	Manufacturer	Composition	Lot No
G-aenial anterior composite	GC Corp, Tokyo, Japan	UDMA (Urethane dimethacrylate), dimethacrylate co-monomers, prepolymerized silica, strontium fluoride-containing fillers (77 wt%) Resin matrix: CQ, UDMA, 73 wt%/64 vol%, Prepolymerized fillers (16–17 mm; silica, strontium and lanthanoid fluoride), 850 nm silica, glass, 16 nm fumed silica • Resin matrix: CQ, UDMA, 73 wt%/64 vol%, prepolymerized fillers (16–17 mm; silica, strontium and lanthanoid fluoride), 850 nm silica, glass, 16 nm silica	2203071
Initial LiSi Block	GC Corp, Tokyo, Japan	Silica (SiO_2), Alumina (Al_2O_3), Lithium disilicate ($Li_2Si_2O_5$), other minerals and oxides 55–80% SiO2, 10–30% Li2O; 5–20% other oxides; pigments: trace	2305191
Cerec Block	Dentsply Sirona	Silica (SiO_2), Alumina (Al_2O_3), Potassium oxide (K_2O), Sodium oxide (Na_2O), Calcium oxide (CaO), Titanium dioxide (TiO_2), pigments Oxide % of total weight SiO2 56 - 64, Al2O3 20 - 23, Na2O 6 - 9, K2O 6 - 8, CaO 0.3 - 0.8, TiO2 0.0 - 0.1, Pigments < 0.1	97480

Preparation of the Simulated Gastric Acid and Immersion Protocol

A standardized gastric acid solution was prepared according to the method of Hunt and McIntyre to simulate erosive conditions comparable to those observed in clinical settings. Specifically, hydrochloric acid (HCl) 0.06 M (0.113% solution in deionized water, pH 1.2) was used, as it has been shown to produce enamel erosive lesions similar to those seen clinically.[22]

The pH of the solution was monitored every 24 hours to ensure stability. Each specimen was immersed in 5 mL of the acidic solution with the polished surface facing upward and maintained at 37°C in an incubator (Termaks, Bergen, Norway) for a total duration of 96 hours. The immersion period of 96 hours was chosen based on literature, as this duration has been estimated to correspond to more than ten years of clinical exposure to gastric acid.[9]

Scanning Electron Microscopy (SEM)

One randomly selected specimen from each group underwent SEM analysis both before and after acid exposure. The specimens were mounted in a charge-reduction specimen holder and examined using a scanning electron microscope (SEM) (JSM-6400 SEM, JEOL, Tokyo, Japan) in backscattered mode under low-vacuum conditions. SEM images were captured at an accelerating voltage of 15 kV with magnifications of ×500 and ×1000.

Surface Roughness (Ra) Measurement

The surface roughness (Ra) of the specimens was assessed both at baseline and after 96 hours of exposure to HCl using a contact-type profilometer with a stylus (Perthometer M2, Mahr GmbH, Göttingen, Germany). To ensure uniform positioning across all measurements, each specimen was secured on a custom-designed jig. The stylus was carefully placed on the specimen surface, and readings were recorded. Three successive measurements were obtained in different orientations (vertical, horizontal, and transversal), recording readings from multiple directions originating from the center of each specimen's surface and averaged. The instrument was calibrated after every three measurements.

Statistical Analysis

The data collected in this study were analyzed using SPSS package (22.0, SPSS organization, Chicago, USA). The Shapiro-Wilk test was used to evaluate the normality of the dataset. Since the data followed a normal distribution, ANOVA was used to compare differences between groups, while paired t-tests were applied for within-group comparisons. A significance threshold of 0.05 was set, with p-values < 0.05 considered statistically significant, whereas p-values > 0.05 indicated no significant difference.

Results

Ra Values of Materials Before Acid Exposure:

Since the Ra values of G-aenial anterior composite, Initial Lisi and Cerec Block materials are quite similar to each other before acid exposure, no significant difference in surface roughness is observed among them ($p > 0.05$). The Ra values of the materials before acid exposure are presented in Table 2.

Table 2. Ra values of materials before acid exposure and statistical analysis using ANOVA

		Group						Anova		
		n	Mean	Median	Minimum	Maximum	ss	F	p	Tukey HSD
Before acid exposure	G-aenial anterior composite	16	0.13	0.14	0.01	0.24	0.08	0.182	0.834	-
	Cerec Block	16	0.14	0.15	0.02	0.33	0.07			
	GC LiSi	16	0.13	0.14	0.07	0.18	0.03			
	Total	48	0.13	0.15	0.01	0.33	0.06			

Ra Values of Materials After Acid Exposure:

Following acid exposure, a statistically significant difference in surface roughness was observed among the materials ($p = 0.002 < 0.05$). Post hoc analysis using the Tukey HSD test revealed that the GC LiSi group exhibited significantly lower Ra values compared to the other two materials. The Ra values obtained after acid exposure are summarized in Table 3.

Among the tested groups, Cerec Block demonstrated the highest surface roughness (0.29 µm), whereas the G-aenial Anterior composite showed intermediate values, higher than GC LiSi but lower than Cerec Block. GC LiSi exhibited the lowest post-exposure surface roughness (0.14 µm).

Table 3. Ra values of materials after acid exposure and statistical analysis using ANOVA

		Group						Anova		
		n	Mean	Median	Minimum	Maximum	sd	F	p	Tukey HSD
After acid exposure	G-aenial anterior composite	16	0.22	0.23	0.06	0.52	0.13	6.97	0.002	3-1 3-2
	Cerec Block	16	0.29	0.30	0.02	0.55	0.14			
	GC LiSi	16	0.14	0.11	0.02	0.29	0.07			
	Total	48	0.22	0.22	0.02	0.55	0.13			

Within-Group Comparisons

G-aenial Anterior composite: Ra values increased from 0.13 to 0.22 µm after acid exposure, and this difference was statistically significant ($p = 0.032 < 0.05$) (Table 4).

GC LiSi: Ra values increased slightly from 0.13 to 0.14 µm; however, this change was not statistically significant ($p = 0.698 > 0.05$) (Table 5).

Cerec Block: Ra values increased from 0.14 to 0.29 µm following acid exposure, and this difference was statistically significant ($p = 0.001 < 0.05$) (Table 6).

SEM Observation

SEM images were utilized to assess the surface characteristics of the specimens prior to and following acid immersion. Visual examination revealed porosity on the surfaces of anterior composite (G-aenial anterior), lithium disilicate-reinforced glass ceramic (GC Initial LiSi), and feldspathic ceramic (Cerec Block) specimens following acid immersion (Figure 1aX–2cY). GC LiSi Block exhibited a rougher surface after acid immersion, indicating that the crystalline component dissolves at a slower pace than the glass matrix, resulting in a rougher surface texture. In SEM images, the most significant surface change after acid was observed in the Cerec Block group, consistent with the statistical surface roughness values. An irregular dissolution of the surfaces was noticed for G-aenial anterior composite. The SEM images of all analyzed materials exhibited an augmentation in surface imperfections during storage in gastric acid. Even minimal surface roughening can result in heightened wear on the opposite dentition and enhance bacterial adhesion via mechanical entrapment. A positive association between plaque accumulation and surface roughness has been showed.

Table 4. Distribution of Ra values in the G-aenial anterior composite group before and after acid exposure

	G-aenial anterior composite						Paired t testi	
	n	Mean	Median	Minimum	Maximum	ss	t	p
Before acid exposure	16	0.13	0.14	0.01	0.24	0.08	-2.36	0.032
After acid exposure	16	0.22	0.23	0.06	0.52	0.13		

Table 5. Distribution of Ra values in the GC Lisi group before and after acid exposure

	GC Lisi						Paired t testi	
	n	Mean	Median	Minimum	Maximum	ss	t	p
Before acid exposure	16	0.13	0.14	0.07	0.18	0.03	-0.395	0.698
After acid exposure	16	0.14	0.11	0.02	0.29	0.07		

Table 6. Distribution of Ra values in the Cerec Block group before and after acid exposure

	Vita Cerec						Paired t testi	
	n	Mean	Median	Minimum	Maximum	ss	t	p
Before acid exposure	16	0.14	0.15	0.02	0.33	0.07	-4.1	0.001
After acid exposure	16	0.29	0.30	0.02	0.55	0.14		

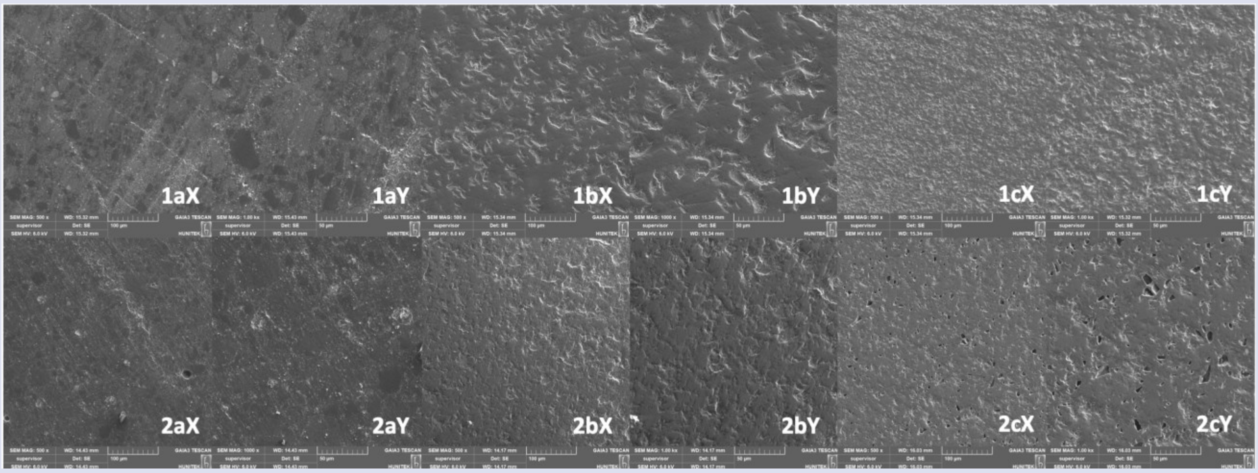

Figure 1. Scanning electron microscope (SEM) images of the composite resin (a), LiSi glass ceramic (b), feldspathic ceramic (c); before (1) and after (2) simulated gastric acid exposure. X= x500 magnifications, Y= x1000 magnifications.

Discussion

This in vitro study aimed to evaluate the effects of simulated gastric acid exposure on the surface roughness of anterior composite resin, lithium disilicate-reinforced glass ceramic, feldspathic ceramic materials after polishing. The results showed that, while there was no statistically significant change in surface roughness in the lithium disilicate-reinforced glass ceramic (LDS) group following acid exposure, a significant increase in surface roughness was observed in the feldspathic ceramic (FC) and anterior composite resin groups. Therefore, the null hypothesis was partially rejected.

Gastric acid attacks associated with conditions such as gastritis and GERD can lead to progressive damage and substantial material loss in dental tissues. In such cases, laminate veneer restorations are frequently recommended as both a protective measure and a means to restore lost function and esthetics.[23] For laminate veneer restorations, composite resins are commonly used in direct techniques, while high-esthetic glass ceramics are preferred in indirect techniques.[24]

In this study, composite resin, lithium disilicate-reinforced glass ceramic blocks, and feldspathic ceramic materials were used. To simulate severe acid attacks, previous studies were referenced, and the polished samples were immersed in a 0.2 mol HCl solution (pH 1.2) for 96 hours at 37 °C, aiming to recreate a 10-year clinical scenario.[5,9] However, in diseases such as reflux and bulimia nervosa, where stomach acid comes into contact with the oral cavity, there is a demineralization-remineralization cycle. Clinical conditions and the buffering remineralization mechanism of saliva could not be simulated the experiment.

Surface roughness was evaluated using a contact profilometer and SEM, allowing for both quantitative and qualitative assessment of topographical changes. In this study, among the materials with similar surface roughness values before acid exposure. This study is consistent with the study of Alnasser et al.[25] After acid exposure, no statistically significant difference was observed in the Ra values of the LDS group, while a statistically significant difference was found in the composite resin and CEREC groups. The local composition and microstructure of the restorative material are the main reasons for surface roughness changes.[26]

The study confirmed that acidic exposure affects the glassy phase of restorative materials, leading to surface degradation.[27] Literature findings suggest that GERD-related gastric acid exposure alters the surface properties of dental materials over time.[10,28,29] Among the tested materials, feldspathic ceramics (CEREC group) showed the most pronounced increase in surface roughness after acid exposure. Additionally, visible changes in optical properties were noted in this group, though this aspect requires further investigation.

The Ra value of the composite resin material increased from 0.13 µm before acid exposure to 0.22 µm after exposure, and this increase was found to be statistically significant ($p < 0.05$). This finding is consistent with previous studies, indicating the susceptibility of composite materials to acidic environments.[19,20] The alteration of surface characteristics in composite resins under acidic conditions can be attributed to the degradation of the organic matrix by hydrogen ions and the detachment of inorganic filler particles from the surface.[2]

The results of this study align with those reported by Somacal et al.[20], who found that gastric acid exposure increases the surface roughness of composite materials, which in turn may enhance bacterial adhesion. The acidic environment weakens the filler-matrix bond of the composite resin, leading to a rougher surface. However, Harryparsad et al.[30] suggested that prolonged acid exposure might decrease surface roughness in certain ceramics. Nonetheless, this effect was not observed in composite materials, where surface degradation became more pronounced.

When compared to lithium disilicate-reinforced glass ceramic (GC Lisi), composite resins exhibited a more significant change in surface roughness. While no statistically significant difference was observed in the Ra values of lithium disilicate after acid exposure ($p > 0.05$), the significant increase in roughness in composite materials suggests that they are less resistant to acidic conditions.

Some studies in the literature have reported a significant increase in roughness after the effect of gastric acid on a lithium disilicate-reinforced glass ceramic,[9,10] however, this is not observed in the current study. According to Sulaiman et al.,[9] the glass-like matrix of lithium disilicate glass-ceramic dissolves faster than the crystalline grains, leading to the formation of a rougher surface. However, in another study [30] the erosion pattern of lithium disilicate glass-ceramic when exposed to hydrochloric acid led the authors to hypothesize that longer exposure would result in a smoother material compared to the starting point, which is consistent with the present study. Presumably, the initial removal of the glass-like matrix on the surface would result in the appearance of the crystalline phase, which would undergo acidic attack and reduce the surface roughness.

According to the previous study [30] the size of glass particles lost after acidic solution in glass ceramics is directly proportional to the amount of change in surface roughness. Therefore, since the grain size of feldspathic porcelain (4 micrometers) is larger than lithium disilicate (0.2-1.0 micrometers), it shows more change in surface roughness than lithium disilicate.

In summary, this in vitro study demonstrated that feldspathic ceramics were the most affected by gastric acid exposure, followed by composite resin, while lithium disilicate-reinforced glass ceramics exhibited the highest resistance.

Overall, this study provides valuable insights into the behavior of different restorative materials under acidic conditions; however, it also has certain limitations that should be acknowledged, as in vitro experiments cannot fully replicate the complexity of the oral environment. In vivo, restorative materials are simultaneously exposed to multiple factors, including salivary flow and buffering capacity, pH fluctuations, temperature changes, mechanical forces such as mastication or bruxism, and the presence of oral microbiota. These dynamic interactions were not simulated in the present work. Moreover, only surface roughness was evaluated, although other clinically relevant parameters such as microhardness, color stability, optical characteristics, and bacterial adhesion could provide a more comprehensive understanding of the impact of gastric acid exposure. In addition, feldspathic and lithium disilicate ceramics were tested only in their polished form without glazing. While this approach allowed for direct assessment of the material's response to acid, it does not fully represent clinical conditions, since feldspathic ceramics are routinely glazed prior to intraoral use. Therefore, the findings of this study should be interpreted within these limitations, and future research should include a wider variety of restorative materials, assess multiple surface and mechanical properties, and simulate dynamic intraoral conditions to provide more clinically relevant insights.

Conclusions

Within the limitations of this in vitro study, it can be stated that restorative materials respond differently to gastric acid challenges. The findings underline the clinical importance of careful material selection for patients who are at risk of recurrent exposure to gastric acid, such as those with gastroesophageal reflux disease or eating disorders. Selecting materials with higher resistance to acidic environments is therefore essential for ensuring long-term functional and esthetic success. In addition, the study emphasizes the need to consider not only laboratory outcomes but also intraoral variables, including salivary buffering and mechanical wear, when assessing long-term material performance. Future investigations incorporating these dynamic factors will provide more comprehensive insights into the clinical durability of restorative materials.

Conflicts of Interest Statement

The authors declare no conflict of interests.

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