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Original article

The effects of simulated gastric acid on the mechanical, optical, and physicochemical properties of different esthetic CAD-CAM materials

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Abstract

Purpose: To investigate the effects of coffee and orange juice on 3 different esthetic ceramic materials regarding color changes, Vickers microhardness, and solubility & sorption changes among patients with reflux.

Methods: A glass-ceramic material (IPS Emax CAD), a polymer-infiltrated ceramic material (Vita Enamic), and a nano-hybrid ceramic material (Cerasmart) were selected for this study (n=32/group). Following the polishing procedure, all the samples were immersed in artificial saliva for 21 days. Half the samples were assigned to the control group and exposed only to artificial saliva (pH 7.3). The remaining 16 samples were exposed to saliva or simulated gastric acid. Sixteen samples from each group were exposed to gastric acid 3 times daily for 30 seconds. The color, Vickers microhardness, and solubility & sorption were then measured. Following this procedure, the samples were exposed to coffee and orange juice (n=8/per group). The samples were exposed to the solutions for 16 hours and 48 minutes to simulate 21 days of consumption. Final measurements were then obtained. Statistical significance was determined using Levene's test to compare variances, and three-way analysis of variance (ANOVA) followed by Tukey's post-hoc test, Welch's ANOVA, and Games–Howell's test were applied to reveal differences between groups.

Results: According to ANOVA, restorative material type and immersion media had a significant effect on color change ($P < 0.001$), microhardness ($P < 0.001$), and solubility & sorption ($P < 0.001$).

Conclusions: The choice of material is crucial for erosion-prone patients.

Keywords: CAD-CAM ceramics, Gastric reflux, Color, Hardness, Solubility

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1. Introduction

The oral cavity is a highly dynamic and challenging environment, in which both natural tooth structures and dental restorations are continuously subjected to various factors that can alter their physical and chemical properties[1]. Dental restoration is required in situations such as trauma, dental caries, abrasion, erosion, and congenital anomalies[2]. Various studies confirmed that exogenous or endogenous factors are responsible for erosion of dental hard tissues and changes in surface, in color, in hardness, in weight and in water solubility of restorations[3,4]. Exogenous factors cause these problems through excessive consumption of acidic beverages, such as fruit juices and coffee, while endogenous factors, such as exposure to gastric acid, are also responsible for these problems, especially in patients with reflux[4].

Gastroesophageal reflux disease (GERD) is a dysfunction or insufficiency of the antireflux barrier that may lead to the development of this chronic pathological condition. Under normal physiological conditions, the retrograde flow of gastric contents into the esophagus is prevented by the lower esophageal sphincter, which constitutes the primary component of the antireflux mechanism[5]. Dental erosion is recognized as the primary oral manifestation of gastroesophageal reflux disease, initially presenting as subtle alterations in the enamel surface and potentially progressing to a substantial loss of tooth structure, which has various effects on dental restorations[6]. The objectives of treatment are to eliminate the underlying causes of acid

WHAT IS ALREADY KNOWN ABOUT THE TOPIC?

» *Dental restorations are exposed to various challenges in the oral environment including acidic agents from diet and reflux. However, limited research is available on the effects of simulated gastric acid on the mechanical, optical, and physicochemical properties of different esthetic CAD-CAM materials.*

WHAT THIS STUDY ADDS?

» *Although gastric reflux did not exert a significant influence on the properties of the various esthetic CAD-CAM materials, the type of immersion medium may considerably affect their behavior. Furthermore, the choice of restorative material is a critical factor in the management of patients susceptible to erosion.*

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Table 1. Materials and their specifications used in the study

Material	Type	Manufacturer	Lot no.	Composition
Cerasmart	Hybrid nanoceramic	GC Dental Products Europe, Leuven, Belgium	1504291	Composite resin material (BisMEPP*, UDMA**, DMA***) with 71 wt% silica and barium glass nanoparticles
Vita Enamic	Polymer infiltrated ceramic	VITA Zahnfabrik, Bad Säckingen, Germany	43660	86 wt% feldspar ceramic, 14 wt% polymer
IPS Emax CAD	Lithium disilicate glass-ceramic (LS2)	Ivoclar Vivadent, Schaan, Liechtenstein	Z0366W	Lithium disilicate glass ceramic CAD/CAM blocks (SiO_2 57-80%, Li_2O 11-19%, K_2O 0-13%, P_2O_5 0-11%, ZrO_2 0-8%, ZnO 0-8%, others and coloring oxides 0 - 12%

*Bisphenol A methacryloyloxy polyethoxyphenyl propane; ** Urethane Dimethacrylate; *** Dimethacrylate

exposure, mitigate its effects when complete control is not feasible, and manage the symptoms associated with soft tissue irritation and dental erosion, as well as restoration of dentition to a functionally and esthetically acceptable condition. Definitive restorative treatment of the dentition should be deferred until adequate control of the underlying reflux disorder is achieved[6].

Restorative materials in the oral cavity are also frequently exposed to dynamic challenges, such as oral masticatory forces and changes in pH and temperature. To mitigate the adverse effects of these challenges on both teeth and restorations, it is essential for restorative materials to exhibit optimal resilience and longevity within the intraoral environment[7].

In dentistry, various types of ceramic materials, such as glass-ceramics, hybrid ceramics, and resin nanoceramics, are used. IPS Emax CAD (Ivoclar Vivadent, Schaan, Liechtenstein) is a glass-ceramic material commonly used as a veneering ceramic in dentistry[1]. In particular, it is the best material for esthetics. However, it shows some limitations, such as low strength and brittleness, which can lead to fracture[8]. However, it exhibits great translucency. Because of this property, hybrid ceramics have been created as alternatives to glass-ceramics[9]. Vita Enamic (VITA Zahnfabrik, Bad Säckingen, Germany), which is a CAD/CAM hybrid ceramic composed of a dominant ceramic matrix (Feldspar) and infiltrated by a polymer (UDMA and TEGDMA), was manufactured in 2013. Moreover, it has characteristics of both composites and ceramics. This material shows high strength and resistance, and is considered to have mechanical properties similar to those of natural teeth[10]. The color stability of this category is important and should be monitored over time[11]. Cerasmart (GC Dental Products Europe, Leuven, Belgium) is also a hybrid ceramic/resin nanoceramic that contains a nano-hybrid resin composite and inorganic ceramic fillers, which are mainly 71% silica and barium glass by weight. It has high fracture resistance and high strength under compressive load[12].

The intraoral exposure of ceramic restorations to acidic agents can alter their mechanical properties, which vary depending on the material's specific microstructure and chemical composition[13]. In addition, the restorative material is intended to substitute the absent tooth structure; it must possess sufficient strength to endure the forces linked with chewing[14]. There will be some changes in the properties after exposure to erosive products. Consequently, this study sought to examine the impact of coffee and orange juice on three distinct esthetic ceramic materials in terms of color variation, Vickers Hardness Number (VHN), and solubility & sorption in patients experiencing reflux.

The null hypotheses were as follows: 1) Orange juice and coffee would have no effect on the microhardness of the investigated ceramic materials in a patient with reflux. 2) There would be no difference in the color of the different materials in the patients with reflux. 3) The water sorption of the tested ceramic materials would not be different after orange juice and coffee solutions in patients with reflux. 4) Exposure to orange juice and coffee solutions would not produce a statistically significant difference in the solubility of the tested ceramic materials in patients with reflux.

2. Materials and Methods

2.1. Preparation of the samples

A glass-ceramic material (IPS Emax CAD), polymer-infiltrated ceramic material (Vita Enamic) and a nano-hybrid ceramic material (Cerasmart) were selected for this study (n=32/group). The test materials, manufacturers, and their compositions are listed in **Table 1**. Each disc-shaped sample with a 10 mm diameter and 1.5 mm height was polished with metallographic SiC papers (FEPA-P #400, 600, 800, and 1000 grit) at the baseline under water cooling. Each sample was ultrasonically cleaned (Quantrex 90; L&R Ultrasonics, Kearny, NJ, USA) in distilled water for 10 min and air dried for 20 sec before testing. Subsequently, the samples were stored dry in the dark at 37°C for 24 h before testing.

Before the assessment, all samples were immersed in artificial saliva for 21 days. Artificial saliva was formulated by dissolving the following components in 1 L of deionized water at specified concentrations (g/L): xanthan gum (0.92), KCl (1.2), NaCl (0.85), $MgCl_2$ (0.05), $CaCl_2$ (0.13), NaH_2PO_4 (0.13), and $C_8H_8O_3$ (0.13)[15]. Sixteen of the 32 samples for each material group were separated into the control group and exposed only to artificial saliva (pH 7.3). The remaining 16 samples were exposed to saliva and gastric acid. The simulated gastric acid was prepared according to the method described by Hunt and McIntyre. A 0.06 M hydrochloric acid (HCl) solution (0.113% in deionized water, pH 1.2) was utilized[16]. Throughout the study, a gastric acid solution was freshly prepared each day. Sixteen samples from each group were exposed to gastric acid 3 times daily for 30 seconds. Using this procedure, we attempted to imitate the 21-day oral condition of a patient with reflux[17,18]. Then, the color, weight, and microhardness were measured.

Following this procedure, the samples were exposed to coffee and orange juice. Before adding the samples, the initial pH of the solutions was assessed using a pH meter (Jenway 3510 Standard Digital pH Meter, Cole-Parmer North America 625 East Bunker Court Vernon Hills, IL 60061, USA). The pH levels of the various immersion solutions were artificial saliva= 7, orange juice= 3.7, and coffee= 4.9-5.2[1]. Samples of each restorative material were divided into two subgroups: immersion in coffee and orange juice (n=8/per group). The samples were exposed to the solutions for 16 hours and 48 minutes to simulate 21 days of consumption. According to Guler *et al.*, a 24-hour immersion in coffee is considered to simulate the effects of approximately 30 days of regular consumption under clinical conditions[19]. The first measurement for each sample was performed before artificial saliva or gastric acid exposure. The second measurement for each sample was performed after artificial saliva or gastric acid exposure. The third measurement was performed after immersion in coffee and orange juice.

2.2. Color analysis

The samples were assessed using a reflective spectrophotometer (M-700d, Konica Minolta Sensing, Inc., Osaka, Japan) to evaluate the optical characteristics. The aperture dimension was adjusted to 4 mm, and the samples were meticulously aligned with the instrument. Assessments were conducted at the midpoint of each sample against a white and black backdrop in relation to the CIE standard illuminant D65 and a 2-degree standard observer. The samples were positioned at the center of the measuring port and maintained in the same orientation for both backgrounds. Assessments were repeated three times for every sample without replacement, and the results were averaged to derive a singular value for each specific sample[11]. The alteration in color (ΔE_{00}) for every sample was determined by computing the color variation of the sample in contrast to a white backdrop (w) according to the CIEDE 2000 color difference formula (ΔE_{00}), prior to and after acid exposure, following the equation provided below[20]:

$$\Delta E_{00} = \left[\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta C'}{K_C S_C}\right)^2 + \left(\frac{\Delta H'}{K_H S_H}\right)^2 + R_T \left(\frac{\Delta C'}{K_C S_C}\right)\left(\frac{\Delta H'}{K_H S_H}\right)\right]^{1/2}$$

In this study, ΔL′, ΔC′, and ΔH′ represent the differences in lightness, chroma, and hue, respectively. The correction factors KL, KC, and KH were introduced to account for potential variations in the experimental conditions and were assigned a value of 1. The parameters SL, SC, and SH represent the weighting functions applied to the lightness, chroma, and hue components, respectively[21,22].

2.3. Vickers microhardness test

Microhardness values were measured using a microhardness instrument (Shimadzu HMV; Shimadzu Corporation, Tokyo, Japan), where a 200-gr force was applied gently without impact, pressing the indenter into the sample under examination. The indenter was maintained in this position for 15 sec. The material properties of the indenter and the precision of the exerted load were monitored to achieve accurate results. Once the load was lifted, the indentation was examined using a magnifying lens, and the two diagonals of the impression were measured to the nearest 0.1 μm using a micrometer, then averaged[12].

2.4. Solubility & sorption test

A total of eight disc-shaped specimens per group (1.5 mm thick, 10 mm in diameter) were fabricated using a stainless-steel mold positioned between two glass slides lined with matrix (Mylar) strips to ensure a uniform surface finish. The samples were kept in a drying oven at a temperature of 37 °C for a duration of 24 h, and their weights were assessed using a precision analytical balance with an accuracy of 0.001 g (GR-200, A&D Company Limited, Toshimaku, Tokyo, Japan). This procedure was repeated until a stable weight (m_1) was obtained. To assess the sample volume, the diameter and thickness of each sample were measured using a digital caliper with an accuracy of 0.001 mm (Mitaka, Japan) at three locations, and the average value was calculated. Each sample was subsequently placed into a sealed plastic container filled with approximately 10 ml immersion media (coffee and orange juice) at a temperature of 37 °C. The coffee and orange juice bottles were agitated before being poured into the containers to ensure that all components were uniformly dispersed. At regular time intervals, the samples were removed, patted dry to eliminate surplus fluid, weighed, and placed back into the liquid bath[23].

Solubility & sorption of the samples were determined in accordance with BS EN ISO 4049:2019 employing the subsequent formula[24]: Sorption = $m_2 - m_3/V$; Solubility = $m_1 - m_3/V$, where m_1 represents the mass under specific conditions, m_2 signifies the mass of the sample following 21 days of submersion, and m_3 denotes the mass of the sample after it has been reconditioned.

2.5. Statistical analysis

The data were analyzed for normal distribution (Shapiro–Wilk's test) with determination of skewness and kurtosis parameters. A three-way ANOVA and the Welch ANOVA analysis was selected to investigate the effects of different factors (material, agent and reflux) on color, microhardness test, and solubility & sorption of 3 ceramic materials ($P < 0.001$). Tukey's honest significant difference (HSD) or Games-Howell post-hoc tests were performed to determine statistically significant differences between the groups. Multiple comparisons arising from significant ANOVA findings were adjusted using the Bonferroni post-hoc test for multiple pairwise comparisons to control for type 1 errors. Statistical significance was set at $P < 0.05$, with a 95% confidence interval applied to the mean values; all tests were 2-tailed. (SPSS 31.0, Chicago, IL).

3. Results

3.1. Color change (ΔE)

The color analysis used in this study is shown in **Figure 1**. Levene statistics showed that variances for ΔE values of tested materials between the groups was not equal ($P < 0.05$). Welch ANOVA showed that the effect of restoration material and immersion media has significant effect on color ($P < 0.001$ for each parameter). However, the presence of gastric acid did not statistically significantly affect the color of the materials ($P = 0.003$). There was a significant interaction between the restoration materials and immersion media ($P < 0.001$). The mean ΔE values of tested materials can be ranked as follows: Vita Enamic ≥ Cerasmart > IPS Emax CAD ($P < 0.05$).

3.2. Vickers microhardness test

For the Vickers microhardness measurement, the distribution normality test results were statistically significant at $P < 0.001$ just for the tested materials. In contrast, the variances were equal for the immersion media ($P = 0.151$) and gastric acid ($P = 0.334$). Welch's robust variance and Games-Howell's post-hoc tests revealed that the tested restoration materials varied statistically significantly ($P < 0.001$). However, the immersion media and presence of reflux had no significant

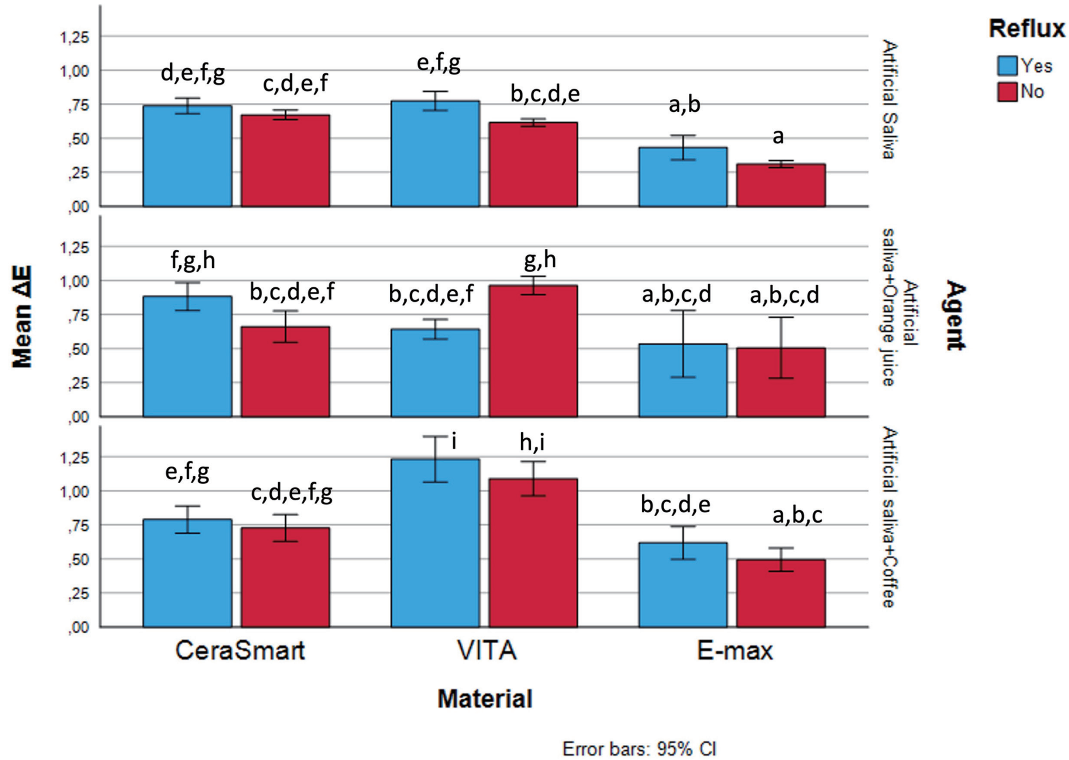

Fig. 1. Color analysis values based on different immersion medias, restoration materials and the presence or absence of reflux disease. Groups with different letters have statistically significant differences from each other (significance level: $P < 0.05$).

effect on the microhardness ($P = 0.656$ and $P = 0.844$, respectively).

The microhardness differed for the tested materials and was affected by the tested solutions ($P < 0.001$).-The statistical ranking for microhardness mean values among restoration materials was obtained as follows: IPS Emax CAD > Vita Enamic > Cerasmart ($P < 0.05$). The microhardness test results are shown in **Figure 2**.

3.3. Sorption test

Levene's test revealed an unequal variance across the sorption results ($P < 0.004$). According to the statistical analysis, the tested restorative materials displayed different sorption values ($P < 0.05$). The order of overall sorption values among the tested restorative materials was Cerasmart > Vita Enamic > IPS Emax CAD ($P < 0.05$). Additionally, a significant effect of restoration material ($P < 0.001$) and immersion media was found on sorption characteristics ($P < 0.05$), and no significant alteration was observed in the presence of simulated gastric acid ($P = 0.03$). The sorption characteristics of the tested restorative materials after immersion in various solutions in the presence of simulated gastric acid are presented in **Figure 3**.

3.4. Solubility test

The variances were equal for the solubility test results ($P = 0.428$). Statistical analysis revealed that the restorative materials had similar solubility values ($P = 0.225$). Additionally, a three-way ANOVA revealed no significant interaction between the independent variables (restorative materials, immersion media, and presence of reflux) for the solubility values ($P = 0.007$), and the presence of simulated gastric acid was not significant ($P = 0.114$). However, the solubility was affected by the immersion medium tested ($P < 0.001$). Moreover, the variation in the tested restoration material was not statistically significant ($P = 0.081$). The mean solubility values of the test groups are shown in **Figure 4**.

4. Discussion

This study was conducted to evaluate the effect of exposure to orange juice or coffee on restorations in patients with or without reflux. Ceramics are primary materials used in prosthetic rehabilitation. In addition, the persistent nature of systemic conditions such as chronic reflux raises concerns about the long-term durability and performance of these materials in affected patients. Although ceramics have undergone significant advancements in recent decades resulting in enhanced optical and functional properties, the extent to which these characteristics are compromised in acidic oral environments remains to be fully elucidated[25]. It is imperative that clinicians consider the potential impact of gastric acid on the selected restorative materials. The chemical resistance of dental materials is a fundamental requirement for successful intraoral application and serves as a critical criterion in the selection of appropriate restorative options[26]. In addition, dental ceramics are among the most chemically stable restorative materials[27]. The results of this study demonstrated that the presence of reflux did not affect the microhardness of CAD/CAM ceramic materials, leading to the acceptance of the first hypothesis; that is, orange juice and coffee would have no effect on the microhardness of the investigated ceramic materials in a patient with reflux.

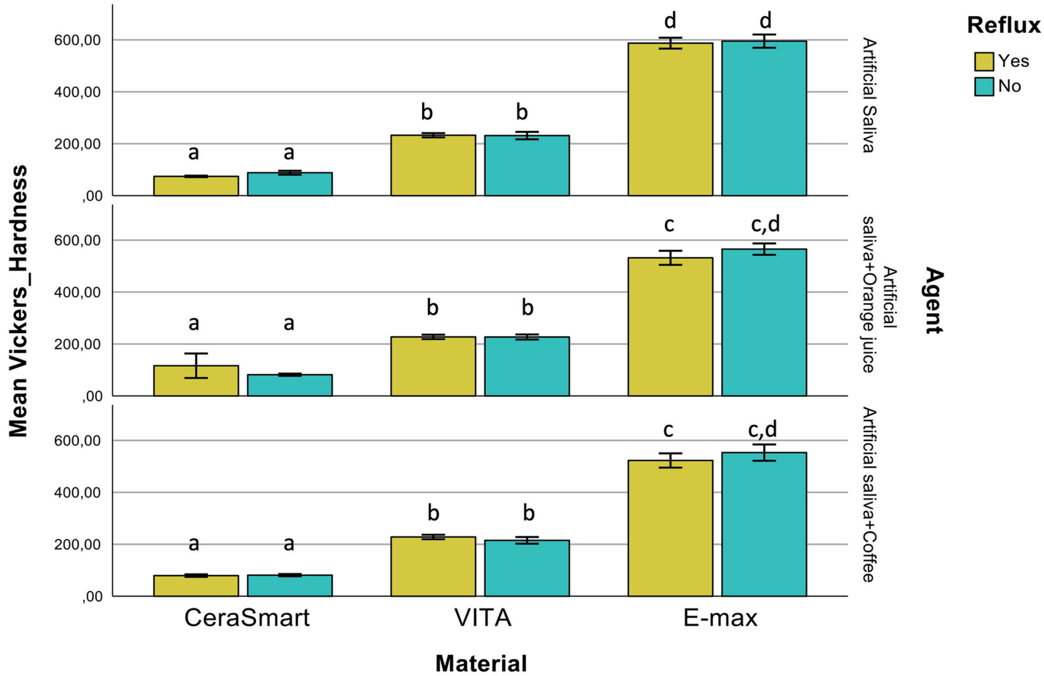

Fig. 2. Vicker's microhardness test results analysis based on different immersion medias, restoration materials and the presence or absence of reflux disease. Groups with different letters have statistically significant differences from each other (significance level: $P < 0.05$).

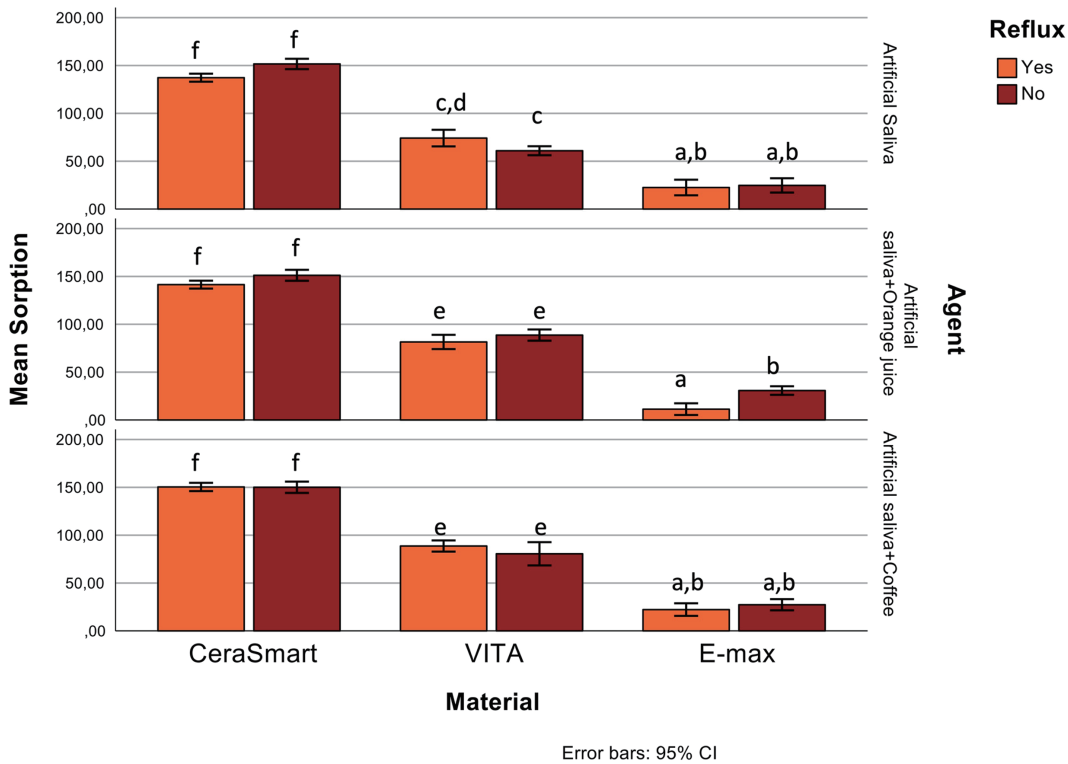

Fig. 3. Sorption characteristic of the tested restorative materials after immersion in various solutions and the presence of reflux disease. Groups with different letters have statistically significant differences from each other (significance level: $P < 0.05$).

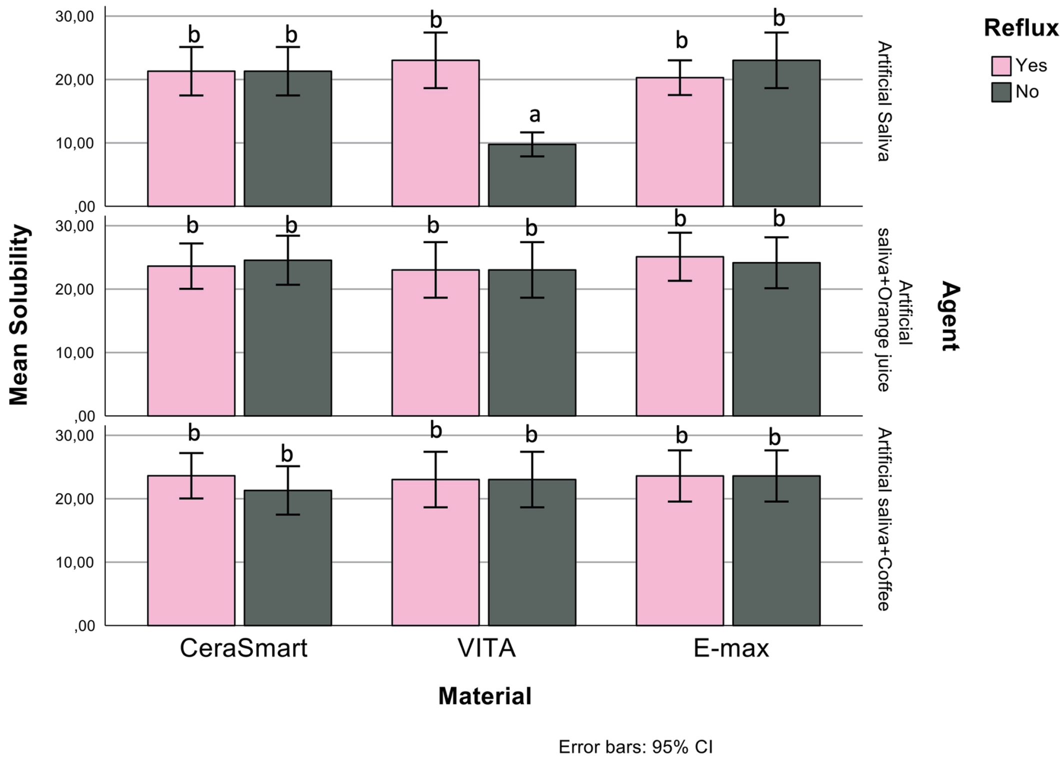

Fig. 4. Solubility characteristic of the tested restorative materials after immersion in various solutions and the presence of reflux disease. Groups with different letters have statistically significant differences from each other (significance level: $P < 0.05$).

Gastric acid is known to demineralize enamel, dentin, and cement. Owing to its very low pH, it can dissolve the glassy matrix of ceramic materials[26]. However, their properties may be influenced by various factors, including the composition and microstructure of the ceramic, the chemical nature of the material itself, the chemical characteristics of the abrasive or acidic agents to which the ceramic is exposed, the duration of exposure, and the environmental temperature[27]. Gulakar *et al.* analyzed the different properties of restorative materials and concluded that exposure to gastric acid adversely influences the hardness of dental restorative ceramic materials, with varying effects observed among different types of ceramics; IPS Emax CAD demonstrated superior resistance to acidic degradation, suggesting that it may be a preferable choice for restorative treatments in patients with GERD and bulimia nervosa to mitigate the deleterious effects of gastric acid[27]. Similarly, in the present study, IPS Emax CAD was the least affected by gastric acid exposure.

In some studies, in contrast to acid exposure, the type of material played a more significant role in determining the hardness, as it demonstrated a markedly high effect size on this property[28].

Several mechanisms have been proposed to explain the degradation of dental ceramics under aqueous and acidic conditions. Upon exposure to such conditions, alkali oxides, primarily sodium and potassium, leach from the glassy matrix, leading to the formation of porosities and diffusion pathways that facilitate the movement of water molecules. This process ultimately disrupts the siloxane (Si–O–Si) bonds within the glass network. The significantly higher stability of alkali oxides in the crystalline phase than that in the glassy phase may account for the different degrees of degradation observed among dental materials[29]. In previous studies, the concentration of released ions from dental materials can vary substantially depending on the type of material, the pH level of the solution and the duration of exposure and the effects of simulated gastric fluid and citric acid on various composite resins, particular attention has been given to the acid-induced softening of the polymer matrix. The observed change in the material is likely attributable to the dissolution of the ceramic phase, which constitutes most of the structure[27].

Therefore, the presence of reflux had no significant effect on the microhardness. However, after immersion in orange juice and coffee, all tested ceramic materials differed significantly in the microhardness test. In addition, the IPS Emax CAD showed the highest result, whereas Cerasmart had the lowest. This can be attributed to variations in the microstructural composition and inherent material behavior of the ceramics. As Vita Enamic had the highest filler loading and substantial ceramic content, Cerasmart had a resin matrix composition[30].

The second null hypothesis, that is, there would be no difference in the color of different materials between patients with reflux, was accepted. A previous study by Aldamaty *et al.* investigated the effect of simulated gastric acid exposure on the optical properties of monolithic ceramics. In that study, different ceramic materials such as Ceramill Zolid fx, IPS Emax CAD, Vita Suprinity, and Cerasmart were tested. Among the tested materials, Cerasmart exhibited the highest degree of color change. According to this study, this was attributed to the resin matrix composition, followed by group IPS Emax CAD, Vita Suprinity and the least change was with group Ceramill Zolid fx. Following immersion in simulated gastric acid, Zolid fx demonstrated the highest color stability and greater resistance to aging than the partially stabilized zirconia, whereas Cerasmart showed the lowest color stability. This phenomenon may be attributed to the direct correlation between the staining susceptibility of ceramic materials and their degree of water sorption. The capacity of ceramics to absorb water also facilitates the uptake of pigment-containing fluids, thereby serving as a medium for stain penetration into the internal structure of the material[25]. The absorptive properties of the resin matrix permit acidic agents to compromise the interface between the glass particles and polymer network. This interaction results in polymer degradation and subsequent ceramic deterioration, ultimately producing a roughened surface that negatively affects both the color stability and light-reflective properties of the restoration[31–33]. The composition and structural characteristics of the polymer matrix play a decisive role in determining the degree of conversion, water sorption, solubility, and color stability of restorative materials[34]. Water sorption adversely affects both the mechanical and physicochemical properties of restorative materials. In particular, hydrophilic materials exhibit greater susceptibility to discoloration and staining, which are strongly influenced by the extent of water uptake[35]. In addition, the composition of the resin matrix plays a critical role in discoloration because UDMA-based matrices demonstrate lower water sorption and greater resistance to staining than Bis-GMA-based matrices[36].

In this study, the color parameters of the three ceramic materials were assessed using a spectrophotometer both before and after immersion in simulated gastric acid, and subsequently in orange juice and coffee. The impacts of the simulated gastric acid solution and immersion media on the optical properties of all three dental ceramic materials differed among the samples. However, simulated gastric acid, which indicates the presence of reflux disease, had no significant effect on the color change, whereas the immersion media had a significant effect on color stability. According to the results obtained, ΔE values of tested materials, Vita Enamic showed the highest value, while E-max showed the lowest result. This result could be attributed to Cerasmart and Vita Enamic, which are categorized as hybrid ceramics and differ from conventional resin composites primarily because of the absence of Bis-GMA in their composition. Instead, they incorporated UDMA, a monomer characterized by a higher degree of polymerization and lower water sorption, which contributed to the improved color stability[37]. Vita Enamic is a polymer-infiltrated ceramic network (PICN) with a dual-phase structure in which a sintered ceramic scaffold is interpenetrated by a polymer matrix. In contrast, Cerasmart is composed of ultrafine glass fillers that are uniformly distributed within a highly cross-linked resin matrix. The intrinsic properties of ceramic materials, including their composition and shade, play critical roles in influencing the color stability of these restorations[38].

According to the CIEDE2000 color difference formula, the final color difference (ΔE_{00}) was calculated based on the variation between the material and immersion media–presence of reflux assemblies. The results were evaluated using thresholds for clinical perception (0.80) and clinical acceptability (1.80)[39]. Additionally, according to the ΔE values obtained in the present study, of the Cerasmart–orange juice–reflux, Vita Enamic–orange juice–no reflux, Vita Enamic–coffee–reflux, and Vita Enamic–coffee–no reflux groups exhibited color differences that were perceptible but within clinically acceptable limits ($0.80 \leq \Delta E_{00} \leq 1.80$). Conversely, the rest of the groups demonstrated color differences that were below the perceptibility threshold and were clinically acceptable ($\Delta E_{00}<0.80$).

The third null hypothesis that the water sorption of the tested ceramic materials would not differ following orange juice and coffee solutions in patients with reflux was also accepted. Considering that both direct resin composites and subtractive manufactured CAD-CAM materials used in dental restorations are routinely exposed to moist environments, it is crucial to investigate the effects of water sorption on their physical and mechanical properties. Water sorption can compromise the chemical integrity of restorative materials and is often associated with alterations in surface topography, including surface softening and smoothing[35]. In a comparative study investigating the effect of water immersion on direct composite resins and subtractively processed composite resins, four CAD/CAM materials (Vita Enamic, Brilliant, Cerasmart, and Tetric) along with three direct composite resins were evaluated. The results indicated that Vita Enamic exhibited the greatest stability in terms of water sorption[35].

Previous studies have reported that resin composites containing quartz fillers demonstrate lower water sorption than those containing zirconia, barium, or zinc glass fillers[40,41]. According to our study, Vita Enamic is composed of 86% feldspar and aluminum oxide and is a hybrid ceramic that exhibits significantly lower susceptibility to water sorption than conventional polymer-based matrices. Cerasmart exhibited inferior performance compared to Vita Enamic because barium glass was used as a filler in Cerasmart[35]. The water sorption capacity of a resin matrix is predominantly influenced by the filler volume fraction relative to the total volume of the restorative material. Resin composites with reduced filler content and a correspondingly higher proportion of resin matrix tend to exhibit greater water uptake[42].

Although numerous studies have investigated water sorption, a direct comparison of the findings is hindered by variations in experimental durations, units of measurement, and sample sizes[43,44]. In the present study, the selection of materials was based on their chemical composition, morphology, and particle size, as variations in the filler content and matrix composition may account for the differences observed in the results. These materials were selected based on the premise of understanding their differences in water solubility & sorption. This information is essential for making informed material choices for diverse clinical scenarios.

Taken together, these results indicate that sorption facilitates the outward diffusion of residual monomers and ions, thereby increasing the solubility of the resin-based materials. This process may compromise the biocompatibility of the materials, induce volumetric reduction, impair their mechanical properties, and promote discoloration through the chemical degradation of the filler-resin interface within the resin matrix[45].

The results of the solubility & sorption values for dental ceramic materials revealed that there was a significant effect of the restoration material and immersion media on the sorption characteristics, and no significant alteration in the presence of reflux. Cerasmart had the highest sorption value, whereas IPS Emax CAD had the lowest. One possible explanation is that the acidic solutions significantly compromised the structural integrity of the hybrid ceramics, whereas the crystalline-based ceramics were minimally affected[46].

The fourth null hypothesis that the solubility of the tested ceramic materials would not differ following orange juice and coffee solutions in patients with reflux was partially accepted that the immersion media had significant effects on the results. In addition, the rigid ceramic framework of Vita Enamic, combined with the presence of hydrophilic monomers such as UDMA and TEGDMA, may contribute to matrix degradation or the release of unreacted components. In contrast, inorganic fillers present in materials, such as ceramic mart, enhance matrix stability and reduce solubility. Therefore, Vita Enamic exhibited significantly low water solubility & sorption. Studies on hybrid ceramics suggest that densely packed ceramic networks effectively limit the water uptake. Nonetheless, some evidence indicates that hydrophilic monomers, such as TEGDMA, may contribute to increased solubility[47].

This study was performed as an *in vitro* experiment, and the following limitations should be noted: In daily life, the exposure of ceramic materials to acidic substances from foods and beverages is typically brief because these agents are rapidly neutralized or cleared by saliva. However, the present study did not consider the protective role of saliva. Moreover, the oral cavity is a complex and dynamic environment, where factors such as the presence of saliva, temperature fluctuations, and varying pH levels can substantially influence the behavior and longevity of restorative materials. Therefore, long-term clinical studies are required to gain a comprehensive understanding of the effects of acidic agents on dental ceramics[27]. Most studies assessing the optical properties of restorative materials have employed the continuous immersion of samples in stained beverages, which limits the clinical relevance of their findings. In the oral environment, restorations are intermittently exposed to these beverages, alternating between periods of contact with the saliva. Therefore, future studies should incorporate thermal and immersion cycling into solutions with varying temperatures to simulate the dynamic conditions of the oral cavity[48].

Future investigations should evaluate the behavior of materials over extended immersion periods to better simulate long-term clinical conditions. Continued research on advanced biomaterials is essential to enhance the performance and longevity of prosthetic dental restorations.

5. Conclusions

Within the limitations of this *in vitro* study, the following conclusions were drawn:

(1) Exposure to different immersion media may alter the microhardness, color stability, and solubility & sorption of esthetic CAD/CAM ceramics.

(2) Although the selection of restorative materials plays a critical role in managing patients prone to erosive challenges, the presence of reflux did not have a statistically significant impact on the microhardness, color stability, or solubility & sorption characteristics of various CAD/CAM ceramic materials.

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Conflict of interest

There are no conflicts of interest to declare regarding this study.

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